

BAPA
BEN

ENERGY, CLIMATE CHANGE
AND SUSTAINABLE DEVELOPMENT

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বাংলাদেশের জ্বালানী খাতের ১১টি সুনির্দিষ্ট সমস্যা এবং একটি বৃহত্তর সমস্যা

নজরুল ইসলাম

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ভূমিকা

বিগত কয়েক দশকে বাংলাদেশের বিদ্যুৎ উৎপাদন সক্ষমতা বহুগুণ বৃদ্ধি পেয়েছে। এটা নিঃসন্দেহে একটা সাফল্য। কিন্তু এই সাফল্যের সাথে অনেক সমস্যারও উদ্ভব ঘটেছে। ভবিষ্যতে এগিয়ে যাওয়ার জন্য এসব সমস্যার আলোচনা এবং সমাধান প্রয়োজন। সে লক্ষ্যে এই প্রবন্ধে ১১টি সুনির্দিষ্ট সমস্যা চিহ্নিত এবং আলোচিত হয়েছে। এগুলো হলো: (ক) সরবরাহের সাথে চাহিদার সামঞ্জস্য নিশ্চিতকরণের সমস্যা; (খ) জ্বালানীর সর্বোত্তম-মিশ্রণ অর্জনের সমস্যা; (গ) সরকারী এবং বেসরকারি খাতের ভূমিকার সর্বোত্তম মিশ্রণ অর্জনের সমস্যা; (ঘ) জাতীয় বনাম বিদেশী কোম্পানির ভূমিকার সর্বোত্তম মিশ্রণ অর্জনের সমস্যা; (ঙ) বিদ্যুৎ উৎপাদন কেন্দ্রের সর্বোত্তম আকার-বিতরণ অর্জনের সমস্যা; (চ) বিদ্যুৎ উৎপাদন কেন্দ্রের সর্বোত্তম ভৌগলিক বিতরণ অর্জনের সমস্যা; (ছ) উৎপাদিত বিদ্যুতের সঞ্চালন এবং বিতরণের জন্য পর্যাপ্ত অবকাঠামো নিশ্চিতকরণের সমস্যা; (জ) বিদ্যুৎ ও জ্বালানী খাতের আর্থিক স্থায়িত্বশীলতা সমস্যা; (ঝ) বিদ্যুৎ ও জ্বালানীখাতের পরিবেশগত স্থায়িত্বশীলতার সমস্যা; (ঞ) ঝুঁকি প্রশমনের সমস্যা; এবং (ট) সনাতনী

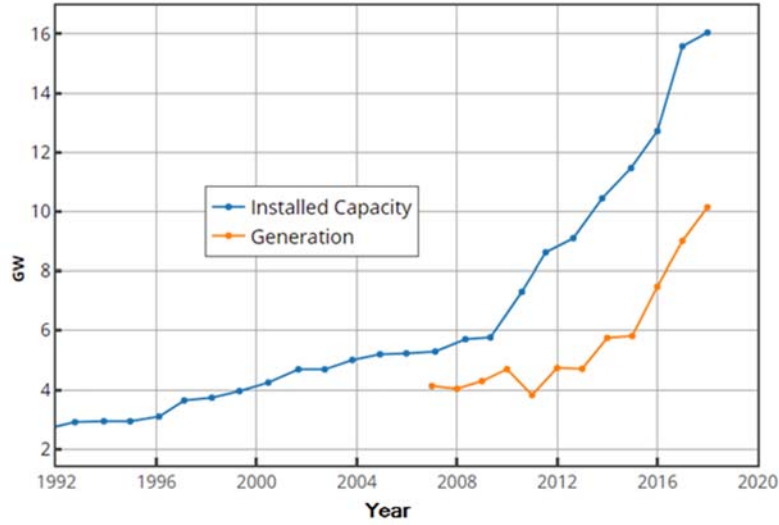
জ্বালানীর সর্বোত্তম ব্যবহার অর্জনের সমস্যা। এসন সুনির্দিষ্ট সমস্যা ছাড়া এ প্রবন্ধে একটি বৃহত্তর সমস্যার কথা আলোচিত হয়েছে; সেটা হলো, বাংলাদেশের বিদ্যুৎ এবং জ্বালানী খাতের নীতি ও পরিকল্পনা প্রণয়নে বিদেশী সংস্থার উপর নির্ভরতার সমস্যা। আলোচনাসূত্রে এসব সমস্যার নিরসনের উপায় সম্পর্কেও সুপারিশ প্রস্তাবিত হয়েছে। সবশেষে, উপসংহারে, বাংলাদেশের জ্বালানী এবং বিদ্যুৎ খাতের বিকাশ সম্পর্কে বাপা-বেন বিভিন্ন সময়ে যেসব উদ্যোগ গ্রহণ করেছে এবং সুপারিশ পেশ করেছে তার একটি সংক্ষিপ্ত বিবরণ পরিবেশিত হয়েছে। এই বিবরণে জ্বালানী ও বিদ্যুৎ বিষয়ে বাপা-বেনের অবস্থানের মূল বৈশিষ্ট্যসমূহের একটি তালিকা প্রদান করা হয়েছে এবং এসব বৈশিষ্ট্যপূর্ণ জ্বালানী ও বিদ্যুৎ নীতি কিভাবে এই প্রবন্ধে আলোচিত সমস্যাবলীর উদ্ভব প্রতিহত করতে এবং আগামীতে তা সমাধানে সহায়তা করতে পারে তা প্রবন্ধের পূর্বালোচনার ভিত্তিতে স্পষ্ট করা হয়েছে।

এই প্রবন্ধের আলোচনা কাঠামো নিম্নরূপ। দ্বিতীয় অনুচ্ছেদে বিদ্যুৎ উৎপাদন ক্ষমতা বৃদ্ধিতে বাংলাদেশের সাম্প্রতিক সাফল্যের বিষয়টি তুলে ধরা হয়েছে। তৃতীয় থেকে ত্রয়োদশ অনুচ্ছেদে উপর্যুক্ত ১১টি সুনির্দিষ্ট সমস্যার আলোচনা করা হয়েছে। চতুর্দশ অনুচ্ছেদে জ্বালানী ও বিদ্যুৎ নীতি প্রণয়নের পরনির্ভরতার সমস্যাটি আলোচিত হয়েছে। পঞ্চদশ অনুচ্ছেদে উপসংহার পরিবেশিত হয়েছে।

বিদ্যুৎ উৎপাদন ক্ষমতা বৃদ্ধিতে সাম্প্রতিক সাফল্য

সাম্প্রতিককালে বাংলাদেশের বিদ্যুৎ উৎপাদন ক্ষমতা অনেকগুণ বৃদ্ধি পেয়েছে। চিত্র-১ দেখায় যে, ১৯৯২ সনের মাত্র ২.৭ গিগাওয়াটের তুলনায় ২০১৮ সন নাগাদ দেশের বিদ্যুৎ উৎপাদন ক্ষমতা ১৬ গিগাওয়াটে উন্নীত হয়েছে। ২০১৯-২০২২ সময়কালে তা আরও বৃদ্ধি পেয়েছে। সুতরাং, সন্দেহ

নেই যে, বিদ্যুৎ উৎপাদন ক্ষমতা বৃদ্ধিতে বাংলাদেশ বেশ সফল হয়েছে। এই বৃদ্ধি স্বতঃস্ফূর্ত ছিল না। বিভিন্ন সরকারী পদক্ষেপ এবং নীতি গ্রহণ এটাকে সম্ভব করেছে। লক্ষ্যণীয় যে, ২০০৯ সনের পর থেকে এই বৃদ্ধি ত্বরান্বিত হয়েছে। সে কারণে এসময়কালের সরকারসমূহ সঙ্গত কারণেই এ বিষয়ে কৃতিত্বের দাবী করতে পারে।



সূত্র: Majumder, Asif, and Singh (2020).

চিত্র ১: সাম্প্রতিককালে বাংলাদেশের বিদ্যুৎ উৎপাদন ক্ষমতা বৃদ্ধি
১৯৯২-২০১৮

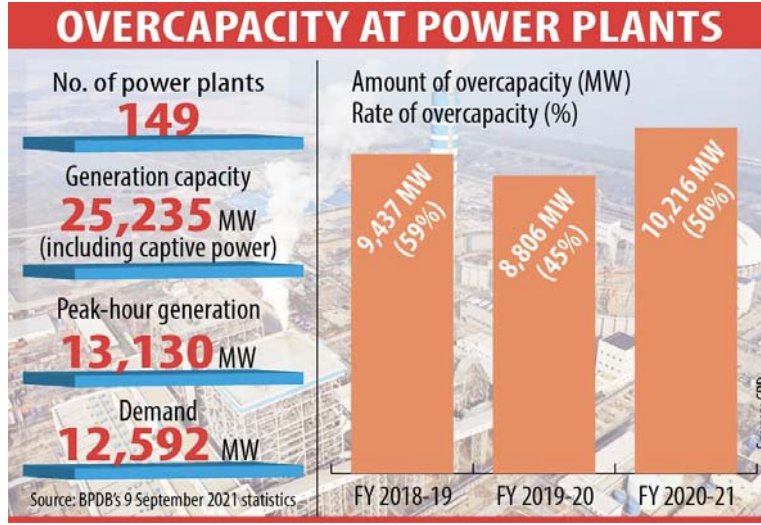
যে কোনো সাফল্য নতুন সমস্যা ডেকে আনে। বাংলাদেশের বিদ্যুৎ উৎপাদন ক্ষমতা বৃদ্ধিতে সাফল্যও তার ব্যতিক্রম নয়। বিগত এক যুগেরো বেশী সময় ধরে যেসব নীতি এবং পরিকল্পনার অধীনে উপর্যুক্ত সাফল্য অর্জিত হয়েছে তা অনেক নতুন সমস্যাও ডেকে এনেছে। আগামীতে সাফল্যের সাথে এগিয়ে

যাওয়ার জন্য এখন প্রয়োজন এসব নতুন সমস্যার মোকাবেলা করা। নীচের অনুচ্ছেদসমূহে এরূপ ১১টি সুনির্দিষ্ট সমস্যার কথা আলোচিত হলো।

চাহিদার সাথে সরবরাহের সামঞ্জস্য নিশ্চিতকরণের সমস্যা

প্রথমেই যেটার কথা উল্লেখ করা প্রয়োজন তা হলো চাহিদার সাথে সরবরাহের সামঞ্জস্য নিশ্চিত করার সমস্যা। বাংলাদেশ এক্ষেত্রে এক বড় সমস্যার সম্মুখীন হয়েছে। বাংলাদেশে বিদ্যুৎ উৎপাদন ক্ষমতা যে হারে বৃদ্ধি পেয়েছে, বিদ্যুতের চাহিদা সে তুলনায় বৃদ্ধি পায় নি; ফলে বিদ্যুৎ উৎপাদন ক্ষমতার একটি বড় অংশ অব্যবহৃত থেকে যাচ্ছে। চিত্র-১ থেকেই তার কিছু প্রতিফলন দেখা যায়। এই চিত্র অনুযায়ী ২০১৮ সনে বিদ্যুৎ উৎপাদন ক্ষমতা ১৬ গিগাওয়াট হলেও, উৎপাদিত হয়েছে মাত্র ১০ গিগাওয়াট; অর্থাৎ উৎপাদন ক্ষমতার ৩৭.৫ শতাংশ অলস থেকে গেছে। চিত্র-২ অনুযায়ী, অতিরিক্ত উৎপাদন ক্ষমতার সমস্যা আরও তীব্র। এই চিত্র থেকে আমরা জানতে পারি যে, অতিরিক্ত উৎপাদন ক্ষমতা ২০১৮-১৯, ২০১৯-২০, এবং ২০২০-২১ সনে যথাক্রমে ৫৯, ৪৫, এবং ৫০ শতাংশে বৃদ্ধি পেয়েছে। অর্থাৎ, বাংলাদেশের বিদ্যুৎ উৎপাদন ক্ষমতার প্রায় অর্ধেকই অব্যবহৃত থেকে যাচ্ছে। ফলে, সরবরাহের সাথে চাহিদার এই অসামঞ্জস্যতা একটা বড় সমস্যা হয়ে দেখা দিয়েছে।

লক্ষ্যণীয়, অর্থনৈতিক উন্নয়নের প্রাথমিক পর্যায়ে বিদ্যুৎ ক্ষমতার কিছু অংশ উদ্ভূত থাকা অপ্রত্যাশিত নয়। বিদ্যুৎ সরবরাহের নিশ্চয়তা না থাকলে একটি দেশে শিল্পায়ন অগ্রসর হতে পারে না। তদুপরি, বিদ্যুৎ কেন্দ্র নির্মাণ সময় সাপেক্ষ ব্যাপার। চাহিদা দেখা মাত্রই বিদ্যুৎ উৎপাদন ক্ষমতার সম্প্রসারণ ঘটানো যায় না। এই উভয় কারণেই বিদ্যুৎ উৎপাদন ক্ষমতার বৃদ্ধি চাহিদা বৃদ্ধির চেয়ে দ্রুততর গতিতে অগ্রসর হওয়া প্রয়োজন এবং তার ফলে বিদ্যুৎ ক্ষমতার কিছু উদ্ভূত থাকাটাই স্বাভাবিক।



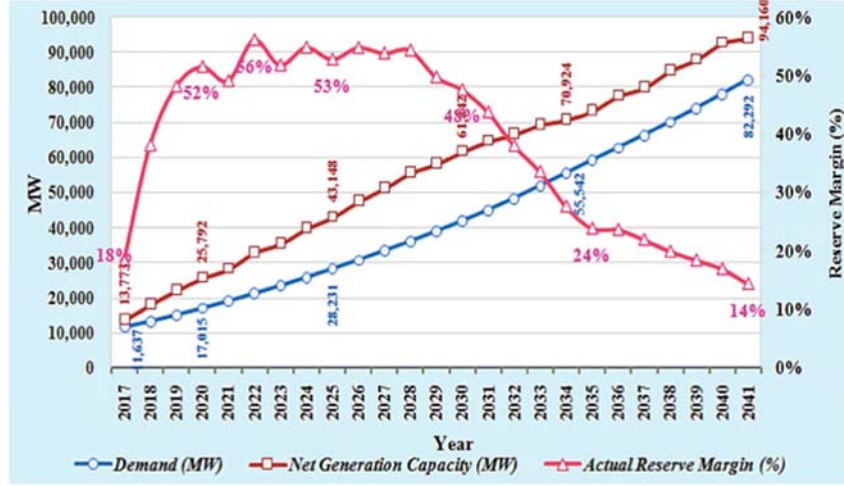
উৎস: Centre for Policy Dialogue (CPD), based on information from Bangladesh Power Development Board (BPDB)

চিত্র ২: সাম্প্রতিক বছরসমূহে বাংলাদেশে অতিরিক্ত বিদ্যুৎ উৎপাদন ক্ষমতা

এই উদ্ভূতকে সাধারণত বলা হয় “রিজার্ভ মার্জিন,” যার সংজ্ঞা হলো: (উৎপাদন ক্ষমতা – চাহিদা)/চাহিদা। সাধারণত, এই রিজার্ভ মার্জিন ১০ থেকে ২০ শতাংশে সীমাবদ্ধ রাখা হয়। বাংলাদেশের জন্য জাপানের “টোকিও ইলেকট্রিক কোম্পানি” কর্তৃক প্রণীত “বিদ্যুৎ সিস্টেম মহাপরিকল্পনা” (“পাওয়ার সিস্টেম মাস্টার প্ল্যান,” সংক্ষেপে “পি-এস-এম-এস”) অনুযায়ী ২০১৭ সনে রিজার্ভ মার্জিন হওয়ার কথা ১৮ শতাংশ। এই রিজার্ভ মার্জিনের সর্বোচ্চ মাত্রা (৫৬ শতাংশ) অর্জনের কথা ২০২২ সনে, এবং তারপর থেকে এটা ধীরে ধীরে কমে ২০৪১ সনে ১৪ শতাংশে হ্রাস পাওয়ার কথা। কিন্তু চিত্র-২ থেকে দেখা যায় যে, বাংলাদেশে এই রিজার্ভ মার্জিন ২০১৮-১৯, ২০১৯-২০, এবং ২০২০-২১ সনে যথাক্রমে ১৪৪, ৮২, এবং ১০০ শতাংশে

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পৌঁচেছিল। বলা নিশ্চয়োজন, এটা পরিকল্পনা ও তার বাস্তবায়নে একটি বড় ব্যর্থতা এবং তা গোটা অর্থনীতির উপর নেতিবাচক প্রভাব ফেলেছে। বিদ্যুৎ ও জ্বালানী খাতের চাহিদা এবং সরবরাহের মধ্যে এই অসামঞ্জস্য বাংলাদেশের বর্তমান (২০২২ সনের) অর্থনৈতিক সংকটের অন্যতম মূল কারণ। কীভাবে এই চাহিদার সাথে সরবরাহের অসামঞ্জস্যতা কাটিয়ে রিজার্ভ মার্জিনকে স্বাভাবিক মাত্রায় নিয়ে আসা যায় সেটাই বর্তমানে বাংলাদেশের বিদ্যুৎ খাতের এক বড় সমস্যা।



উৎস: Power System Master Plan (RPSM) (Revised), Tokyo Electric, 2016

(Figure 17)

চিত্র ৩: “বিদ্যুৎ সিস্টেম মহাপরিকল্পনা” অনুযায়ী রিজার্ভ মার্জিনের প্রক্ষেপণ
(২০১৭-২০৪১)

জ্বালানীর সর্বোত্তম মিশ্রণ অর্জনের সমস্যা

দ্বিতীয় যে গুরুত্বপূর্ণ সমস্যার উদ্ভব ঘটেছে, তা হলো জ্বালানীর সর্বোত্তম মিশ্রণ অর্জনের সমস্যা। জ্বালানী মিশ্রণ সম্পর্কে বিদ্যুৎ মহাপরিকল্পনার প্রস্তাবটি ১ নং সারণীতে পরিবেশিত হলো।

সারণী ১: জ্বালানী মিশ্রণ সংক্রান্ত বিদ্যুৎ মহাপরিকল্পনার প্রস্তাবনা

বৎসর	২০১৬	২০২০	২০২১	২০২৫	২০৩০	২০৩৫	২০৪১
কয়লা	১	১১	১৭	৩১	৪০	৩৯	৩২
গ্যাস/এল-এন-জি	৬২	৪৯	৪৬	৪২	৩৭	৩৯	৪৩
তরল জ্বালানী	৩০	৩৪	৩১	১৭	১০	৩	২
আমদানি	৫	৬	৫	৭	১০	১২	১৫
আণবিক	০	০	০	৩	৪	৬	৭
জলবিদ্যুৎ	২	১	১	১	১	০.৪	০.৪
মোট	১০০	১০০	১০০	১০০	১০০	১০০	১০০

সূত্র: Revisiting Power system Master Plan 2016, p. 45.

এই সারণী থেকে কয়েকটি বিষয় স্পষ্ট হয়ে আসে। প্রথমত, কয়লার উপর নির্ভরতার নাটকীয় বৃদ্ধি— ২০১৬ সনের মাত্র ১ শতাংশ থেকে ২০৩০ সনে তা ৪০ শতাংশে বৃদ্ধি পাওয়ার কথা। দ্বিতীয় বৈশিষ্ট্য হলো, বিদ্যুৎ উৎপাদনে গ্যাসের ভূমিকা হ্রাস – ২০১৬ সনের ৬২ শতাংশ থেকে ২০৩০ সনে ৩৭ শতাংশে হ্রাস। এই চিত্রে দেশজ বনাম বিদেশী গ্যাসের হিসাব আলাদা করা হয় নি। সন্দেহ নেই যে, সেটা করা হলে আমরা দেশজ গ্যাসের ক্ষেত্রে আরও নাটকীয় পরিবর্তন দেখতে পেতাম। তৃতীয় হলো, নবায়নযোগ্য জ্বালানীর অনুপস্থিতি। জলবিদ্যুৎ এবং আণবিক বিদ্যুৎকে নবায়নযোগ্য জ্বালানী বলা যায় কিনা, সে বিষয়ে বিতর্ক আছে। সারণী-১ অনুযায়ী আণবিক শক্তির ভূমিকা ৭ শতাংশে উন্নীত হবে, আর জল-বিদ্যুতের ভূমিকা ০.৪ শতাংশে হ্রাস পাবে।

চতুর্থ বৈশিষ্ট্য হলো, আমদানির বৃদ্ধি -- ২০১৬ সনের ৫ শতাংশের তুলনায় ২০৪১ সনে যা ১৫ শতাংশে পৌঁছাবে। বলাবাহুল্য, এই সবগুলি বৈশিষ্ট্যই প্রশংসাপেক্ষ। কয়লার গুরুত্ব বৃদ্ধি সম্পর্কে বলা দরকার যে, বিদ্যুৎ সংক্রান্ত ২০১০ সনের মহাপরিকল্পনায় জ্বালানী ব্যালেন্সে কয়লার অংশকে ৫০ শতাংশ করার প্রস্তাব করা হয়েছিল (PSMS 2010, Summary, p. 2-1)। বাপা, বেন, ও অন্যান্য বিভিন্ন মহলের প্রতিবাদের মুখে এবং সম্ভবত অন্যান্য কারণে এর অংশ এখন (২০১৬ সনের মহাপরিকল্পনা অনুযায়ী) ২০৪১ সনের জন্য ৩২ শতাংশে নির্ধারিত হয়েছে।

তা সত্ত্বেও, সারা পৃথিবী যখন কয়লা থেকে সরে আসছে তখন বাংলাদেশের এই উল্টোযাত্রা প্রশ্নের উদ্বেক করে। বলাবাহুল্য, এই উল্টোযাত্রা ২০১৫ সনে গৃহীত জাতিসংঘের “স্থায়িত্বশীল উন্নয়ন লক্ষ্যমালা” (United Nations 2015) এবং জলবায়ু পরিবর্তন সংক্রান্ত “প্যারিস চুক্তি”র (UNFCCC 2015) স্পৃহা বিরোধী। লক্ষ্যণীয়, জাতিসংঘের জলবায়ু পরিবর্তন বিষয়ক “সর্বাধিক ছুমকিসম্পন্ন দেশসমূহের গ্রুপে”র সভাপতি নির্বাচিত হওয়ার পর বাংলাদেশ কয়লার গুরুত্ব বৃদ্ধির নীতি থেকে কিছুটা সরে আসার প্রয়োজনীয়তা বোধ করে। যেমন COP-26 সম্মেলনের প্রাক্কালে ২০২১ সনের জুন মাসে সরকার দশটি কয়লা-ভিত্তিক বিদ্যুৎ প্রকল্প থেকে সরে আসার সিদ্ধান্ত ঘোষণা করে। তারমধ্যে ৫টি প্রকল্প সম্পূর্ণ বাতিল এবং বাকী ৫টি কয়লার পরিবর্তে গ্যাসে রূপান্তরিত করার সিদ্ধান্ত গ্রহণ করা হয় (দৈনিক সমকাল, ২৭শে জুন, ২০২১)। জলবায়ু পরিবর্তন প্রশমন এবং পরিবেশ রক্ষার দিক থেকে এই সিদ্ধান্ত নিঃসন্দেহে সমর্থনযোগ্য। কিন্তু সামগ্রিকভাবে বাংলাদেশ যেভাবে কয়লার দিকে ঝুঁকছে তা একটি উদ্বেগের বিষয় হিসেবে থেকেই যাচ্ছে। দেশজ গ্যাসের অনুসন্ধান, উত্তোলন, এবং ব্যবহারের উপর অগ্রাধিকার না দিয়ে বিদেশ থেকে আমদানিকৃত তরলীকৃত গ্যাসের উপর নির্ভরতার নাটকীয় বৃদ্ধিও একটি প্রশংসাপেক্ষ বিষয়।

নবায়নযোগ্য জ্বালানীর সম্পূর্ণ অনুপস্থিতি বিস্ময়ের উদ্রেক না করে পারে না। তবে এই মহাপরিকল্পনাতেই অন্যত্র উল্লেখ করা হয় যে, “বাংলাদেশ নবায়নযোগ্য জ্বালানী নীতি ২০০৮” অনুযায়ী দেশের মোট জ্বালানীতে নবায়নযোগ্য জ্বালানীর অংশ ২০১৫ সনের মধ্যে ৫ শতাংশে এবং ২০২০ সনের মধ্যে ১০ শতাংশে উন্নীত করা হবে। এখানে আরও উল্লেখ করা হয় যে, ২০২০ সনের পর ২০৪১ সনের মধ্যে এই অংশ আরও বৃদ্ধি করা হবে। সেখানে প্রদত্ত তথ্য থেকে আমরা আরও জানতে পারি যে, উপর্যুক্ত লক্ষ্য অর্জন করতে হলে নবায়নযোগ্য জ্বালানী থেকে ২০২০ সন নাগাদ ২,৮০০ মেগাওয়াট এবং ২০৪১ সন নাগাদ ৯,৪০০ মেগাওয়াট বিদ্যুৎ উৎপাদন করতে হবে (RPSMS, পৃ ৫৭)। পরিতাপের বিষয় যে, ২০২০ সনের লক্ষ্য মোটেও অর্জিত হয় নাই। নবায়নযোগ্য জ্বালানী সংক্রান্ত সংস্থা, SREDA-র প্রদত্ত তথ্য অনুযায়ী ২০১৮ নাগাদ নবায়নযোগ্য জ্বালানী থেকে মাত্র ৩৩০ মেগাওয়াট বিদ্যুৎ উৎপাদন করা সম্ভব হয়েছে, যা কিনা ২০২০ সনের লক্ষ্যমাত্রার মাত্র ১২ শতাংশ (সারণী ২ দ্রষ্টব্য)।

সারণী ২: বাংলাদেশে নবায়নযোগ্য জ্বালানী ব্যবহারে অগ্রগতি

Technology	Off-grid (MW)	On-grid (MW)	Total (MW)
Solar	286.72	39.1	325.82
Wind	2	0.90	2.90
Biogas to Electricity	0.68	0	0.68
Biomass to Electricity	0.40	0	0.40
Total	289.80	40	329.80

Source: SREDA, November 2018.

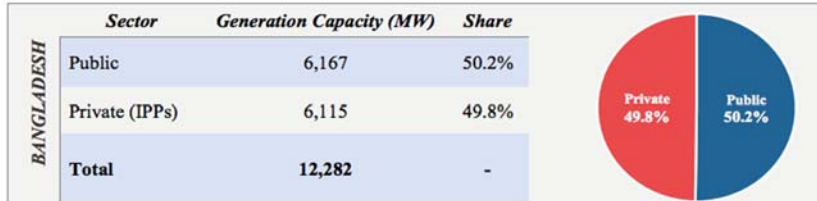
উপরে উল্লিখিত হয়েছে, জাতিসংঘের জলবায়ু পরিবর্তন বিষয়ক “সর্বাধিক জুমকিসম্পন্ন দেশসমূহের গ্রুপে”র সভাপতি নির্বাচিত হওয়ার পর বাংলাদেশ নবায়নযোগ্য জ্বালানীর প্রতিও অধিকতর মনোযোগ দিতে প্রবুদ্ধ হয়। ফলে COP-26 সম্মেলনের সময় বাংলাদেশ ঘোষণা করে যে, ২০৪১ সন নাগাদ মোট জ্বালানীতে নবায়নযোগ্য জ্বালানীর অংশ ৪০ শতাংশে বৃদ্ধি করা হবে।

অতীতের নৈরাশ্যজনক সম্পাদনার আলোকে বাংলাদেশ কীভাবে এই লক্ষ্য অর্জন করবে তা বলা কঠিন

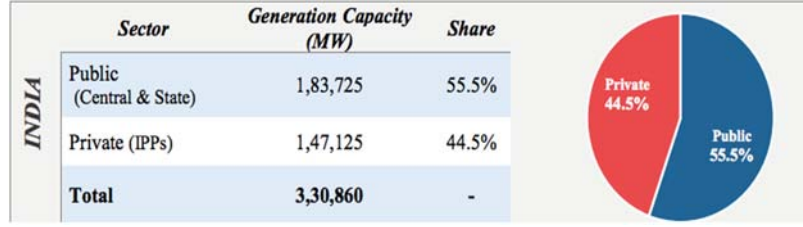
সব মিলিয়ে আমরা দেখতে পাই যে, বিদ্যুৎ উৎপাদন ক্ষমতা বৃদ্ধিতে সক্ষম হলেও বাংলাদেশ কয়লার দিকে বেশী ঝুঁকিয়েছে; নবায়নযোগ্য জ্বালানীকে অবহেলা করেছে; এবং দেশজ গ্যাস অনুসন্ধান, উত্তোলন, এবং ব্যবহার বৃদ্ধির প্রতি মনোযোগ দেয় নি। ফলে এসব দুর্বলতা অতিক্রম করে জ্বালানীর সর্বোত্তম মিশ্রণ অর্জন বর্তমানে বাংলাদেশের জন্য একটি বড় সমস্যা।

সরকারী বনাম বেসরকারি খাতের ভূমিকার সর্বোত্তম মিশ্রণ অর্জনের সমস্যা

বাংলাদেশে বিদ্যুৎ উৎপাদন বহুকাল যাবত সরকারী খাতে সীমাবদ্ধ ছিল। পরবর্তীতে এ খাতকে বেসরকারি বিনিয়োগের জন্য উন্মুক্ত করা হয়েছে। এর ফলে বেসরকারি খাতের ভূমিকা দ্রুত বৃদ্ধি পেয়েছে এবং বর্তমানে তা বিদ্যুৎ উৎপাদন ক্ষমতার প্রায় অর্ধেকের অধিকারী (চিত্র ৪ক)। বস্তুত, এই দৃষ্টিকোণ থেকে বাংলাদেশ ভারতকে ছাড়িয়ে গেছে। ভারতে এখনও বিদ্যুৎ উৎপাদন ক্ষমতার বেশী অংশ সরকারী খাতে অবস্থিত (চিত্র ৪খ)।



চিত্র ৪ক: বাংলাদেশের বিদ্যুৎ উৎপাদন ক্ষমতায় সরকারী এবং বেসরকারি খাতের অংশ

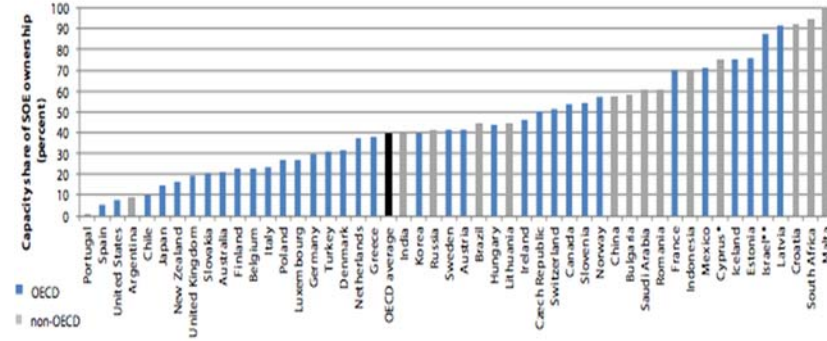


চিত্র ৪খ: ভারতে বিদ্যুৎ উৎপাদন ক্ষমতায় সরকারী এবং বেসরকারি খাতের অংশ

সঠিক নীতিমালার অধীনে বিদ্যুৎ উৎপাদনে ব্যক্তি খাতের অংশগ্রহণ উপকারী হতে পারে। অর্থনৈতিক তৎপরতায় সরকারী খাতে প্রায়শ দুর্নীতি, অপচয়, অদক্ষতা, দীর্ঘসূত্রিতা, ইত্যাদি দুর্বলতা দেখা যায়। ব্যক্তি খাতে এসব দুর্বলতা কম থাকার সম্ভাবনা। তদুপরি, ব্যক্তি খাতের সাথে প্রতিযোগিতা সরকারী খাতের উপর্যুক্ত দুর্বলতাসমূহ কাটিয়ে উঠতে সহায়তা করতে পারে। তবে লক্ষ্যণীয়, বিদ্যুৎ উৎপাদনে বেসরকারি খাতের বড় ভূমিকা একটি দেশের উন্নয়নের পূর্বশর্ত নয়। চিত্র ৫ পৃথিবীর বিভিন্ন দেশে বিদ্যুৎ উৎপাদনে সরকারী খাতের অনুপাত তুলে ধরে। এই চিত্র থেকে আমরা দেখি অনেক উন্নত দেশেও বিদ্যুৎ খাতের সিংহভাগ সরকারী খাতের অধীন; যেমন ফ্রান্সে বিদ্যুৎ উৎপাদন ক্ষমতার ৭০ শতাংশ সরকারী খাতে।

RPSMP 2016 অনুযায়ী বাংলাদেশের বিদ্যুৎ খাতে সরকারী-বেসরকারী খাতের আপেক্ষিক ভূমিকা সম্পর্কে যে পরিকল্পনা করা হয় তা চিত্র ৬ থেকে দেখা যেতে পারে। এই চিত্র অনুযায়ী বাংলাদেশে বিদ্যুৎ খাতে বেসরকারি খাতের ভূমিকা সর্বোচ্চ ৪৫ শতাংশে (২০২০ সনে) পৌঁছানোর কথা। তারপর

থেকে এই ভূমিকা দ্রুত হ্রাস পেয়ে ২০৪১ সন নাগাদ মাত্র ৪ শতাংশে পৌঁছানোর কথা।¹

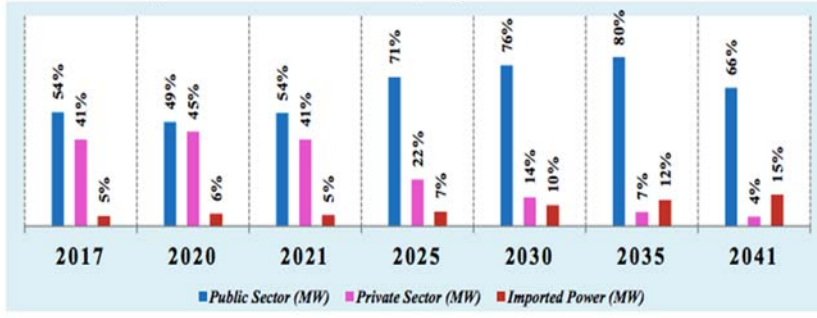


Source: OECD (2018), State-Owned Enterprises and the Low Carbon Transition, based on OECD data and World Electric Power Plant Database.

চিত্র ৫: পৃথিবীর বিভিন্ন দেশে বিদ্যুৎ উৎপাদনে সরকারী খাতের ভূমিকা

সাধারণতঃ ধারণা করা হয় যে, উন্নয়নশীল দেশে প্রথম দিকে বিদ্যুৎ খাতে সরকারী খাতের ভূমিকা বেশী থাকবে কারণ বিদ্যুৎ উৎপাদন কেন্দ্র নির্মাণ ব্যয়বহুল এবং ব্যক্তি খাতের এত বড় আকারের বিনিয়োগ করার সক্ষমতা থাকে না। সময়ে ব্যক্তি খাতের বিনিয়োগ সক্ষমতা বৃদ্ধি পাবে এবং বিদ্যুৎ খাতেও তার ভূমিকা বাড়বে। RPSMP 2016-র প্রক্ষেপণে কেন উপর্যুক্ত যুক্তির প্রতিফলন পাওয়া যায় না তা পরিষ্কার নয়। আমরা আরও দেখি যে, বাস্তবের চিত্রের সাথেও RPSMP 2016-র প্রক্ষেপণ সামঞ্জস্যপূর্ণ নয়। বাস্তবে বেসরকারি খাতের ভূমিকা ইতিমধ্যেই প্রায় ৫০ শতাংশে পৌঁছেছে এবং অবস্থাদৃষ্ট প্রতীয়মান হয় যে আগামীতে এই অনুপাত আরও বৃদ্ধি পাবে।

¹ এই চিত্রে অবশ্য ২০৪১ সনের বাকী ২১ শতাংশ বিদ্যুৎ কোথা থেকে আসবে তা বলা হয় না।



চিত্র ৬: RPSMP 2016 অনুযায়ী বাংলাদেশের বিদ্যুৎ খাতে সরকারী-বেসরকারী খাতের আপেক্ষিক ভূমিকা

এক্ষেত্রে গুরুত্বপূর্ণ হলো, কী নীতি-কাঠামোর অধীনে বিদ্যুৎ উৎপাদনে বেসরকারি খাতের বিকাশ সাধিত হচ্ছে। অবস্থাদৃষ্টে পরিক্ষার যে, এই নীতি-কাঠামোতে বহু দুর্বলতা রয়েছে, যার ফলে এখন বেসরকারি খাতের অলস উৎপাদন ক্ষমতার দায়ভার সরকারকে গ্রহণ করতে হচ্ছে। বিদ্যুৎ উৎপাদন সক্ষমতা দ্রুত বৃদ্ধির জন্য সরকার দায়মুক্তি আইন প্রণয়ন করেছিল যার ফলে বিনা প্রতিদ্বন্দ্বিতায় প্রকল্প বাছাই করা সম্ভব হয়। এর ফলে প্রকল্পের ব্যয় বৃদ্ধির সুযোগ সৃষ্টি হয়। তার চেয়ে বড় কথা, সরকার বেসরকারি খাতে স্থাপিত বিদ্যুৎ কেন্দ্রের বিদ্যুৎ ক্রয়ের গ্যারান্টি দেয় এবং ক্রয়ে অপারগ হলে অলস উৎপাদন ক্ষমতার জন্য “ক্যাপাসিটি চার্জ” দিতে সম্মত হয়। এর ফলে বিদ্যুৎ খাতে বেসরকারি উদ্যোক্তারা একদিকে বিনিয়োগের সকল ঝুঁকি সরকারের (তথা জাতির) উপর চাপিয়ে দিতে পারে (যেটাকে “ঝুঁকির সামাজিকীকরণ” বলা হয়), অন্যদিকে সকল উচ্চহারের মুনাফা আহরণের সুযোগ লাভ করে (যেটাকে “মুনাফার ব্যক্তিকরণ” বলা হয়)। এর ফলে একদিকে বাংলাদেশে বিদ্যুৎ উৎপাদন সক্ষমতায় বেসরকারি খাতের ভূমিকা দ্রুত বৃদ্ধি পেয়েছে; কিন্তু একই সাথে বৃদ্ধি পেয়েছে বেসরকারি বিদ্যুৎ কেন্দ্রের মালিকদেরকে প্রদত্ত ভর্তুকির পরিমাণ, যা এখন বাংলাদেশের ব্যাষ্টিক অর্থনীতির স্থিতিশীলতার জন্য

চ্যালেঞ্জ হয়ে দাঁড়িয়েছে। কীভাবে এই চ্যালেঞ্জ মোকাবেলা করা যায়, তা এখন একটি বড় সমস্যা। নিম্নে ১০ নং অনুচ্ছেদে এ বিষয়ে আমরা আরও আলোচনা করবো।

জাতীয় বনাম বিদেশী কোম্পানির ভূমিকার সর্বোত্তম মিশ্রণ অর্জনের সমস্যা

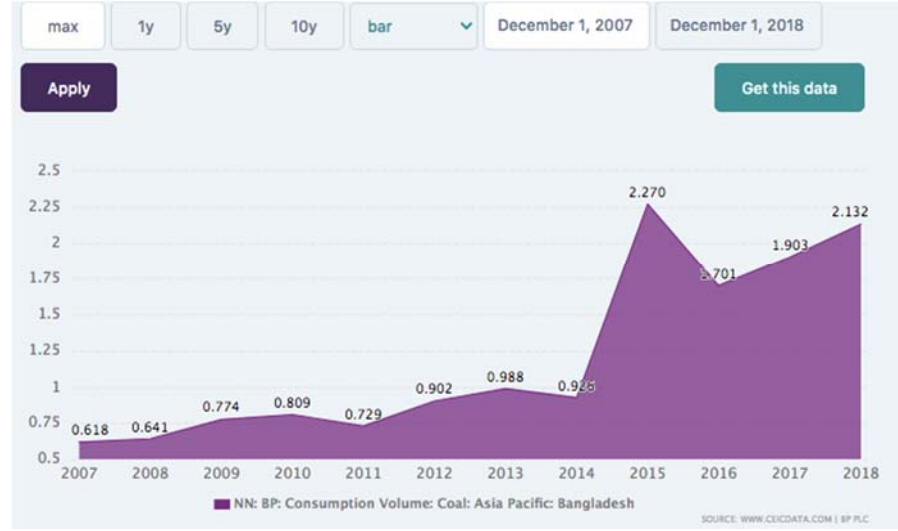
জাতীয় বনাম বিদেশী কোম্পানির ভূমিকার দু'টি দিক রয়েছে। একটি হলো “বিদ্যুতের উৎস” হিসেবে ভূমিকা; আর দ্বিতীয় হলো “জ্বালানীর উৎস” হিসেবে ভূমিকা। বিদ্যুতের উৎসের দৃষ্টিকোণ থেকে আগেই লক্ষ্য করা হয়েছে, RPSMP 2016-র প্রক্ষেপণ অনুযায়ী ২০৪১ সন নাগাদ আমদানিকৃত বিদ্যুতের ভূমিকা ১৫ শতাংশে পৌঁছাবে (চিত্র ৬)। দেশের বিদ্যুৎ ক্ষমতার বিপুল বৃদ্ধি সত্ত্বেও কেন বাংলাদেশকে বৈদেশিক মুদ্রা ব্যয় করে ক্রমবর্ধমান পরিমাণে এবং অনুপাতে বিদেশ থেকে বিদ্যুৎ আমদানি করতে হবে তা বোধগম্য নয়। বিদ্যুতের উৎস হিসেবে বিদেশী কোম্পানির ভূমিকার দ্বিতীয় দিক হলো বাংলাদেশের ভেতরে এসব কোম্পানির সম্পূর্ণ নিজ কর্তৃক অথবা দেশীয় কোম্পানির সহযোগে বিদ্যুৎ কেন্দ্র স্থাপন। এসব সহযোগিতা সরকারী এবং বেসরকারি, উভয় খাতেই হতে পারে। যেমন, রামপাল বিদ্যুৎ কেন্দ্র স্থাপিত হয়েছে ভারতীয় সরকারী কোম্পানির সাথে বাংলাদেশের সরকারী কোম্পানির সহযোগিতায়। আবার মাতারবাড়িতে বিদ্যুৎ কেন্দ্র স্থাপিত হচ্ছে জাপানী ব্যক্তিখাতের কোম্পানির সাথে বাংলাদেশের ব্যক্তিখাতের কোম্পানির সহযোগিতায়।

বিদেশী কোম্পানি কর্তৃক বাংলাদেশে বিদ্যুৎ খাতে বিনিয়োগের ভালমন্দ দু'টি দিকই আছে। বিদেশী কোম্পানি যদি উন্নত মানের হয় তাহলে এই কোম্পানির উন্নত প্রযুক্তি এবং ব্যবস্থাপনা পদ্ধতি দ্বারা বাংলাদেশ উপকৃত হতে পারে। এটা হলো ভালর দিক। মন্দের দিকের একটি হলো যে, এসব কোম্পানি কর্তৃক মুনাফা প্রত্যাবর্তনের জন্য বাংলাদেশ বৈদেশিক মুদ্রা প্রদানের

বাধ্যবাধকতায় আবদ্ধ হয়। এছাড়া বিদেশী কোম্পানির প্রায়শ লক্ষ্য হয় অন্যান্য বিভিন্ন সুযোগ সুবিধা আদায় এবং বাংলাদেশের শ্রম এবং প্রাকৃতিক সম্পদের অপব্যবহার করে মুনাফা অর্জন। চট্টগ্রামে অবস্থিত জাপানের মারুবেনি কোম্পানি কর্তৃক নির্মিত “কর্ণফুলি ফার্টিলাইজার কোম্পানি (কাফকো)” তার একটি প্রমাণ। এই কোম্পানি বাংলাদেশের সস্তা গ্যাস ব্যবহার করে উৎপাদিত সার বিদেশে রপ্তানি করে বহু বছর ধরে লাভবান হয়েছে। কাজেই বিদ্যুৎ খাতে বিদেশী কোম্পানির অংশগ্রহণ সতর্কতার সাথে প্রণীত নীতিমালার ভিত্তিতে হওয়া প্রয়োজন। নতুবা বাংলাদেশের জন্য তা উপকারের পরিবর্তে অপকারই বেশি করতে পারে।

দীর্ঘকাল ধরে বিদ্যুৎ উৎপাদনের জন্য বাংলাদেশ দেশজ গ্যাসের উপর নির্ভরশীল ছিল। ২০০৫ সনের জ্বালানী পরিকল্পনায় বাংলাদেশে দেশজ কয়লা উৎপাদনের প্রচেষ্টা গ্রহণ করা হয়। কিন্তু জনগণের প্রতিরোধের কারণে ফুলবাড়িতে উন্মুক্ত পদ্ধতিতে কয়লা উত্তোলনে বিফল হওয়ার পর বাংলাদেশ আমদানিকৃত কয়লা এবং তরলীকৃত প্রাকৃতিক গ্যাস (এল-এন-জি)-র দিকে ঝুঁকে পড়ে। একদিকে দেশে বহু সংখ্যক আমদানিকৃত কয়লা-ভিত্তিক বিদ্যুৎ কেন্দ্র স্থাপনের পরিকল্পনা গৃহীত হয়। তারমধ্যে রামপাল কেন্দ্র নির্মাণ সম্পন্ন হয়েছে। আরও বেশ কয়েকটি নির্মাণাধীন। ফলে, কয়লা আমদানি এবং তারজন্য প্রয়োজনীয় বৈদেশিক মুদ্রার পরিমাণ দ্রুত বৃদ্ধি পাচ্ছে এবং ভবিষ্যতে আরও বৃদ্ধি পাবে (চিত্র ৭)। একইভাবে, =এল-এন-জি আমদানি বিপুল পরিমাণে বৃদ্ধি পেয়েছে এবং পাচ্ছে। চিত্র ৮ দেখায় যে, ২০১৮ সনের মাত্র ০.৬৭ মিলিয়ন টন থেকে ২০২০ সনে তা ৪.১৮ মিলিয়ন টনে পৌঁছেছে। এল-এন-জি আমদানির বার্ষিক বৃদ্ধির হার ২.৫ শতাংশ থেকে ৩.৪ শতাংশে বৃদ্ধি পেয়েছে। এল-এন-জি আমদানির দৃষ্টিকোণ থেকে ২০১৯ সনে বাংলাদেশ ইতিমধ্যে পৃথিবীর ৭ নম্বর স্থান অধিকার করেছে। প্রতিটি ৩.৮ MPTA পুনর্গ্যাসিকরণ ক্ষমতা সম্পন্ন দু’টি এল-এন-জি বন্দর মহেশখালীতে ইতিমধ্যে

নির্মিত হয়েছে; এবং মাতারবাড়িতে ৭.৫ MPTA পুনর্গ্যাসিকরণ ক্ষমতা সম্পন্ন এল-এন-জি বন্দরের নির্মাণকাজ ২০২৪ সনে সম্পন্ন হওয়ার কথা।

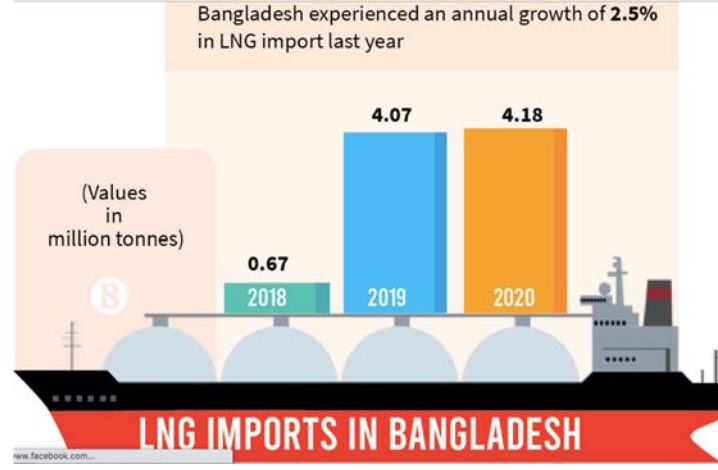


সূত্র: CEICdata.com/

চিত্র ৭: আমদানিকৃত কয়লার উপর ক্রমবর্ধমান নির্ভরতা

বিশেষজ্ঞরা মনে করেন যে, এল-এন-জি আমদানিতে সরকারের যেরকম উৎসাহ লক্ষ্য করা যায়, দেশজ গ্যাস অনুসন্ধান ও উত্তোলনে তা দেখা যায় না (Imam 2022)। গত বিশ বছরে মাত্র ১৯টি অনুসন্ধানমূলক গ্যাসকূপ স্থাপন করা হয়েছে। সুতরাং, বলা যেতে পারে, স্থলভাগ এবং সমুদ্র উভয়স্থানেই গ্যাস অনুসন্ধান তৎপরতা প্রায় বন্ধ হয়ে আছে। পরিত্যক্ত গ্যাস ফিল্ডে “ওয়ার্কওভারে”র মাধ্যমে গ্যাস উত্তোলনের সম্ভাবনার প্রতিও উৎসাহ লক্ষ্য করা যায় না। বিশেষজ্ঞদের মতে, এল-এন-জি আমদানীকারকদের লবির প্রভাবেই দেশজ গ্যাসের প্রতি অবহেলা এবং আমদানিকৃত গ্যাসের প্রতি উৎসাহ লক্ষ্য করা যাচ্ছে (পূর্বোক্ত)। অথচ, ক্রমবর্ধমান হারে জ্বালানী

আমদানির জন্য প্রয়োজনীয় বৈদেশিক মুদ্রার বোঝা দেশের বৈদেশিক লেনদেন ভারসাম্যে বড় সংকটের সৃষ্টি করছে। কীভাবে এই সংকট কাটিয়ে ওঠা যায় তা বাংলাদেশের জন্য এখন একটি বড় সমস্যা হিসেবে আবির্ভূত হয়েছে।



সূত্র: Farabi (2021)

চিত্র ৮: ক্রমবর্ধমান পরিমাণে এল-এন-জি আমদানি

বিদ্যুৎ কেন্দ্রের সর্বোত্তম আকার-বিতরণ অর্জনের সমস্যা

বাংলাদেশের বিদ্যুৎ খাতে উদ্ভূত আরেকটি সমস্যা হলো বিদ্যুৎ কেন্দ্রের অপটিমাল “আকার-বিতরণের” (ইংরাজিতে, সাইজ-ডিস্ট্রিбуশ্যান) নির্ধারণ। বিদ্যুৎ কেন্দ্র নানান আকারের হয়তে পারে। কয়েক শত মেগাওয়াট থেকে তা কয়েক হাজার মেগাওয়াট ক্ষমতাসম্পন্ন হতে পারে। প্রশ্ন হলো, বাংলাদেশ কী আকারের, কতগুলি বিদ্যুৎ কেন্দ্র নির্মাণ করবে। লক্ষ্য করা প্রয়োজন, বিভিন্ন আকারের বিদ্যুৎ কেন্দ্রের বিভিন্ন ধরনের ভালমন্দ রয়েছে। বৃহদাকার বিদ্যুৎ কেন্দ্রের একটি ভাল দিক হলো, এগুলো দ্বারা উৎপাদিত বিদ্যুতের ইউনিট-প্রতি খরচ কম হয়, অন্তত হওয়ার কথা। অর্থনীতির ভাষায় এটাকে বলে

“ইকনমিজ অফ স্কেল” (বাংলায়, “আকারজনিত সাশ্রয়”) সংক্রান্ত সুবিধা। তবে সমস্যা হলো, বৃহদাকার বিদ্যুৎ কেন্দ্র ব্যয়বহুল এবং দীর্ঘ সময়সাপেক্ষ। তদুপরি, এ ধরনের কেন্দ্র সাধারণত গ্রাহকদের থেকে বহু দূরে স্থাপন করতে হয়, যার ফলে সঞ্চালন এবং বিতরণ ব্যয় অনেক বেশী হয়। ব্যয়বহুল হওয়ার কারণে উন্নয়নশীল দেশে সাধারণত বৃহদাকার বিদ্যুৎ কেন্দ্র সরকারী খাতে প্রতিষ্ঠিত হয়। কিন্তু, আগেই উল্লিখিত হয়েছে, সরকারী খাতে অনেক সময় অপচয়, অদক্ষতা, এবং দুর্নীতির সম্ভাবনা এবং ভুল প্রকল্প নির্বাচন এবং নির্মাণ খরচ স্ফীত করার প্রবণতা থাকে। ফলে অনেকসময় বৃহদাকার বিদ্যুৎ কেন্দ্র লোকসানি শ্বেতহস্তীতেও পরিণত হয়।

অন্যদিকে ক্ষুদ্রাকার বিদ্যুৎ কেন্দ্রেরও সুবিধা এবং অসুবিধা, দুইই আছে। সুবিধার মধ্যে হলো, এগুলোতে বিনিয়োগ কম প্রয়োজন হয় এবং দ্রুততার সাথে নির্মাণ করা যায়। তদুপরি, এগুলো গ্রাহকদের কাছে নির্মাণ করা যায়; ফলে সঞ্চালন এবং বিতরণ খরচ কম হয়। অসুবিধার মধ্যে হলো ক্ষুদ্রাকারের হওয়ায় এগুলো “আকারজনিত সাশ্রয়ে”র সুবিধা বঞ্চিত হয়; ফলে ইউনিট-প্রতি বিদ্যুৎ উৎপাদন খরচ সাধারণত বেশী হয়। গ্রাহকদের কাছে হওয়ায় অনেক সময় জ্বালানী প্রাপ্যতার স্থান থেকে এগুলো দূরে হয়; ফলে জ্বালানী পরিবহন বাবদ তুলনামূলকভাবে বেশী খরচের সম্মুখীন হয়।

সুতরাং, বৃহদাকার এবং ক্ষুদ্রাকার উভয় ধরনের বিদ্যুৎ কেন্দ্রের সুবিধা এবং অসুবিধা দুইই আছে। সে কারণে কোনো দেশে শুধু এক আকারের বিদ্যুৎ কেন্দ্র হয় না। একটি দেশের বিভিন্ন স্থানের বিদ্যুৎ চাহিদা, জ্বালানী সরবরাহ, ইত্যাদি বিভিন্ন পরিস্থিতির আলোকে বিদ্যুৎ কেন্দ্রের আকার নির্ধারণের প্রয়োজন হয়। সে কারণে ছোটবড় মিলিয়ে এমন একটা “আকার-বিতরণে” পৌঁছাতে হয়, যেটা সে দেশের জন্য সবচেয়ে উপযোগী। বিদ্যুৎ কেন্দ্রের আকারের সাথে এগুলোর মালিকানার বিষয়টি জড়িত হয়ে যায়। ক্ষুদ্রাকার

কেন্দ্রসমূহ অনেক সময় ব্যক্তি মালিকানায় স্থাপিত হয়; বিপরীতে বৃহদাকার কেন্দ্রসমূহ সরকারী মালিকানায় নির্মিত হয়।

বাংলাদেশে সূচনায় স্থাপিত বিদ্যুৎ কেন্দ্রসমূহ বেশীরভাগ ক্ষেত্রে মাঝারী আকৃতির ছিল। কিন্তু বর্তমানে বৃহদাকার বিদ্যুৎ কেন্দ্র স্থাপনের দিকে ঝোঁক দেখা যাচ্ছে। আকার-বিতরণের এসব পরিবর্তন সুচিন্তিতভাবে করা হচ্ছে কিনা তা স্পষ্ট নয়। অনেক ক্ষেত্রে দেখা যাচ্ছে অত্যন্ত বৃহদাকার বিদ্যুৎ কেন্দ্র ব্যক্তি মালিকানায় প্রতিষ্ঠিত হচ্ছে। কিন্তু, যেহেতু ব্যক্তি মালিকেরা এগুলো নির্মাণ করছেন “স্বাক্ষর সামাজিকীকরণ” এবং “মুনাফার ব্যক্তিকরণ”মূলক নীতিকাঠামোর মধ্যে সেহেতু এগুলো কতখানি যৌক্তিক ভিত্তির উপর প্রতিষ্ঠিত তা বলা কঠিন। সব মিলিয়ে, বয়া যেতে পারে যে, বাংলাদেশে বিদ্যুৎ কেন্দ্রের আকার-বিতরণ অনেকটা অরাজক উপায়েই নির্ধারিত হচ্ছে। ফলে অর্থনৈতিক এবং সামাজিক বিচারে এর উপযোগিতা একটি সমস্যার বিষয় থেকে যাচ্ছে। এই সমস্যা থেকে উত্তরণ বাংলাদেশের বিদ্যুৎ খাতের জন্য আরেকটি চ্যালেঞ্জ হিসেবে উদ্ভূত হয়েছে।

বিদ্যুৎ কেন্দ্রের সর্বোত্তম ভৌগলিক বিতরণ অর্জনের সমস্যা

বিদ্যুৎ কেন্দ্রের ভৌগলিক অবস্থান আরেকটি গুরুত্বপূর্ণ ইস্যু। এটা উপরে আলোচিত আকার এবং মালিকানা ইস্যুর সাথেও সম্পর্কিত। সূচনায় বাংলাদেশের মূল বিদ্যুৎ কেন্দ্রসমূহ গ্যাস ফিল্ডের কাছাকাছি নির্মিত হয়। কিন্তু অধুনাকালে বহুসংখ্যক বৃহদাকার বিদ্যুৎ কেন্দ্র দেশের উপকূলে নির্মিত হয়েছে এবং হচ্ছে। এর মূল কারণ পূর্বলোচিত জ্বালানী মিশ্রণের পরিবর্তন। দেশজ গ্যাসের বিপরীতে এখন আমদানিকৃত কয়লা এবং তরলীকৃত প্রাকৃতিক গ্যাসের উপর নির্ভর করা হচ্ছে। উপকূলে নির্মিত হলে এসব জ্বালানী দেশের অভ্যন্তরে পরিবহনের প্রয়োজন হয় না। এটা কয়লার জন্য বিশেষভাবে উপযোগী। তবে

বেশীরভাগ গ্রাহক দেশের অভ্যন্তরে হওয়ায় উপকূলে উৎপাদিত বিদ্যুৎ অতিরিক্ত সঞ্চালন ব্যয়ের সম্মুখীন হয়।

বাংলাদেশের বর্তমান উপকূল নির্ভর বিদ্যুৎ উৎপাদন ভবিষ্যতের জন্য কতখানি উপযোগী হবে তা বলা কঠিন, কারণ কয়লা গ্রহণযোগ্য স্থায়িত্বশীল জ্বালানী নয়। উপরে আমরা লক্ষ্য করেছি, বাংলাদেশের PSMP (2010) এবং RPSMS (2016) কর্তৃক কয়লার উপর গুরুত্ব আরোপ যে ভুল ছিল তা এখন সরকার নিজেই স্বীকার করেছে এবং দশটি কয়লা ভিত্তিক প্রকল্প বাতিল করেছে। লক্ষ্যণীয়, কয়লার তুলনায় গ্যাস পরিবহন করা সহজ। দেশে ইতিমধ্যে একটি পাইপলাইন নেটওয়ার্ক নির্মিত হয়েছে; এবং প্রয়োজনে এটাকে আরও প্রসারিত এবং সম্প্রসারিত করা যেতে পারে। ফলে, গ্যাসের ক্ষেত্রে দেশজ উৎসের পরিবর্তে আমদানিকৃত এল-এন-জি'র উপর নির্ভরতা বাড়লেও তা বিদ্যুৎ কেন্দ্রসমূহকে উপকূলে নির্মাণ করার আবশ্যিকতা সৃষ্টি করে না। সুতরাং, গ্যাস নির্ভর ক্ষুদ্র এবং মাঝারী আকৃতির বিদ্যুৎ কেন্দ্র সারা দেশ জুড়েই (গ্রাহকদের নিকটবর্তী) স্থানে নির্মিত হতে পারে।

বৃহৎ অবকাঠামোর ক্ষেত্রে “পথ-নির্ভরতা” (ইংরাজিতে, “পাথ ডিপেন্ডেন্স”) একটি গুরুত্বপূর্ণ বিষয়। একটি বৃহৎ বিদ্যুৎ কেন্দ্র একবার কোথাও নির্মিত হলে সেটা অন্যত্র সরানোর সুযোগ থাকে না। শুধু তাই নয়, একটি বৃহদাকার বিদ্যুৎ কেন্দ্রের উপর নির্ভর করে সে স্থানে আরও বহু অবকাঠামো, শিল্প, বাণিজ্য, এবং জনবসতি গড়ে ওঠে। সে কারণে বিদ্যুৎ কেন্দ্রের ভৌগলিক অবস্থানের বিষয়টি আগে থেকেই সতর্কতার সাথে বিবেচনা করা প্রয়োজন। কিন্তু বাংলাদেশে বর্তমানে, বিদ্যুৎ কেন্দ্রের আকৃতির ক্ষেত্রে যেমন, তেমনি এগুলোর ভৌগলিক অবস্থান (তথা “ভৌগলিক বিতরণ”)-এর বিষয়টিও তেমন কোনো সমন্বিত এবং সুদূরপ্রসারী ভিত্তাভাবনা ছাড়াই অগ্রসর হচ্ছে বলে মনে হয়। কীভাবে এই অবস্থার পরিবর্তন করে বাংলাদেশে বিদ্যুৎ

কেন্দ্রের ভৌগলিক বিতরণকে সুষ্ঠু ধারায় অগ্রসর করানো যায়, সেটি আরেকটি সমস্যা হিসেবে আবির্ভূত হয়েছে।

উৎপাদিত বিদ্যুতের পর্যাপ্ত সঞ্চালন এবং বিতরণ অবকাঠামো নিশ্চিত করার সমস্যা

সাফল্যের সাথে বিদ্যুৎ সরবরাহের জন্য বিদ্যুৎ উৎপাদনই যথেষ্ট নয়; উৎপাদিত বিদ্যুতের সঞ্চালন এবং বিতরণ অবকাঠামো নির্মাণও প্রয়োজন। সাধারণভাবে ধারণা করা হয় যে, বিদ্যুৎ উৎপাদন ক্ষমতার চেয়ে সঞ্চালন ক্ষমতা কমপক্ষে ৫০ শতাংশ এবং বিতরণ ক্ষমতা কমপক্ষে ১০০ শতাংশ বেশী হওয়া প্রয়োজন। সুতরাং, বিদ্যুৎ উৎপাদন ক্ষমতা বৃদ্ধির সাথে উপর্যুক্ত অনুপাত রক্ষা করে সঞ্চালন এবং বিতরণ ক্ষমতা বৃদ্ধি করা প্রয়োজন। লক্ষ্যণীয়, যেহেতু সঞ্চালন এবং বিতরণ কাঠামো গণ-চরিত্রসম্পন্ন, অর্থাৎ সরকারী এবং বেসরকারি খাতের সকল বিদ্যুৎ উৎপাদকদের ব্যবহারের জন্য উন্মুক্ত রাখার প্রয়োজন হয়, সেহেতু বেসরকারি খাত সাধারণত এ ব্যাপারে গুরুত্বপূর্ণ ভূমিকা রাখে না। সরকারকেই এসব কাঠামো নির্মাণে এগিয়ে আসতে হয়।

পরিচালনার বিষয় যে, বাংলাদেশ বিদ্যুৎ উৎপাদন ক্ষমতা বৃদ্ধির পাশাপাশি প্রয়োজনীয় অনুপাত রক্ষা করে সঞ্চালন এবং বিতরণ ক্ষমতা বৃদ্ধি করায় সমর্থ হয় নি। ফলে, দেশে এখন অনেক বিদ্যুৎ কেন্দ্রের নির্মাণ শেষ হলেও প্রয়োজনীয় সঞ্চালন এবং সরবরাহ কাঠামো না থাকায় সেগুলো উৎপাদনে যেতে পারছে না। এর ফলে বিরাট পরিমাণ বিনিয়োগ নিষ্ফল্য থেকে যাচ্ছে এবং তা আর্থিক ক্ষতি সাধন করছে। সঞ্চালন এবং বিতরণ কাঠামো নির্মাণে এই ঘাটতি এখন একটি গুরুত্বপূর্ণ সমস্যা হিসেবে আবির্ভূত হয়েছে। কীভাবে এই সমস্যা দূর করে ভবিষ্যতে বিদ্যুৎ উৎপাদন, সঞ্চালন, এবং বিতরণ

ক্ষমতার আনুপাতিক হারের বৃদ্ধি নিশ্চিত করা যাবে তা বাংলাদেশের জন্য একটি চ্যালেঞ্জ।

বিদ্যুৎ সঞ্চালন ও বিতরণ ব্যবস্থার সাথে জ্বালানী বিতরণ ব্যবস্থার ইস্যুও প্রাসঙ্গিক। বাংলাদেশের গ্যাস সঞ্চালন এবং বিতরণের বিদ্যমান ব্যবস্থাটি একাধিক কারণে প্রশ্নবিদ্ধ। এক্ষেত্রে আঞ্চলিক এবং সামাজিক উভয় ধরনের বৈষম্যের উদ্ভব ঘটেছে। একদিকে, দেশের পশ্চিম এবং দক্ষিণাঞ্চলে গ্যাস পাইপ নেটওয়ার্ক এখনো সমভাবে বিস্তৃত হয় নি। ফলে শিল্পে ব্যবহারের জন্য গ্যাস সরবরাহের ক্ষেত্রে আঞ্চলিক বৈষম্যের সৃষ্টি হয়েছে। অন্যদিকে, গৃহস্থালি পর্যায়ে পাইপ-ভিত্তিক গ্যাস ব্যবহারের নীতি গ্রহণের ফলে আঞ্চলিক এবং সামাজিক উভয় ধরনের বৈষম্যের সৃষ্টি হয়েছে। প্রথম থেকেই যদি গৃহস্থালী ব্যবহারের জন্য সিলিন্ডার পদ্ধতি গ্রহণ করা হতো তাহলে শেষোক্ত বৈষম্যের উদ্ভব ঘটতো না। এই অভিজ্ঞতা প্রমাণ করে যে, বিদ্যুৎ সঞ্চালন এবং সরবরাহের ক্ষেত্রে আঞ্চলিক এবং সামাজিক বৈষম্যের প্রতিও নজর দেয়া প্রয়োজন। সব মিলিয়ে, বিদ্যুৎ সঞ্চালন এবং বিতরণ অবকাঠামোর ক্ষেত্রেও বাংলাদেশ এক গুরুত্বপূর্ণ সমস্যার সম্মুখীন হয়েছে যার নিরসন প্রয়োজন।

বিদ্যুৎ ও জ্বালানী খাতের আর্থিক স্থায়িত্বশীলতার সমস্যা

উপরে উল্লিখিত বেশ কয়েকটি সমস্যার পুঞ্জীভূত প্রকাশ দেখা যায় বিদ্যুৎ ও জ্বালানী খাতের আর্থিক স্থায়িত্বশীলতার সমস্যার মধ্যে। এ প্রসঙ্গে নিম্নরূপ কমপক্ষে চারটি সমস্যার কথা উল্লেখ করা যায়: (ক) অলস ক্যাপাসিটি চার্জ বাবদ দায় পরিশোধ; (খ) জ্বালানী আমদানির ব্যয় বৃদ্ধি; (গ) ক্রমবর্ধমান ঋণের বোঝা; এবং (ঘ) জ্বালানী এবং বিদ্যুতের দাম নির্ধারণে ভ্রান্তি। নীচে এগুলো সম্পর্কে সংক্ষেপে আলোচনা করা হলো।

(ক) অলস ক্যাপাসিটি চার্জ বাবদ ক্রমবর্ধমান দায়

তৃতীয় অনুচ্ছেদে আমরা লক্ষ্য করেছি, বিদ্যুৎ সরবরাহের সাথে চাহিদার অসামঞ্জস্যতা এবং তার ফলে অব্যবহৃত উৎপাদন ক্ষমতার জন্য সরকারকে ব্যক্তি খাতের বিদ্যুৎ কেন্দ্রের মালিকদের বিপুল পরিমাণ ক্যাপাসিটি চার্জ প্রদান করতে হচ্ছে। সেখানে উল্লিখিত হয়েছে, ২০০৮ সনে ক্ষমতায় আসার পর সরকার দ্রুত বিদ্যুৎ সরবরাহ বৃদ্ধির জন্য অনেকগুলো “কুইক রেন্টাল” বিদ্যুৎ কেন্দ্র সংগ্রহ করে। এসব কেন্দ্র থেকে ক্রয়কৃত বিদ্যুতের দাম অনেক চড়া। নতুন, স্থায়ী বিদ্যুৎ কেন্দ্র নির্মাণের পর “কুইক রেন্টাল” বিদ্যুৎ কেন্দ্র সমূহ বন্ধ হয়ে যাওয়ার কথা ছিল। কিন্তু অভিযোগ আছে যে, কুইক রেন্টাল কেন্দ্রের মালিকেরা বিদ্যুৎ বিভাগের কর্মকর্তাদের এবং সংশ্লিষ্ট রাজনৈতিক নেতৃবৃন্দের যোগসাজশে এসব কেন্দ্রের মেয়াদ বাড়িয়ে নিচ্ছে এবং তার ফলে সরকারকে আরও বেশী ক্ষতির সম্মুখীন হতে হচ্ছে।

এক হিসাবমতে অলস বিদ্যুৎ কেন্দ্রের ক্যাপাসিটি চার্জ বাবদ প্রদত্ত অর্থের পরিমাণ ২০১০ সনের ১,৭৯০ কোটি টাকা থেকে বৃদ্ধি পেয়ে ২০১৯ সনে ৮,০২৯ কোটি টাকাতে পৌঁছেছে। পত্রিকায় প্রকাশিত তথ্য অনুযায়ী গত এক দশকে বিদ্যুৎ খাতে সরকারকে মোট ৫২,২৬০ কোটি টাকা ভর্তুকী প্রদান করতে হয়েছে। বস্তুত, বিদ্যুৎ, জ্বালানী, এবং খনিজ সম্পদ বিষয়ক মন্ত্রণালয়ের মোট বাজেটের প্রায় এক-তৃতীয়াংশ এখন অলস বিদ্যুৎ কেন্দ্রের ক্যাপাসিটি চার্জ প্রদানের জন্য ব্যয়িত হচ্ছে। বিদ্যুৎ খাতে প্রদত্ত এই বিপুল ভর্তুকী এখন বাংলাদেশের সামষ্টিক অর্থনৈতিক স্থিতিশীলতার জন্য হুমকি হয়ে দাঁড়িয়েছে।

(খ) জ্বালানী আমদানির ব্যয় বৃদ্ধি

এর সাথে যোগ হয়েছে আমদানিকৃত জ্বালানীর উপর ক্রমবর্ধমান নির্ভরতা। এর ফলে বাংলাদেশকে এখন বিপুল পরিমাণ বৈদেশিক মুদ্রা জ্বালানী আমদানির জন্য ব্যয় করতে হচ্ছে। ফলে, বৈদেশিক লেনদেনে ঘাটতি বেড়ে

যাচ্ছে এবং বাংলাদেশের রিজার্ভ দ্রুত হ্রাস পাচ্ছে। রাশিয়া-ইউক্রেন যুদ্ধের ফলে আন্তর্জাতিক বাজারে তেল এবং তরলীকৃত গ্যাসের দাম বৃদ্ধির ফলে এই সংকট আরও তীব্র হয়েছে। পর্যাপ্ত বৈদেশিক মুদ্রার অভাবে সরকার প্রয়োজনীয় পরিমাণে জ্বালানী আমদানি করতে পারছে না; ফলে বিদ্যুৎ উৎপাদন এখন চাহিদার তুলনায় অপরি্যাপ্ত এবং সরকারকে লোড শেডিংয়ের আশ্রয় নিতে হচ্ছে। সাধারণত, দু'টি পদ্ধতিতে আন্তর্জাতিক বাজার থেকে তরলীকৃত গ্যাস কেনা যায়। একটি হলো দীর্ঘমেয়াদী চুক্তি আর অন্যটি হলো স্পট মার্কেটের উপর নির্ভরতা। দীর্ঘমেয়াদী চুক্তির অধীনে কেনা হলে সাধারণত দাম কিছুটা কম হয় এবং, তার চেয়ে বড় কথা, দাম স্থিতিশীল থাকে। অভিযোগ আছে যে, বাংলাদেশ দুর্ভাগ্যজনকভাবে স্পট মার্কেটের উপর বেশী নির্ভর করেছে এবং তার ফলে এখন রাশিয়া-ইউক্রেন যুদ্ধের কারণে দাম বৃদ্ধির শিকার হয়েছে এবং পর্যাপ্ত পরিমাণে জ্বালানী আমদানি করতে সমস্যার সম্মুখীন হচ্ছে। এদিকে বিদ্যুৎ সংকটের ফলে অর্থনৈতিক কর্মকাণ্ড ক্ষতিগ্রস্ত হচ্ছে এবং অনেক ক্ষেত্রে রপ্তানীমুখী শিল্প উৎপাদন বাঁধাগ্রস্ত হচ্ছে। ফলে রপ্তানি আয় হ্রাস পাচ্ছে এবং বৈদেশিক মুদ্রার সংকট আরও তীব্র হচ্ছে। এভাবে দেশের অর্থনীতি একটি অশুভ চক্রের মধ্যে নিপতিত হওয়ার সম্ভাবনা সৃষ্টি হয়েছে।

(গ) ক্রমবর্ধমান ঋণের দায়

বিদ্যুৎ খাতের আর্থিক অস্থায়িত্বশীলতার তৃতীয় উৎস হলো ক্রমবর্ধমান ঋণের বোঝা। সাম্প্রতিককালে বেশিরভাগ বিদ্যুৎ কেন্দ্র “সরবরাহকারীর ঋণ” (ইংরাজিতে “সাপ্লায়ার’স ক্রেডিট”)-এর অধীনে নির্মিত হয়েছে। এসব ঋণের সুদের হার উঁচু। ফলে, এসব ঋণের দায় পরিশোধের পরিমাণ দ্রুত হারে বাড়ছে। এ দৃষ্টিকোণ থেকে বিশেষভাবে উদ্বেগজনক হলো পাবনার ঈশ্বরদীতে নির্মায়মান রূপপুর আণবিক বিদ্যুৎ কেন্দ্র, যার মোট বাজেট ১ লক্ষ আশী হাজার

কোটি টাকার চেয়েও বেশী। অন্যান্য বিদ্যুৎ কেন্দ্রজনিত বৈদেশিক ঋণের বোঝার সাথে যখন এই বিদ্যুৎ কেন্দ্রের জন্য গৃহীত ঋণের দায় যোগ হবে তখন বৈদেশিক ঋণ বাবদ মোট দায়ের পরিমাণ বিপুলভাবে বৃদ্ধি পাবে। ফলে, আগামীতে বিদ্যুৎ ও জ্বালানী খাতের, এবং সেই সূত্রে তথা গোটা অর্থনীতির স্থায়িত্বশীলতার সমস্যা আরও প্রকট হবে।

(ঘ) জ্বালানী ও বিদ্যুতের দাম নির্ধারণে ভ্রান্তি

এ প্রসঙ্গে লক্ষ্যণীয়, বিদ্যুৎ ও জ্বালানী খাতের আর্থিক স্থায়িত্বশীলতা অর্জনের ক্ষেত্রে বিদ্যুৎ ও জ্বালানীর সঠিক দাম নির্ধারণ একটি গুরুত্বপূর্ণ বিষয়। অর্থনীতির একটি স্বীকৃত নিয়ম হলো, কোনো সম্পদের দক্ষ ব্যবহার নিশ্চিত করতে হলে তার “সীমান্ত মূল্য” (ইংরাজিতে, “বর্ডার প্রাইস”) দ্বারা সেটির দাম নির্ধারণ করতে হয়। আমদানিকৃত সম্পদের জন্য এ বিষয়টি বোঝা সহজ। যেমন, আমদানিকৃত এল-এন-জি’র দাম নির্ধারিত হওয়া প্রয়োজন আন্তর্জাতিক বাজারে এর দামের সাথে দেশের সীমান্ত পর্যন্ত এর পরিবহনের খরচ যোগ করার মাধ্যমে। লক্ষ্যণীয়, দাম নির্ধারণের এই নীতি দেশজ সম্পদের জন্যও প্রযোজ্য হওয়া প্রয়োজন। অর্থাৎ, সমধর্মী পণ্যের -- তা আমদানিকৃত কিংবা দেশজ যাইহোক না কেন -- দাম একই হওয়া উচিত। অর্থনীতির এই নীতির আলোকে বাংলাদেশে দীর্ঘকাল যাবত দেশজ গ্যাস সস্তা দামে শিল্পের এবং গৃহস্থালী প্রয়োজনে সরবরাহ করা এক বড় ভুল ছিল এবং তা দেশের এই গুরুত্বপূর্ণ সম্পদের অপচয়মূলক ব্যবহারকে উৎসাহিত করেছে। যতদিন পর্যন্ত দেশজ গ্যাস প্রয়োজনের তুলনায় পর্যাপ্ত ছিল ততদিন এই অদক্ষতার বিষয়টি তেমন নজরে আসে নি। কিন্তু এখন যেহেতু বাংলাদেশকে বিদেশ থেকে গ্যাস আমদানী করতে হচ্ছে সেহেতু বিদেশী গ্যাস আর দেশজ গ্যাসের দামের বিরাট পার্থক্য এক সমস্যার সৃষ্টি করেছে। দীর্ঘকাল ধরে দেশজ গ্যাসের সস্তা দামের সাথে অভ্যস্ত গ্রাহকেরা এখন “সীমান্ত মূল্য”

দ্বারা গ্যাসের দাম নির্ধারণ মেনে নিতে চাচ্ছে না এবং সে কারণে সরকারকে ভর্তুকী দিয়ে আমদানিকৃত গ্যাস গ্রাহকদের নিকট সরবরাহ করতে হচ্ছে। ফলে, গ্যাস আমদানি যতো বাড়ছে এ বাবদ ভর্তুকীর পরিমাণও ততো বাড়ছে এবং তা শুধু জ্বালানী খাতের নয় বরং গোটা সামষ্টিক অর্থনীতির স্থায়িত্বশীলতার জন্য হুমকি হয়ে দাঁড়িয়েছে (Moazzem, Mostofa, and Habib 2021)।

সুতরাং, একাধিক কারণে বর্তমানে বাংলাদেশের বিদ্যুৎ ও জ্বালানী খাতের আর্থিক স্থায়িত্বশীলতার সমস্যার উদ্ভব ঘটেছে এবং তা গোটা অর্থনীতির জন্য সমস্যার সৃষ্টি করেছে। এই সমস্যা থেকে উৎক্রান্তি অর্জন এখন বাংলাদেশের জন্য এক বড় চ্যালেঞ্জ।

বিদ্যুৎ ও জ্বালানী খাতের পরিবেশগত স্থায়িত্বশীলতার সমস্যা

আর্থিক অস্থায়িত্বশীলতার পাশাপাশি বাংলাদেশের বিদ্যুৎ ও জ্বালানী খাত পরিবেশগত অস্থায়িত্বশীলতার সমস্যারও সম্মুখীন। এই সমস্যার একটি বড় কারণ হলো জ্বালানী হিসেবে কয়লার উপর ক্রমবর্ধমান নির্ভরতা। সকল জীবাত্ম জ্বালানীর মধ্যে কয়লা সবচেয়ে দূষণকারী। কয়লার ব্যবহার শুধু নির্গত ধোঁয়ার মাধ্যমে বায়ু দূষিত করে না। কয়লা পোড়ানোর ফলে যে ছাই সৃষ্ট হয় তা নিকটবর্তী জমি এবং জলাশয় দূষণের একটি বড় কারণ হয়ে দাঁড়ায়।

দুর্ভাগ্যবশত, সরকার PSMP 2010 এবং RPSMP 2016-এর অধীনে আমদানিকৃত কয়লাকেই অন্যতম মূল জ্বালানী হিসেবে গ্রহণ করেছে। ফলে, যতো বেশী সংখ্যক কয়লা-ভিত্তিক বিদ্যুৎ কেন্দ্র নির্মিত এবং চালু হচ্ছে ততোই পরিবেশের উপর হুমকি বৃদ্ধি পাচ্ছে। এই হুমকির একটি বড় দৃষ্টান্ত হলো রামপালে নির্মিত কয়লা-ভিত্তিক বিদ্যুৎ কেন্দ্র। সুন্দরবনের অতি নিকটবর্তী হওয়ায় এই কেন্দ্রের দূষণ এই বনের জন্য একটি বড় হুমকি হয়ে দাঁড়িয়েছে। তদুপরি, এই বিদ্যুৎ কেন্দ্র সুন্দরবনের উত্তর এবং পূর্ব সীমায় আরও বহু

দূষণকারী শিল্প এবং বাণিজ্যিক স্থাপনা নির্মাণকে উৎসাহিত করেছে, যার ফলে রামপাল বিদ্যুৎ কেন্দ্র সুন্দরবনের জন্য এক বৃহত্তর হুমকি সৃষ্টি করেছে।

লক্ষ্যণীয়, সুন্দরবন জাতিসংঘের ইউনেস্কো কর্তৃক স্বীকৃত “বিশ্ব প্রাকৃতিক উত্তরাধিকার” মর্যাদা সম্পন্ন একটি স্থান। সে কারণে এই বনের প্রতি রামপাল বিদ্যুৎ কেন্দ্র কর্তৃক সৃষ্ট হুমকির সত্যতা যাচাইয়ের জন্য ইউনেস্কো একাধিকবার প্রতিনিধিদল পাঠিয়েছে এবং তাঁরা সরকারকে এই বিদ্যুৎ কেন্দ্র স্থাপন থেকে বিরত থাকার অনুরোধ করেছে (Gatenby 2019)। দুর্ভাগ্যবশত, সরকার এসব সুপারিশ উপেক্ষা করে রামপাল বিদ্যুৎ কেন্দ্র নির্মাণ সম্পন্ন করেছে এবং এখন তা পরীক্ষামূলকভাবে চালু করেছে।

বাপা এবং বেন প্রথম থেকেই রামপাল বিদ্যুৎ কেন্দ্রের বিরোধিতা করেছে। সে উদ্দেশ্যে বাপা বহু সেমিনার, সভা, মানব বন্ধন, এবং জনসভা করেছে; নীতি নির্ধারকদের নিকট প্রসঙ্গিক গবেষণা-ফলাফল, সুপারিশ, প্রস্তাব, স্মারকপত্র পেশ করেছে; এবং তাদের সাথে আলোচনায় মিলিত হয়েছে। এসব প্রচেষ্টা বিফল হওয়ার প্রেক্ষিতে এক পর্যায়ে বেনের পক্ষ থেকে প্রস্তাব দেয়া হয়েছিল যে, যদি এই বিদ্যুৎ কেন্দ্র নির্মাণের পরিকল্পনা একেবারে বাতিল করা সম্ভব না হয় তাহলে এটাকে কয়লার পরিবর্তে গ্যাসে রূপান্তরিত করা হোক। পরিতাপের বিষয় যে, কপ-২৬-এর প্রাক্কালে সরকার যে ৫টি বিদ্যুৎ কেন্দ্রকে কয়লার পরিবর্তে গ্যাসে রূপান্তরিত করার সিদ্ধান্ত ঘোষণা করেছে তার মধ্যে রামপাল বিদ্যুৎ কেন্দ্র অন্তর্ভুক্ত হয় নি। সুতরাং, সুন্দরবনের প্রতি হুমকির কোনো অবসান ঘটেনি।

একইভাবে, একাধিক কয়লাভিত্তিক বিদ্যুৎ কেন্দ্র এবং সংশ্লিষ্ট অন্যান্য স্থাপনা নির্মাণের ফলে উপকূলের দক্ষিণ-পূর্বে অবস্থিত কক্সবাজার জেলার বিভিন্ন স্থানের পরিবেশও মারাত্মক হুমকির সম্মুখীন। সেখানকার কোহেলিয়া নদী ইতিমধ্যেই বহুলাংশে দখল এবং বিনষ্ট করে ফেলা হয়েছে। অন্যান্য নদী, বন, এবং সমুদ্র উপকূলও এসব তৎপরতা দ্বারা ক্ষতিগ্রস্ত হচ্ছে।

এসব ঘটনা এবং প্রক্রিয়া প্রমাণ করে যে, বাংলাদেশের জ্বালানী নীতি এবং বিদ্যুৎ খাতের বিকাশ বহুলাংশ পরিবেশ বিধ্বংসী ধারায় অগ্রসর হয়েছে এবং তা পরিবেশগত অস্থায়িত্বশীলতার সমস্যা সৃষ্টি করেছে। এই সমস্যা নিরসন করে বিদ্যুৎ খাতের বিকাশকে পরিবেশসম্মত করা এখন একটি জরুরী কর্তব্য হিসেবে সমুপস্থিত হয়েছে।

ঝুঁকি প্রশমনের সমস্যা

বাংলাদেশ কর্তৃক অনুসৃত জ্বালানী এবং বিদ্যুৎ সম্প্রসারণ নীতি বেশ কয়েক ধরনের ঝুঁকি ডেকে এনেছে। এক ধরনের ঝুঁকি হলো অর্থনৈতিক, যার কথা আমরা দশম অনুচ্ছেদে আলোচনা করেছি। সেখানে আমরা দেখেছি, কিভাবে অনুসৃত জ্বালানী এবং বিদ্যুৎ নীতি আর্থিক অস্থায়িত্বশীলতার সৃষ্টি করেছে। দ্বিতীয় ধরনের ঝুঁকি হলো পরিবেশগত, যার কথা আমরা একাদশ অনুচ্ছেদে আলোচনা করেছি। তৃতীয় ধরনের ঝুঁকি হলো আরও ব্যাপক এবং বিধ্বংসী চরিত্রের এবং তা হলো দুর্ঘটনাজনিত পারমাণবিক তেজস্ক্রিয়তার বিস্তারের ঝুঁকি। রুপপুর আণবিক বিদ্যুৎ কেন্দ্র নির্মাণের মধ্য দিয়ে বাংলাদেশ এই নতুন ঝুঁকি গ্রহণ করলো।

আন্তর্জাতিক অঙ্গনে আণবিক বিদ্যুৎ নিয়ে একটি বিতর্ক এর সূচনা থেকেই বিরাজমান। অনেকে আণবিক বিদ্যুৎকে দূষণহীন মনে করেন এবং সেজন্য এটাকে স্বাগত জানান। অন্যরা এটাকে বিপজ্জনক মনে করেন দুই কারণে। প্রথমত, সফলভাবে পরিচালিত হলেও আণবিক বিদ্যুৎ কেন্দ্র যে বর্জ্য সৃষ্টি করে তা তেজস্ক্রিয়তাসপন্ন এবং পরিবেশের জন্য ঝুঁকিপূর্ণ। বর্তমানে কিছু দেশের মাটির অত্যন্ত গভীরে প্রোথিত বিশেষ আধারে এই বর্জ্য নিক্ষেপিত হচ্ছে। বাংলাদেশের এ ধরনের কোনো ব্যবস্থা নেই। সেজন্য বাংলাদেশ এই বর্জ্য নিক্ষেপনের জন্য রাশিয়ার উপর নির্ভরশীল হবে এবং যদি কোনো কারণে

এক্ষেত্রে কোনো ব্যত্যয় দেখা দেয় তাহলে সমূহ বিপদের সম্মুখীন হবে। দ্বিতীয়ত, প্রাকৃতিক অথবা মনুষ্যসৃষ্ট কোনো কারণে যদি আণবিক বিদ্যুৎ কেন্দ্র দুর্ঘটনা কবলিত হয় তাহলে বিরাট এলাকা জুড়ে তেজস্ক্রিয়তা বিস্তৃত হবে এবং তার ফলে বহু মানুষের প্রাণহানি, অঙ্গহানি, এবং অন্যান্য শারীরিক বিকৃতি ঘটবে এবং অনেক ক্ষেত্রে তা বংশানুক্রমে সঞ্চারিত হবে। তদুপরি তেজস্ক্রিয়তা আক্রান্ত এলাকা বহুকাল মানুষের বসবাসের অযোগ্য হয়ে পড়বে। সাম্প্রতিককালে বিশ্ব এ ধরনের দুটি বড় দুর্ঘটনার নজীর দেখেছে। একটি হলো ১৯৮৬ সনে ইউক্রেনের চেরনোবিল দুর্ঘটনা, আর অন্যটি হলো ২০১১ সনের ফুকুশিমা দুর্ঘটনা। এসব অভিজ্ঞতার প্রেক্ষিতে জার্মানী এবং জাপান উভয় দেশ তাদের সকল আণবিক বিদ্যুৎ কেন্দ্র বন্ধ করে দেয়ার সিদ্ধান্ত ঘোষণা করে।

উপর্যুক্ত আন্তর্জাতিক অভিজ্ঞতার প্রেক্ষিতে বাংলাদেশ কর্তৃক আণবিক বিদ্যুৎ কেন্দ্র নির্মাণ একটি প্রশ্নবিদ্ধ পদক্ষেপ। অন্যান্য দেশের তুলনায় এ কারণে বাংলাদেশের জন্য সৃষ্ট ঝুঁকির মাত্রা বেশী। প্রথমত, বাংলাদেশ অত্যন্ত ঘন বসতি সম্পন্ন দেশ। ফলে, দুর্ঘটনাজনিত তেজস্ক্রিয়তার বিস্তারের ফলে বাংলাদেশে বহুগুণ মানুষ আক্রান্ত হবে। দ্বিতীয়ত, বেশিরভাগ ক্ষেত্রে আণবিক বিদ্যুৎ কেন্দ্র সমুদ্র উপকূলে নির্মিত হয়। এতে, একদিকে, এসব কেন্দ্রের শীতলীকরণের জন্য পানির লভ্যতা নিশ্চিত হয়। অন্যদিকে, বিদ্যুৎ কেন্দ্রের অন্তত একপাশে কোনো জনবসতি থাকে না, ফলে দুর্ঘটনার কারণে অপেক্ষাকৃত কম সংখ্যক মানুষ আক্রান্ত হয়। বাংলাদেশের রূপুর বিদ্যুৎ কেন্দ্রের অবস্থান দেশের অভ্যন্তরে, প্রায় মাঝখানে। ফলে দুর্ঘটনাজনিত তেজস্ক্রিয়তা সারা দেশ ছড়িয়ে পড়বে এবং বহুগুণ মানুষ আক্রান্ত হবে। তৃতীয়ত, বেশিরভাগ আণবিক বিদ্যুৎ কেন্দ্র সম্পন্ন দেশের তুলনায় বাংলাদেশের কারিগরি সক্ষমতার মান নিচু। চতুর্থত, সামাজিক শৃঙ্খলার দৃষ্টিকোণ থেকেও বাংলাদেশ বেশিরভাগ আণবিক বিদ্যুৎ কেন্দ্র সম্পন্ন দেশের

তুলনায় পিছিয়ে আছে। এসব বিভিন্ন দৃষ্টিকোণ থেকেই বাংলাদেশের জন্য আণবিক বিদ্যুৎ কেন্দ্র নির্মাণ সঠিক সিদ্ধান্ত হয়েছে কিনা তা নিয়ে সংশয় রয়েছে। উদ্বেগের বিষয় যে, এ বিষয়ে বিস্তারিত আলোচনা না করার পরিবর্তে সরকার আরও আণবিক বিদ্যুৎ কেন্দ্র নির্মাণের ঘোষণা দিয়েছে। এর ফলে দুর্ঘটনাজনিত তেজস্ক্রিয়তা বিস্তারের ঝুঁকি আরও বৃদ্ধি পাবে।

অনেক গবেষক মত প্রকাশ করেছেন যে, আণবিক বিদ্যুতের দিকে অগ্রসর হওয়ার ক্ষেত্রেও এক লাফে বৃহদাকার বিদ্যুৎ কেন্দ্র স্থাপন না করে বাংলাদেশ ক্ষুদ্রাকার মডুলার আণবিক বিদ্যুৎ কেন্দ্র স্থাপনের বিকল্প গ্রহণ করতে পারতো (দ্রষ্টব্য, Bhattacharya 2021)। আধুনিক প্রযুক্তি এ ধরনের মডুলার বিদ্যুৎ কেন্দ্র স্থাপনের সুযোগ সৃষ্টি করেছে। এই বিকল্প গ্রহণের মাধ্যমে কম ঝুঁকি গ্রহণ করে আণবিক শক্তি সম্পর্কে অভিজ্ঞতা সঞ্চয়, কারিগরি মান, ও সামাজিক শৃঙ্খলার উন্নতি সাধন করে পর্যায়ক্রমে বৃহদাকার আণবিক বিদ্যুৎ কেন্দ্রের দিকে অগ্রসর হতে পারতো। অবস্থাদৃষ্টে প্রতীয়মান হয় যে, বাংলাদেশের নীতি নির্ধারকেরা এই বিকল্পের কথা আগেও বিবেচনা করেন নি এবং এখনও করতে আগ্রহী নন। তাঁদের উৎসাহ বরং বহুসংখ্যক বৃহদাকার আণবিক বিদ্যুৎ কেন্দ্র স্থাপনের দিকে দ্রুত অগ্রসর হওয়া। সুতরাং, বিদ্যুৎ খাতের ভবিষ্যৎ বিকাশের জন্য ঝুঁকির বিষয়টি আরেকটি গুরুত্বপূর্ণ সমস্যা হিসেবে আবির্ভূত হয়েছে।

সনাতন জ্বালানীর সর্বোত্তম ব্যবহার অর্জনের সমস্যা

জ্বালানী খাতের জন্য বাংলাদেশ আরেকটি যে সমস্যার সম্মুখীন তা হলো দেশের সনাতনী জ্বালানী সংক্রান্ত। এসব জ্বালানীর মধ্যে রয়েছে কাঠের খড়ি, পাটখড়ি, গোবর, তুষ, অন্যান্য কৃষি বর্জ্য, জৈব গ্যাস, ইত্যাদি। বাংলাদেশের গ্রামীণ জনগণ এবং শহরের একাংশ এখনও তাদের জ্বালানী চাহিদার একটি উল্লেখযোগ্য অংশ এসব জ্বালানী দ্বারা পূরণ করে। আধুনিক জ্বালানী (বিশেষত

প্রাকৃতিক গ্যাস) সংক্রান্ত সরকারী নীতি সনাতনী জ্বালানীর উপর তাদের এই নির্ভরতা অব্যাহত রাখার পেছনে অনেকাংশে কাজ করেছে। নবম অনুচ্ছেদের আলোচনায় আমরা দেখেছি, গৃহস্থালী ব্যবহারের জন্য পাইপ-ভিত্তিক গ্যাস সরবরাহের নীতি গ্রামের মানুষদের এবং শহরের বহু বস্তিবাসী দরিদ্রদের গ্যাস ব্যবহারের সুযোগ থেকে বঞ্চিত রেখেছে। দেশের যেসব অঞ্চলে গ্যাসের পাইপ লাইন পৌঁছায় নি সেসব অঞ্চলে কারো পক্ষেই শিল্প কিংবা গৃহস্থালী ব্যবহারের জন্য গ্যাস পাওয়া সম্ভব ছিল না। এসব অঞ্চলে গৃহস্থালী ব্যবহারের জন্য প্রায় সকলকেই সনাতনী জ্বালানীর উপর নির্ভর করতে হয়েছে এবং এখনো হচ্ছে।

সনাতনী জ্বালানীর ভালমন্দ দু'টি দিকই আছে। ভাল দিক সমূহের মধ্যে উল্লেখ্য হলো, প্রথমত, এসব জ্বালানী দেশজ সূত্রের; ফলে তা আমদানি করতে হয় না এবং সে বাবদ বৈদেশিক মুদ্রা ব্যয় করতে হয় না। দ্বিতীয়ত, এসব জ্বালানী এমনসব সূত্রের যার আর তেমন বিকল্প ব্যবহার নেই; ফলে জ্বালানী হিসেবে ব্যবহৃত না হলে এগুলো অপচয়িত হতো। এক্ষেত্রে গোবরের কথা বিশেষভাবে উল্লেখ্য। পাটখড়ি, তুষ, ইত্যাদির জন্যও তা আংশিকভাবে প্রযোজ্য, কেননা যদিও এগুলোর বিকল্প ব্যবহার আছে কিন্তু নীতি-নির্ধারকেরা তার প্রতি যথাযথ মনোযোগ দেয় না। তৃতীয়ত, এসব জ্বালানী দরিদ্র মানুষদের নিকট বেশী লভ্য; ফলে সামাজিক সমতার দৃষ্টিকোণ থেকে এসব জ্বালানীর বিশেষ উপযোগিতা রয়েছে। দু'টি বিষয় এখানে কাজ করে। এক, অনেক ক্ষেত্রে এগুলো বিনামূল্যে পাওয়া যায়। দুই, এগুলোর ব্যবহার যেরূপ শ্রমের দাবী করে তা দরিদ্র পরিবারদের পক্ষে দেয়া সহজ হয়। সনাতনী জ্বালানী হিসেবে গোবরের কথা ভাবলেই এই দুই দিক সম্পর্কে নিঃসন্দেহ হওয়া যায়।

পাশাপাশি, সনাতনী জ্বালানী ব্যবহারের কিছু মন্দ দিকও আছে। তার মধ্যে উল্লেখ্য হলো, প্রথমত, এসব জ্বালানীর ব্যবহার গাছপালার ক্ষতি সাধন করতে পারে। যেমন, কাঠের খড়ি পাওয়ার জন্য গাছ কাটতে হয়, যা কান্ডিত নয়। দ্বিতীয়ত, এসব জ্বালানীর বেশীরভাগ ক্ষেত্রে রান্নার জন্য ব্যবহৃত হয় এবং তা

“গৃহাভ্যন্তরীণ বায়ু দূষণ” সৃষ্টি করে। বলাবাহুল্য, নারী এবং শিশুদের তাতে বেশী স্বাস্থ্যহানি ঘটে, কারণ আমাদের সমাজে নারীরাই রান্না করে এবং শিশুরা মায়েদের কাছাকাছি বেশী থাকতে চায়।

সুতরাং, বাংলাদেশ সনাতনী জ্বালানীর মন্দ দিকসমূহ প্রশমিত করে এগুলোর ভাল দিকগুলোর সর্বোত্তম ব্যবহার নিশ্চিত করার সমস্যার সম্মুখীন। এ সমস্যা একেবারে নতুন নয়; তবে জ্বালানী খাতের অন্যান্য পরিবর্তনের আলোকে এই সমস্যা আরও প্রকট হয়েছে। ওই সমস্যার সমাধানের দৃষ্টিকোণ থেকে দু’টি বিষয়ের উপর গুরুত্ব আরোপ করা যেতে পারে। একটি হলো আধুনিক পদ্ধতিতে জৈব গ্যাস উৎপাদনের প্রসার। এর ফলে কয়েকটি উপকার সাধিত হবে। প্রথমত, দেশের যেসব জৈব বর্জ্য, সেগুলো অপচয়িত না হয়ে দেশের জ্বালানী চাহিদা মেটাতে গুরুত্বপূর্ণ ভূমিকা পালন করবে। দ্বিতীয়ত, আধুনিক পদ্ধতিতে জৈব গ্যাস উৎপাদন করা গেলে তা দ্বারা শুধু গৃহস্থালি নয়, বৃহত্তর পরিধির বাণিজ্যিক এবং গ্রামীণ শিল্পে ব্যবহারও সম্ভব হবে। তৃতীয়ত, পাইপের মাধ্যমে সরবরাহকৃত হয়ে ব্যবহারের ফলে গৃহাভ্যন্তরীণ এবং বহিঃস্থ, উভয় ধরনের দূষণ প্রশমিত হবে।

দ্বিতীয় যে বিষয়ের প্রতি গুরুত্ব আরোপ করা প্রয়োজন তা হলো সনাতনী জ্বালানী ব্যবহার করে রান্নার জন্য “উন্নত চুল্লী” ব্যবহারের প্রসার। এসব চুল্লীর একাধিক উপকার। প্রথমত, তা সনাতনী জ্বালানীর অধিকতর দক্ষ ব্যবহার নিশ্চিত করে। বর্তমানের খোলা চুল্লী দ্বারা রান্নার সময় জ্বালানী সৃষ্ট তাপের বড় অংশ বাইরে চলে যায়; ফলে প্রয়োজনের তুলনায় বেশী জ্বালানী ব্যবহার করতে হয়। উন্নত চুল্লী দ্বারা রান্নার সময় জ্বালানী-সৃষ্ট তাপ বাইরে যেতে পারে না এবং প্রায় সম্পূর্ণভাবে হাঁড়ির দিকে ধাবিত করে; ফলে কম জ্বালানী দিয়ে বেশী রান্না করা যায়। দ্বিতীয়ত, উন্নত চুল্লী দিয়ে রান্নার সময় যে গ্যাস নির্গত হয় তা পাইপের মাধ্যমে বাইরে চলে যায়। ফলে, গৃহাভ্যন্তরীণ দূষণ এবং নারী ও শিশুদের স্বাস্থ্যহানি ঘটে না।

সব মিলিয়ে স্পষ্ট যে, আধুনিকতার নামে সনাতনী জ্বালানী সমূহকে অবহেলা এবং উপেক্ষা করা ঠিক নয়। বরং আধুনিক পদ্ধতিতে জৈব সার উৎপাদনের প্রসার, উন্নত চুল্লীর প্রবর্তন, ইত্যাদি পদক্ষেপের মাধ্যমে এসব জ্বালানীর সম্ভাবনার সর্বোত্তম ব্যবহার নিশ্চিত করার দিকে মনোযোগী হওয়া প্রয়োজন। দুর্ভাগ্যবশত, বাংলাদেশের নীতি নির্ধারকেরা বিদেশী ঋণ নিয়ে, হাজার হাজার কোটি টাকা ব্যয় করে, পরিবেশের প্রতি হুমকি সৃষ্টিকারী বৃহদাকার বিদ্যুৎ কেন্দ্র স্থাপনে যতোটা উৎসাহী, দেশজ জ্বালানী ব্যবহার করে, ক্ষুদ্রাকার, গণমুখী, পরিবেশসম্মত জ্বালানী ব্যবহার প্রসারের বিষয়ে ততোটা নয়। কিভাবে নীতি নির্ধারকদের এ বিষয়ে অগ্রাধিকারের ক্ষেত্রে পরিবর্তন আনা যায় তা বাংলাদেশের জ্বালানী খাতের ভবিষ্যৎ বিকাশের জন্য আরেকটি গুরুত্বপূর্ণ সমস্যা।

জ্বালানী নীতি ও বিদ্যুৎ পরিকল্পনা প্রণয়নে বৈদেশিক নির্ভরতার সমস্যা

উপরের ১১টি অনুচ্ছেদে যেসব সমস্যা আলোচিত হলো সেগুলো বাংলাদেশের জ্বালানী এবং বিদ্যুৎ খাতের বিভিন্ন সুনির্দিষ্ট সমস্যা। প্রাসঙ্গিক আরেকটি সমস্যা হলো বাংলাদেশের নীতি এবং পরিকল্পনা প্রণয়নে বৈদেশিক নির্ভরতার সমস্যা। এটা সমস্যা বৃহত্তর চরিত্রের দুই কারণে। প্রথমত, একাধিক সুনির্দিষ্ট সমস্যার উৎস এই সমস্যার মধ্যে নিহিত। দ্বিতীয়ত, পরনির্ভরতার এই সমস্যা শুধু জ্বালানী এবং বিদ্যুৎ খাতের জন্য সীমাবদ্ধ নয়। দেশের অন্যান্য গুরুত্বপূর্ণ খাতের জন্যও তা প্রযোজ্য।

গত পঞ্চাশ বছরে বাংলাদেশ উল্লেখযোগ্য অর্থনৈতিক অগ্রগতি অর্জন করেছে। কিন্তু বিস্ময়কর হলেও সত্য যে, নীতি এবং পরিকল্পনা প্রণয়নের ক্ষেত্রে বাংলাদেশ যেন আগের চেয়ে আরও বেশী পরনির্ভর হয়ে পড়েছে। জ্বালানী এবং বিদ্যুৎ খাত তার একটি উদাহরণ। এই খাতের পরিকল্পনার

দায়িত্ব দেয়া হয়েছে “টোকিও ইলেকট্রিক কোম্পানী”র উপর। একই ধরনের পরিস্থিতি আমরা দেখি দেশের আরেক গুরুত্বপূর্ণ খাত, পানি উন্নয়নের ক্ষেত্রে। এই খাতের জন্য সাম্প্রতিককালের সবচেয়ে গুরুত্বপূর্ণ পরিকল্পনা -- “বদ্বীপ পরিকল্পনা ২১০০” -- মূলত ওলন্দাজ বিশেষজ্ঞদের দ্বারা প্রণীত হয়েছে। অধুনাকালে, শুধু পরিকল্পনা নয়, কোন সুনির্দিষ্ট প্রকল্প গৃহীত হবে সেটাও বিদেশী কোম্পানিসমূহ বাংলাদেশের জন্য নির্ধারণ করে দিচ্ছে।² বিদ্যুৎ এবং পানি উন্নয়ন, উভয় খাতের জন্যই তা প্রযোজ্য।

দেশের মৌলিক বিষয়াদি সম্পর্কে নীতি ও পরিকল্পনা প্রণয়নে বিদেশী সরকার ও সংস্থার উপর নির্ভরতার একাধিক কুফল লক্ষ্য করা যায়। প্রথমত, বিদেশী সংস্থা এবং বিশেষজ্ঞদের অনেক বিশেষায়িত জ্ঞান এবং দক্ষতা থাকলে বাংলাদেশের সুনির্দিষ্ট পরিস্থিতি, এ দেশের জনগণের আশা আকাঙ্ক্ষা, সম্পদ ও সমস্যা, ইত্যাদি বিষয়ে অনুপংখ জ্ঞানের ক্ষেত্রে তাদের সীমাবদ্ধতা থেকে যায়। ফলে সদিচ্ছা থেকেও তাঁরা যেসব নীতি এবং পরিকল্পনা তৈরি করেন তাতে গুরুত্বপূর্ণ ঘাটতি, দুর্বলতা, এবং ত্রুটি থেকে যায়। উপরে বিভিন্ন অনুচ্ছেদের আলোচনায় আমরা দেখেছি, টোকিও ইলেকট্রিক কোম্পানি বাংলাদেশের বিদ্যুৎ খাতের জন্য যে মহাপরিকল্পনা (যেমন PSMS 2010 এবং RPSMS 2016) প্রণয়ন করেছে, তাতে এ ধরনের দুর্বলতার বহু উদাহরণ পরিলক্ষ্য হয়। যেমন, প্রথমত, বিদ্যুতের চাহিদা এবং সরবরাহের মধ্যে যে গতিশীল সামঞ্জস্য থাকা প্রয়োজন ছিল, এ পরিকল্পনা তা নিশ্চিত করতে অসমর্থ হয়েছে। দ্বিতীয়ত, এই পরিকল্পনায় বিদ্যুৎ উৎপাদনে সরকারী-বেসরকারী খাতের আপেক্ষিক ভূমিকার যে বিবর্তন প্রস্তাবিত হয়েছে তার যৌক্তিকতা বোঝা কষ্টকর। তৃতীয়ত, এই পরিকল্পনায় বাংলাদেশের মোট

² মূলত ওলন্দাজ বিশেষজ্ঞদের দ্বারা প্রণীত হওয়ার কারণে “বাংলাদেশ বদ্বীপ পরিকল্পনা ২১০০”-তে কী কী সমস্যা সৃষ্টি হয়েছে, সে বিষয়ে আলোচনার জন্য দেখুন S. Nazrul Islam (2022)।

বিদ্যুৎ সরবরাহে বিদেশ থেকে আমদানিকৃত বিদ্যুতের অংশ যেভাবে ক্রমাগতভাবে বাড়িয়ে ২০৪১ সন নাগাদ ১৫ শতাংশে বর্ধিত করা হয়েছে তা সচেতন পর্যবেক্ষকদের মতে এ দেশের মানুষের আশা-আকাঙ্ক্ষার সাথে সামঞ্জস্যপূর্ণ নয়। এরূপ আরও বহু উদাহরণের উল্লেখ করা যেতে পারে।

দ্বিতীয়ত, অনেক ক্ষেত্রে বাংলাদেশের জন্য নীতি ও পরিকল্পনা প্রণয়নের ক্ষেত্রে বিদেশী দেশ এবং সংস্থাসমূহ শুধুমাত্র বাংলাদেশের স্বার্থ নয়, তাদের নিজেদের স্বার্থ দ্বারাও পরিচালিত হন। ফলে “স্বার্থের বিরোধ” দেখা দেয় এবং তা প্রণীত নীতি এবং পরিকল্পনাকে নেতিবাচকভাবে প্রভাবিত করে (Moazzem and Preoty 2021)। উদাহরণস্বরূপ, অনেক পর্যবেক্ষক টোকিও ইলেকট্রিক কোম্পানি কর্তৃক প্রণীত বাংলাদেশের বিদ্যুৎ মহাপরিকল্পনায় কয়লার প্রতি অত্যধিক গুরুত্ব প্রদান দ্বারা বিস্মিত হয়েছেন, বিশেষত যখন জাপান নিজেই জলবায়ু পরিবর্তন প্রশমনের জন্য আন্তর্জাতিক সম্প্রদায়ের নিকট কয়লা থেকে সরে আসার নীতি অনুসরণে প্রতিশ্রুতিবদ্ধ। এ প্রসঙ্গে পর্যবেক্ষকেরা লক্ষ্য করেছেন যে, একাধিক জাপানী কোম্পানি কর্তৃক নির্মিতব্য কয়লা ভিত্তিক বিদ্যুৎ প্রকল্প এই পরিকল্পনায় কিংবা তার বাস্তবায়ন কর্মসূচিতে অন্তর্ভুক্ত হয়েছে। ফলে তাঁদের মনে প্রশ্ন জেগেছে, এসব কোম্পানিকে সুযোগ করে দেয়ার জন্য টোকিও ইলেকট্রিক কোম্পানি কর্তৃক প্রণীত বাংলাদেশের বিদ্যুৎ মহাপরিকল্পনায় কয়লার প্রতি এত গুরুত্ব প্রদান করা হয়েছে কিনা।

এসব উদাহরণের আলোকে পরিস্কার যে, বিদেশী দেশ এবং সংস্থা দ্বারা দেশের জাতীয়ভাবে গুরুত্বপূর্ণ নীতি এবং পরিকল্পনা প্রণয়ন সমীচীন নয়। স্বাধীনতার পঞ্চাশ বছর পর বাংলাদেশের নীতি এবং পরিকল্পনা দেশের নিজস্ব জ্ঞান, পারদর্শীতা, এবং অর্থায়নের ভিত্তিতেই প্রণীত হওয়া প্রয়োজন। তাহলেই কেবল দেশের প্রয়োজনীয়তা পূরণ এবং স্বার্থ রক্ষা সুগম হবে। কিভাবে বাংলাদেশ নীতি এবং পরিকল্পনা প্রণয়নের ক্ষেত্রে বিদেশী দেশ এবং সংস্থার

উপর নির্ভরশীলতা থেকে জাতীয় সক্ষমতার উপর নির্ভরতার ধারায় প্রত্যাবর্তন করা যেতে পারে তা একটি বড় সমস্যা। এই সমস্যার নিরসন করা বাংলাদেশের জন্য আজ একটি বড় চ্যালেঞ্জ হইয়ে দাঁড়িয়েছে।

উপসংহার

বিগত সময়কালে বাংলাদেশ বিদ্যুৎ উৎপাদন ক্ষমতার উল্লেখজনক বৃদ্ধি অর্জন করতে সক্ষম হয়েছে। তবে এই সাফল্যের সাথে বহু নতুন সমস্যারও উদ্ভব ঘটেছে। এ প্রবন্ধে এরূপ ১১টি সুনির্দিষ্ট এবং একটি বৃহত্তর সমস্যার কথা আলোচিত হয়েছে। এই আলোচনার উদ্দেশ্য বিদ্যুৎ উৎপাদন ক্ষমতা বৃদ্ধিতে বাংলাদেশ কর্তৃক অর্জিত সাফল্যকে খাটো করে দেখা নয়। উদ্দেশ্য হলো, এসব সমস্যার প্রতি দৃষ্টি আকর্ষণ করা যাতে তা সমাধান করে বাংলাদেশ আগামীতে বিদ্যুৎ ও জ্বালানী খাতে আরও সাফল্য অর্জন করতে পারে।

বাপা ও বেন দীর্ঘকাল থেকে বাংলাদেশের জ্বালানী এবং বিদ্যুৎ খাতের বিকাশকে দক্ষ, গণমুখী, এবং পরিবেশ বান্ধব ধারায় অগ্রসর করার লক্ষ্যে চেষ্টা করে যাচ্ছে। সে উদ্দেশ্যে বাপা-বেন ২০০৬ সনে জ্বালানী বিষয়ক কনভেনশনের আয়োজন করে, যেখানে “জ্বালানী বিষয়ক প্রস্তাব” গৃহীত হয় (BAPA and BEN 2006)। পরবর্তীতে PSMP 2010 প্রকাশিত হলে বাপা-বেন এই পরিকল্পনার কয়লা-নির্ভরতার বিরুদ্ধে প্রতিরোধ গড়ে তোলে এবং বেন একটি বিকল্প জ্বালানী নীতি প্রস্তাব করে (BEN 2017)। RPSMP 2016-এর অধীনে রামপাল বিদ্যুৎ কেন্দ্র প্রকল্পের প্রস্তাব এবং সূচনা করা হলে বাপা ও বেন এই প্রকল্পের বিরুদ্ধে প্রবল আন্দোলন গড়ে তোলে। বাপা-বেন আয়োজিত বাংলাদেশের পরিবেশ বিষয়ক প্রথম, দ্বিতীয়, তৃতীয়, এবং চতুর্থ আন্তর্জাতিক সম্মেলনে (আই-সি-বি-এন) গৃহীত যথাক্রমে ২০০০, ২০০২, ২০১০, এবং ২০২০ সনের “ঢাকা ঘোষণা”তে জ্বালানী ও বিদ্যুৎ বিষয়ক

বাংলাদেশের পরিস্থিতির বিশ্লেষণ এবং অগ্রসর হওয়ার সুপারিশ পরিবেশিত হয়েছে (উদাহরণস্বরূপ দ্রষ্টব্য: বাপা এবং বেন ২০২০)।

বাংলাদেশের জ্বালানী এবং বিদ্যুৎ খাত সম্পর্কে বাপা ও বেনের সুপারিশসমূহের মূল বৈশিষ্ট্যসমূহ নিম্নরূপ: (ক) নবায়নযোগ্য জ্বালানী, বিশেষত সৌর শক্তির সর্বোত্তম ব্যবহারের উপর গুরুত্ব আরোপ; (খ) জীবাশ্ম জ্বালানী অপরিহার্য হলে কয়লার পরিবর্তে প্রাকৃতিক গ্যাসের ব্যবহার; (গ) প্রাকৃতিক গ্যাসের ক্ষেত্রে দেশজ গ্যাস অনুসন্ধান, উত্তোলন, এবং ব্যবহারের উপর গুরুত্ব আরোপ; (ঘ) বিদেশী গ্যাস কেনা অপরিহার্য হলে তা দীর্ঘমেয়াদী চুক্তির অধীনে সাশ্রয়ী মূল্যে ক্রয়; (ঙ) দেশজ গ্যাসের দক্ষ ব্যবহার অর্জনের লক্ষ্যে “সীমান্ত মূল্যের” ভিত্তিতে এর দাম নির্ধারণ; (চ) গৃহস্থালি ব্যবহারের জন্য সিলিন্ডারের মাধ্যমে গ্যাসের বিপণন; (ছ) পাইপের পর্যাপ্ত নেটওয়ার্কের মাধ্যমে বাণিজ্যিক এবং শিল্পে গ্যাস ব্যবহারের লক্ষ্যে সকল অঞ্চলের জন্য সমান সুযোগ সৃষ্টি করা; (জ) সৌর-শক্তি এবং গ্যাস-নির্ভর বিদ্যুৎ উৎপাদনের জন্য গ্রাহকদের নিকটে সারা দেশে বিচ্ছুরিত ক্ষুদ্র এবং মাঝারি আকারের বিদ্যুৎ কেন্দ্র স্থাপন; (ঝ) জ্বালানী এবং বিদ্যুৎ উৎপাদনে সরকারী খাতের সাথে বেসরকারি খাতের উপযোগী সমন্বয় সাধন; বেসরকারী খাতের ভূমিকা মূলত ক্ষুদ্র ও মাঝারি আকৃতির বিদ্যুৎ কেন্দ্রে নিবদ্ধ করা; সরকারী খাতের ভূমিকা বৃহদাকার বিদ্যুৎ কেন্দ্রের উপর নিবদ্ধ করা; এবং সরকারী খাতকে দুর্নীতিমুক্ত এবং দক্ষ করা; (ঞ) বিদ্যুৎ উৎপাদন ক্ষমতা বৃদ্ধির সাথে প্রয়োজনীয় অনুপাত রক্ষা করে সমন্বয় এবং বিতরণ ক্ষমতার সম্প্রসারণ; (ট) আণবিক বিদ্যুৎ পরিহার; একান্ত প্রয়োজন হলে ক্ষুদ্রাকার মডুলার আণবিক কেন্দ্র স্থাপন; এবং (ঠ) সনাতনী জ্বালানীকে উপেক্ষা না করে বরং গ্রামীণ বাংলার কৃষি ও অন্যান্য বর্জ ব্যবহার করে জৈব গ্যাস উৎপাদন ও ব্যবহার এবং উন্নত চুলার বিস্তৃতির মাধ্যমে রান্নার জন্য সনাতনী জ্বালানীর অধিকতর দক্ষ এবং দূষণমুক্ত ব্যবহার অর্জন। বাপা-বেন মনে করে যে, উপর্যুক্ত বৈশিষ্ট্যসম্পন্ন জ্বালানী এবং বিদ্যুৎ

নীতিমালা গৃহীত ও বাস্তবায়িত হলে উপরিলিখিত একাধিক সমস্যা – যেমন, সরবরাহ এবং চাহিদার মধ্যে অসামঞ্জস্যতা, উপযোগী জ্বালানী মিশ্রণের অনুপস্থিতি; আর্থিক ও পরিবেশগত স্থায়িত্বশীলতা – ইত্যাদি সমস্যার সমাধানও অর্জিত হবে।

পরিতাপের বিষয় যে, বাংলাদেশের নীতি নির্ধারকেরা এ যাবত বাপা-বেনের এসব সুপারিশের প্রতি তেমন কর্ণপাত করে নি। যার ফলে বাংলাদেশের জ্বালানী ও বিদ্যুৎ খাত আজ বহুবিধ চ্যালেঞ্জ ও সমস্যা দ্বারা আকীর্ণ। বাপা-বেন আশা করে যে, এই প্রবন্ধের আলোচনা বাংলাদেশের নীতি নির্ধারকদের কর্তৃক এসব সমস্যার প্রকৃতি এবং তা নিরসনের উপায় সম্পর্কে চিন্তা করতে সহায়তা করবে এবং তার ফলে আগামীতে বাংলাদেশ জ্বালানী ও বিদ্যুৎ খাতে আরও বেশী সাফল্য অর্জন করবে।

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**BANGLADESH POWER DEVELOPMENT BOARD
FINANCIAL RESULTS TY2020-21: GROWING
INDEPENDENT POWER PLANT COSTS THREATEN TO
OVERWHELM POWER SYSTEM**

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Executive Summary

The burden of capacity over-expansion based on imported fossil fuels threatens to overwhelm the financial status of the Bangladesh Power Development Board (BPDB). Significant and economically damaging power tariff growth looks increasingly likely. In January 2022, the BPDB proposed a bulk power tariff increase of up to 64% to the Bangladesh Energy Regulatory Commission (BERC) due to the increasing cost of power generation and purchase based on imported coal, liquefied natural gas (LNG) and oil. The BPDB is reportedly maintaining that it will have a Tk325 billion (US\$3.8 billion) shortfall if tariffs are not raised as proposed

Whatever the outcome of these proposals, this won't be the last time tariffs come under pressure to rise significantly. The BPDB's financial status is being eroded by overcapacity, rising capacity payments – which reportedly increased again to Tk132 billion (US\$1.5 billion) in FY2020-21 – and growing reliance on price-volatile imported fossil fuels. On the current trajectory, it can be expected that the BPDB's operating losses will continue to grow, necessitating further government subsidies as BPDB's operating loss doubled in FY2020-21, driven by a very significant rise in the cost of electricity purchases from independent power plants (IPPs), which rose 58% over the prior year. The result of BPDB's very large operating loss was that the necessary government subsidy to bail out BPDB's losses reached a record Tk117.8 billion (US\$1.4 billion), up from Tk74.4 billion in the prior year.

For the first time, the cost of electricity purchased from IPPs now represents more than 50% of BPDB's total operating expenses. The single largest contributor to the IPP burden was the new Payra coal-fired power plant. The cost of each unit of power purchased from the plant increased in FY2020-21, reaching Tk8.6/kWh – a 36.5% increase from the prior year figure of Tk6.3/kWh. This was driven by capacity payments made to the plant as one of its units stands idle due to a delay in construction of power transmission infrastructure. The BPDB is paying Tk1.3 billion (US\$15 million) a month in capacity charges to the Payra power station. With more large coal IPPs under construction and large capacities of LNG-fired IPPs planned, the BPDB's IPP cost likely will continue to increase significantly.

According to the BPDB's FY2020-21 annual report, 12,967 megawatts (MW) of new power capacity is under construction and 19,651MW is planned to be added by the end of FY2024-25. Over the same period, only 3,990MW of old capacity is planned to be retired, according to the BPDB. Approaching power additions include 600MW of further oil-fired power plants, the 2,400MW Rooppur nuclear plant, the much-delayed Rampal coal plant and the significantly over-budget and over-schedule Matarbari 1 coal plant. In addition, Adani Power's Godda coal power project in Jharkhand, India, which will export power to Bangladesh, is due for commissioning in 2022 according to the BPDB.

There is also significant capacity of LNG- fired power due to come online by 2025 and much more planned to follow, increasing Bangladesh's exposure to the volatile LNG market. LNG prices soared to record highs in 2021, surging past US\$50/MMBtu. Bangladesh was subsequently forced to pay record spot LNG prices, highlighting the risk in the country becoming increasingly reliant on the imported fuel. This has resulted in gas distributors proposing a more-than-doubling of tariffs to BERC.

The result of these large capacity additions in excess of likely power generation growth will be that overall power plant utilisation will drop further by FY2024-25. Even if power generation grows at a very high 12% per annum out to FY2024-25, overall power capacity utilisation may drop to just 38%.

The implication of such low utilisation of new power plants

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including IPPs is that there will be further growth in capacity payments to these plants while they stand idle much of the time, increasing the BPDB's expenses and losses.

The record high government subsidy to the BPDB in FY2020-21 cannot be regarded as a peak. With more capacity due to come online – leading to worsening overcapacity and increasing capacity payments – larger and larger government subsidies will likely be required in the future to cover BPDB's growing losses. The BPDB has predicted that the government subsidy required for FY2021-22 may be Tk200 billion – a 71% increase on the record subsidy in FY2020-21.

A new Integrated Energy and Power Master Plan (IEPMP) is currently being prepared for Bangladesh, funded by the Japan International Cooperation Agency (JICA) – this represents an opportunity to reset plans for the power sector to provide a financially sustainable power system for the long term.

The transformation to a low carbon energy system JICA has envisaged cannot be achieved if the IEPMP focuses on fossil fuelled LNG plants and coal power stations like Matarbari 2. JICA, if it calls for a continued expansion of power capacity fuelled by imported fossil fuels, would be contributing to worsening overcapacity, rising capacity payments, deteriorating BPDB operating losses and the resultant increases in government subsidies and power tariffs.

Instead, the steps needed to be taken for Bangladesh's power system to ensure long- term financial sustainability while meeting growing power demand include:

- *With 2021 clearly highlighting the significant risk of becoming too reliant on LNG, the new IEPMP must not lock in a shift from over-reliance on imported coal to an over-reliance on imported LNG.*
- *Given the overcapacity, new power capacity growth should be limited as far as possible for the first half of this decade. Power plants that have not begun construction need to be halted – this applies to expensive LNG- and oil-fired plants as well as coal-fired power proposals such as Matarbari 2.*
- *Instead, given the power system's very low overall utilisation of*

just 42%, the new IEPMP should prioritize grid investments so that better use can be made of existing capacity and reliability of power supply can be improved.

- *Energy efficiency can help limit the amount of expensive new power capacity needed to meet long term demand growth. Japan, as an energy efficiency world leader, is well placed to help Bangladesh plan for increased efficiency via the new IEPMP.*
- *More ambitious renewable energy target needs to be committed to. The government's Mujib Climate Prosperity Plan has target of 30% renewable energy by 2030 and 40% by 2041 which should be reflected in the IEPMP. The Climate Prosperity Plan calls for significant scaling up of renewable energy investment including offshore wind.*
- *In addition, the Sustainable and Renewable Energy Development Authority (SREDA) has proposed incorporating a new target of 10,000MW of renewables by 2030 – representing about 25% of capacity by that date*
- *into the new IEPMP. Wind and solar plants – like the new Orion Group solar project in Mongla, Bangladesh's largest – don't receive capacity payments like fossil fueled power plants. Instead, they are paid only for power produced.*
- *This SREDA target – along with the Mujib Climate Prosperity Plan – represent a significant increase in renewable energy ambition. If Bangladesh wishes to start enjoying the benefits of low-cost renewable energy as much of the rest of the world is doing, such ambitious wind and solar targets need to be locked into the new IEPMP.*

INTRODUCTION

In early 2020, following the release of the Bangladesh Power Development Board's (BPDB) 2019-20 Annual Report, IEEFA published a briefing note warning that overcapacity, allied with increasing reliance on coal and LNG imports, was likely to have significant implications for the financial sustainability of

Bangladesh's power system.¹

Following the release of its 2020-21 Annual Report, we revisit the financial status of the BPDB, consider how this status is likely to change and suggest an alternative path forward that is more likely to lead to a financially sustainable power system of the type required to support Bangladesh's fast-growing economy.

OVERVIEW OF THE POWER SYSTEM IN FY2020-21

According to the BPDB's FY2020-21 Annual Report,² overall power capacity increased by 1,648MW or 8% over the prior year (Table 1). Most of this came from new installations of coal-fired power, gas-fired power and expensive oil-fired power that, despite its high cost, continues to be built in Bangladesh. Meanwhile just 91MW of utility-scale solar was added during the year. Total utility-scale solar installations languish at just 129MW as solar installations around the world continue to surge.

However, a positive step forward on renewables occurred after fiscal year end. In December 2021, Bangladesh's largest solar plant (134MW) began operations on a site that had previously been earmarked for a coal-fired power plant. With the agreement of BPDB the Orion Group switched focus from coal to solar – the new plant doubles the total utility-scale solar capacity in Bangladesh.³

In terms of power generation, FY2020-21 saw a correction back to significant power generation growth of 12.6% following the earlier economic impacts of COVID-19 on FY2019-20. This was driven to a large extent by increased oil-fired power generation – a very expensive source. In addition, there was an increase in coal-fired power generation with the Payra coal-fired power plant available throughout the year. On the other hand, gas-fired power generation dropped compared to FY2019-20 as LNG prices rose to record levels.

With 2020-21 power generation growth bouncing back from the depressed level in the previous fiscal year, overall utilisation of Bangladesh's power fleet saw a slight improvement in the year although it remains very low at 42% (Figure 1). In addition, given the amount of new capacity under construction and to be added to

the power system over the next five years, it can be expected that the utilisation rate will soon continue its downward trend (See 'Overcapacity Set to Worsen Going Forward' below).

Table 1: Power capacity, generation and capacity utilisation FY2020-21 and FY2019-20

	FY2020-21			FY2019-20		
Source	Capacity (MW)	Generation (GWh)	Utilisation %	Capacity (MW)	Generation (GWh)	Utilisation %
Coal	1,768	4,997	32.3%	1,146	2,968	29.6%
Gas	11,450	48,403	48.3%	10,979	51,290	53.3%
Hydro	230	655	32.5%	230	825	40.9%
Utility scale solar	129	158	14.0%	38	62	18.6%
Furnace Oil	6,004	17,497	33.3%	5,540	9,461	19.5%
Diesel	1,290	609	5.4%	1,290	139	1.2%
Imports - India	1,160	8,103	79.7%	1,160	6,674	65.7%
Total	22,031	80,422	41.7%	20,383	71,419	40.0%

Source: Bangladesh Power Development Board, IEEFA calculations.

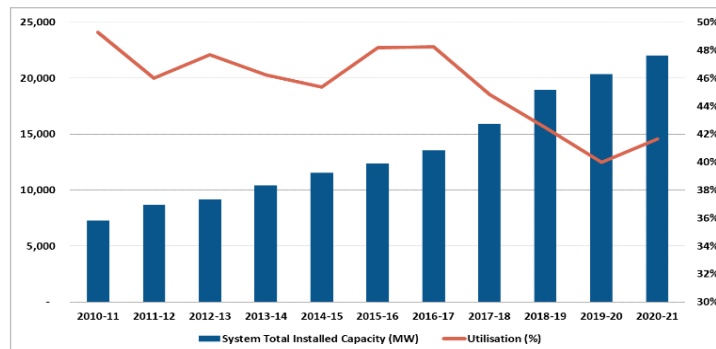


Figure 1: Bangladesh Power Capacity (MW) and Overall Capacity Utilisation (%) (Source: Bangladesh Power Development Board, IEEFA calculations).

The increase in capacity utilisation was led by oil-fired power plants. Utilisation of coal-fired power improved slightly but remained unsustainable at 32% (Table 1) with half of the capacity at the new Payra coal-fired power plant unable to be used because sufficient transmission infrastructure is not yet in place.⁴

POWER DEVELOPMENT BOARD 2020-21 FINANCIAL RESULTS

Table 2 breaks down the BPDB's operating revenue and expenses, highlighting that its operating loss doubled in FY2020-21. The increased loss was caused by operating expenses rising more than revenues, the former's growth clearly driven by a very significant rise in the cost of electricity purchases from independent power plants (IPPs), which rose 58% over the prior year.

Table 2: BPDB Statement of Income showing operational losses

	FY2020-21	FY2019-20	Change
	Millions of Taka	Millions of Taka	%
Operating Revenue	417,703	355,354	18%
Generation Expenses	58,545	64,234	-9%
Electricity Purchase from IPP	277,374	175,190	58%
Electricity Purchase from India	47,129	40,171	17%
Electricity Purchase from Rental	33,282	32,164	3%
Electricity Purchase from Public Plant	69,170	66,717	4%
Transmission Expenses for Wheeling Charge	2,439	2,320	5%
Distribution Expenses	11,817	13,541	-13%
General and Admin Expenses	4,594	4,535	1%
Total Operating Expenses	504,350	398,872	26%
Operating Loss	(86,647)	(43,518)	99%

Source: Bangladesh Power Development Board.

The result of BPDB's very large operating loss was that a similarly large government subsidy was needed to avoid a significant cashflow shortfall and net loss. The Bangladesh

government has been required to provide subsidies to the BPDB for a decade to cover losses made by selling power at a price lower than the cost of power generation and electricity purchases from independent generators. In FY2020-21, the subsidy was a record at Tk117.8 billion (US\$1.4 billion), up from Tk74.4 billion in the prior year – an increase of 58%.

IPP COSTS WILL CONTINUE TO RISE

For the first time, the cost of electricity purchase from IPPs now represents more than 50% of BPDB's total operating expenses (Figure 2). The 58% increase in the IPP cost was partly as a result of increased power units purchased from these plants – 34.6TWh in FY2020-21 up from 25TWh in the prior year, an increase of 38%. However, a further driver was the higher per unit cost of each kWh purchased from the IPPs, rising to more than Tk8/kWh in 2020-21 from Tk7/kWh in the prior year, a 15% increase. This drove an overall per unit electricity supply cost increase of 11.8% in FY2020-21.

Additional expensive oil-fired power generation has contributed to losses in FY2020-21 but the single largest contributor to the increased cost of IPP power purchases was the new Payra coal-fired power plant. This was to a large extent because the first unit was online all year in FY2020-21 as opposed to just a small part of FY2019-20. Power purchases from the Payra plant reached 3.8TWh in FY2020-21 compared to just 0.8TWh in the prior year.

However, the cost of each unit of power purchased from Payra also increased in FY2020-21, rising to Tk8.6/kWh, a 36.5% increase on the previous year's Tk6.3/kWh. This was driven by capacity payments made to the plant whilst one of its units stands idle due to a delay in construction of power transmission infrastructure. The BPDB is paying Tk1.3 billion (US\$15 million) a month in capacity charges to the Payra power station.⁵

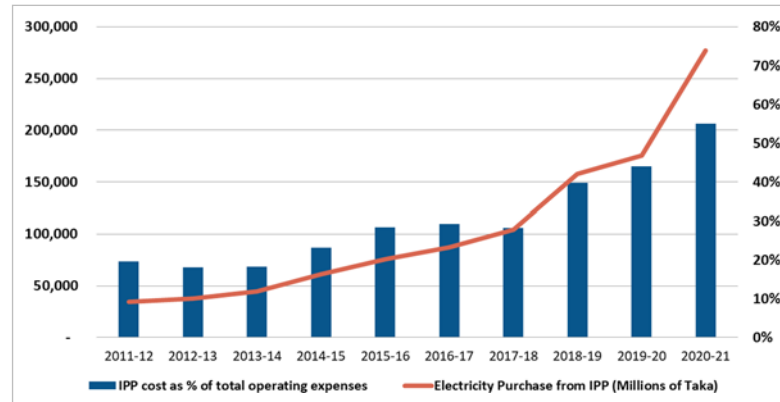


Figure 2: BPDB's Independent Power Producer Cost Rising (Source: Bangladesh Power Development Board, IEEFA calculation).

Total capacity payments to private power plants reportedly increased again to Tk132 billion (US\$1.5 billion) in FY2020-21, up 25% from the prior year.⁶ With more large coal IPPs under construction and large capacities of LNG-fired IPPs planned, it can be expected that the BPDB's IPP cost will continue to increase significantly. At the same time, these large additional capacities will exacerbate Bangladesh's overcapacity problem – further adding to the IPP cost by necessitating large capacity payments to power plants lying idle much of the time.

OVERCAPACITY SET TO WORSEN GOING FORWARD

The expensive capacity payments being made to the Payra coal-fired power plant are a result of a lack of transmission infrastructure meaning half the plant is lying idle. However, the overall utilisation of Bangladesh's power plants is just 42%. Despite a large increase in power generation in FY2020-21, many power plants are standing idle much of the time even where the necessary transmission infrastructure is available. With much more power capacity on the way, overcapacity can be expected to

worsen in Bangladesh. According the BPDB's FY2020-21 annual report, 12,967MW of new power capacity is under construction and 19,651MW is planned to be added by the end of FY2024-25. Over the same period, only 3,990MW of old capacity is planned to be retired, according to the BPDB.

The FY2020-21 annual report makes clear that more than 600MW of further oil- fired power plants are to be added in the next two fiscal years. In addition, there are large additions of coal-fired power plants to due to come online by 2025. This includes the much-delayed Rampal coal plant which, like Payra, faces a delay on the needed transmission infrastructure⁷ and the significantly over-budget and over- schedule Matarbari 1 coal power plant.⁸ In addition, Adani Power's Godda coal power project in Jharkhand, India – which will export power to Bangladesh – is due for commissioning in 2022 according to the BPDB. The need to transport imported coal 700km from port to the power plant and then transmit power across the border means this will prove to be an expensive source of electricity for Bangladesh.

Significant capacity of LNG-fired power is due to come online by 2025 with much more planned (although there is significant doubt over the financial capacity to add all this planned capacity).⁹ This will increase Bangladesh's exposure to the volatile LNG market (see '2021 Demonstrated the Risk of Reliance on LNG' below).The BPDB is expecting that the first, 1,200MW unit of the Rooppur nuclear power plant will be commissioned in October 2024 with another 1,200MW to follow. In the unlikely event that this power plant is completed on budget it will have cost Tk1.13 trillion (US\$13 billion).¹⁰ Nuclear power plants cannot be ramped up and down easily and need to operate at high utilisation rates, only shutting down for maintenance and refuelling. The Rooppur plant can be expected to run at a muchhigher utilisation rate than other power plants in Bangladesh – about 85%.

However, this will have a detrimental impact on the utilisation of the thermal power fleet. All these capacity additions suggest that it is likely that capacity growth will significantly outpace power generation growth over the coming years. The result of this will be that overall power plant utilisation will drop further by FY2024-

25. A simple calculation taking into account planned capacity additions and retirements according to the BPDB FY2020-21 Annual Report suggests that, even if power generation grows at a very high 12% per annum out to FY2024-25, overall power capacity utilisation may drop to just 38% (Figure 3).

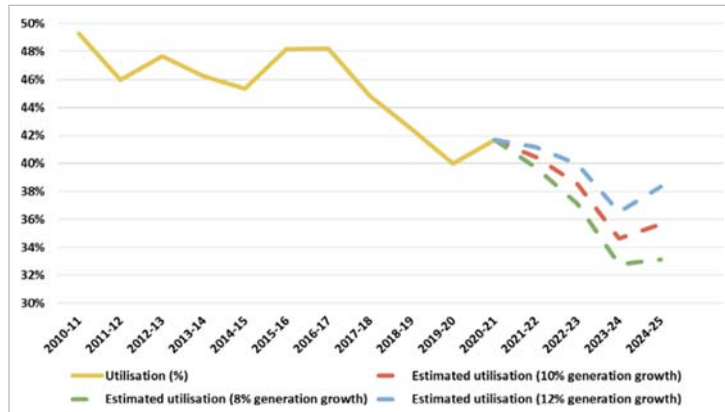


Figure 3: Actual and Estimated Future Total System Capacity Utilisation (%) (Source: Bangladesh Power Development Board, IEEFA estimates)

The implications of such low utilisation of new power plants including IPPs is further growth in capacity payments to these plants while they stand idle much of the time, increasing the BPDB's expenses and losses. The average cost of power supply would increase and place unsustainable financial pressure on Bangladesh's power system.

2021 DEMONSTRATED THE RISK OF RELIANCE ON LNG

Amid ongoing global momentum away from coal-fired power – including the continuing shift away from coal by financial institutions – the Bangladesh government accepted the inevitable and cancelled 10 coal-fired power plants in 2021.¹¹ Some of these cancelled projects are intended to be switched to LNG as Bangladesh plans to become increasingly reliant on LNG imports

going forward. However, LNG prices are even more volatile than imported coal, a fact clearly demonstrated by the record LNG price spikes seen in 2021 (Figure 4). LNG prices soared to record highs at the beginning of 2021, calling into question the sense of any developing nation investing large sums on LNG import terminals, pipelines and LNG-fired power plants.¹² However, this price spike was dwarfed by the one that occurred in September/October 2021 when spot LNG prices surged past US\$50/MMBtu for the first time.¹³ There is no guarantee it will be the last time.

In the second half of 2021 – after FY2020-21 – Bangladesh was forced to reverse a decision to avoid the increasingly expensive spot LNG market amid significant gas shortages that impacted industry, power plants and households.¹⁴ Bangladesh was subsequently forced to pay record spot LNG prices,¹⁵ highlighting the risk to the country of increasing reliance on the imported fuel. Furthermore, Bangladesh's contracted LNG suppliers will reduce deliveries in 2022 according to Petrobangla.¹⁶ Qatargas and Oman Trading International can reduce deliveries to Bangladesh, without violating their contract terms, to take advantage of the volatile spot market. This will likely cause gas shortages unless Bangladesh can itself make up the difference via opportunities in the spot market.

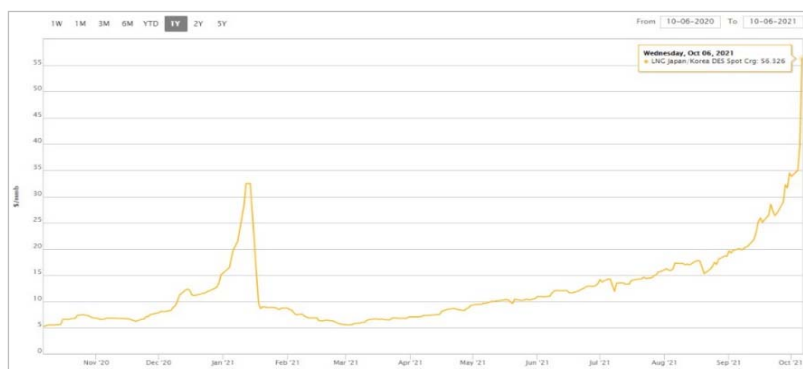


Figure 4: LNG Prices Spiked Dramatically in 2021 (Source: S&P Global Platts Dimensions Pro.)

In January 2022, Bangladesh once again resumed spot purchases of LNG after avoiding the spot market for several months due to high prices. For February 2022 delivery, Bangladesh will pay at least US\$30/MMBtu.¹⁷

The International Energy Agency's (IEA) most recent Gas Market Report notes that high LNG price volatility is likely to be maintained into 2022 with prices reacting to weather and geopolitical events as well as commercial and physical factors. The IEA also highlights the damage done by high LNG prices to consumers, utilities and wholesalers around the world. Emerging markets have been particularly impacted and are "already experiencing power cuts, industrial demand destruction and potential food supply issues in the absence of affordable gas-based fertilisers".¹⁸

GOVERNMENT SUBSIDIES TO BAIL OUT BPDB'S LOSSES EXPECTED TO CONTINUE GROWING

The record high government subsidy to the BPDB in FY2020-21 cannot be expected to be a peak. With more capacity due, taking the Bangladesh power system even deeper into overcapacity, capacity payments can be expected to keep rising, and the BPDB's expenses burden to become even weightier. Ever larger government subsidies will likely be required to cover BPDB's worsening losses. The BPDB itself has predicted that the government subsidy required for FY2021-22 may need to be Tk200 billion – a 71% increase on the record subsidy in FY2020-21.¹⁹

Bangladesh's 8th Five-Year Plan for 2020-2025 acknowledges that the issues of overcapacity and the rising capacity payments that accompany it, as well as a rise in reliance on expensive fossil fuel imports, jeopardise the financial sustainability of the power system.^{20 21}

Increasing subsidies for BPDB will put pressure on the Bangladesh government's budget. It may be necessary to further increase power tariffs. The Bangladesh Energy Regulatory Commission

(BERC) increased retail power tariffs by 5.3% from March 2020 and more increases are likely to be needed. In addition, the Bangladesh Energy Regulatory Commission (Amendment) Bill, passed in 2020, allows BERC to increase tariffs as often as needed. Previously, tariffs could only be raised once per fiscal year.

More frequent tariff increases can therefore be expected, transferring some of the burden of overcapacity and expensive fossil fuel imports onto consumers. Gas prices are also subsidized and sold at below-cost to the largest users, of which the power sector is by far the largest. The beginning of LNG imports in 2018 led to a rise in the cost of gas and a significant gas tariff hike (33%) for all sectors in July 2019 – the largest gas tariff increase in Bangladesh so far. Growing dependence on LNG imports amid declining domestic gas production will lead to further tariff hikes.

GROWING PRESSURE TO RAISE TARIFFS

Bangladesh's 8th Five-Year Plan notes that a future in which Bangladesh becomes more reliant on imported coal and LNG risks even further increases in the cost of electricity.²² More pressure for major increases to gas and power prices is already being felt. In January 2022 gas distributors proposed a more-than-doubling of gas tariffs to BERC following the spike in the cost of LNG imports.²³ The proposal applies to all gas consumers including industry and households. For power generators, the tariff is proposed to increase from Tk4.45 per cubic meter to Tk9.66 – a 117% increase.²⁴ Following this, the BPDB has proposed its own major increase to its bulk power tariff to BERC.²⁵ Citing the increase in the cost of purchasing power as well as the spike in LNG, oil and coal costs, the BPDB is proposing that its electricity supply tariff should rise from Tk5.64 per unit to Tk8.58 – a 52% increase. Power distributors who purchase at the bulk rate will then be under severe pressure to pass on this tariff increase to retail customers.

If gas prices more than double as proposed by distributors, then the BPDB wants a further increase to Tk9.27 per unit – an increase of 64%. The BPDB is reportedly maintaining that it will

have a Tk325 billion (US\$3.8 billion) shortfall if tariffs are not raised as proposed. It foresees its power generation and purchase requirement reaching Tk745 billion (US\$8.6 billion) in calendar year 2022. For fiscal year 2020-21, the BPDB cost of power purchase and generation was Tk485.5 billion (US\$5.6 billion). Whatever the outcome of these tariff proposals, this won't be the last time tariffs come under pressure to rise significantly.

NEW POWER MASTER PLAN IS AN OPPORTUNITY FOR A RESET

A new Integrated Energy and Power Master Plan (IEPMP) is currently being prepared for Bangladesh – this represents an opportunity to reset plans for the power sector to provide the country with a financially sustainable power system for the long term. In March 2021, the Japan International Cooperation Agency (JICA) signed a Record of Discussions with the Bangladesh government for the development of the new IEPMP. In its announcement of the signing of the Record of Discussions for the IEPMP, JICA talks of a “transformation to a low or zero carbon energy system”, noting that its work will contribute to two of the 17 Sustainable Development Goals established by the United Nations General Assembly in 2015 – Sustainable Development Goal 7 (Affordable and Clean Energy) and 13 (Climate Action).²⁶

JICA funded the IEPMP's predecessor – the 2016 Power System Master Plan (PSMP 2016), which called for a major roll-out of power stations to be fuelled by imported coal and LNG. Unsurprisingly, coal- and LNG-fired power generation were technologies that Japanese companies were keen to sell to developing Asian nations like Bangladesh. JICA itself financed the Matarbari 1 coal-fired power plant which is currently under construction by Japanese company Sumitomo Corporation. JICA is now also considering financing a second coal power plant in Bangladesh – Matarbari 2 –despite Bangladesh's worsening overcapacity and Matarbari 1 running significantly over-budget and over-schedule.

Japan also has a considerable interest in seeing Bangladesh commit to further LNG infrastructure investment. In January 2021,

Tokyo Gas was hired to conduct the feasibility study for an onshore LNG terminal at Matarbari and prepare the Request for Proposal (RFP) documents to select a qualified bidder.²⁷ The transformation to a low carbon energy system that JICA has promised cannot be achieved if the IEPMP focuses on fossil-fuelled LNG plants and coal power stations like Matarbari 2. JICA would be contributing to worsening overcapacity, rising capacity payments, deteriorating BPDB operating losses and the resultant increases in government subsidies and power tariffs if it calls for a continued, major expansion of power capacity fuelled by imported fossil fuels. Instead, the following steps need to be taken for Bangladesh's power system to ensure long-term financial sustainability while meeting growing power demand:

- Ten coal-fired power projects were cancelled in Bangladesh in 2021. However, with 2021 clearly highlighting the significant risk of becoming too reliant on LNG, the new IEPMP must not lock in a shift from over-reliance on imported coal to an over-reliance on imported LNG.
- Given the overcapacity – and its growing financial burden – new power capacity growth should be limited as far as possible for the first half of this decade. The new IEPMP must also employ more realistic power demand growth forecasts to prevent the continued over-build of new power capacity. Power plants that have not begun construction should be halted – this applies to expensive LNG- and oil-fired plants as well as any further coal- fired power proposals such as Matarbari 2.
- Instead, given the power system's very low overall utilisation of just 42%, the new IEPMP should prioritize grid investments to make better use of existing capacity and improve reliability of power supply. In December 2021, the World Bank approved a US\$500 million fund to improve Bangladesh's power distribution system and help it catch up with the major expansion in the country's power generation capacity over the past 10 years.²⁸

- Bangladesh's 8th Five-Year Plan clearly identified energy efficiency (EE) gains as a key goal. EE can help limit the amount of expensive new power capacity needed to meet demand growth. Japan, an energy efficiency world leader, is well placed to help Bangladesh plan for increased efficiency via the new IEPMP.
- More ambitious renewable energy targets need to be committed to and reflected in the IEPMP. At the Glasgow climate conference in 2021, Bangladesh submitted new Nationally Determined Contributions (NDC) to carbon emissions reductions, including a conditional target of adding more than 4,000MW of renewable energy projects by 2030 (depending on external financial and technical support).²⁹ However, the government's Mujib Climate Prosperity Plan has more ambitious targets of 30% renewable energy by 2030³⁰ and 40% by 2041.³¹ The Plan calls for a significant scaling up of renewable energy investment, including offshore wind. Renewable energy costs continue to fall and such installations do not receive burdensome capacity payments.
- More recently, the Sustainable and Renewable Energy Development Authority (SREDA) has proposed that a new target of 10,000MW of renewables by 2030 – representing about 25% of capacity by that date – be incorporated into the new IEPMP.³² This includes a wind power target of 5,000MW,³³ a major increase in wind power ambition for Bangladesh. This target – along with the Mujib Climate Prosperity Plan – represent a significant increase in renewable energy ambition. If Bangladesh wishes to start enjoying the benefits of low-cost renewable energy as much of the rest of the world is doing, such ambitious wind and solar targets need to be reflected in the IEPMP.

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PURCHASING PRICES OF ELECTRICITY OF THE PUBLIC SECTOR AND PRIVATE SECTOR: HOW TO EXPLAIN THE DIFFERENCES?

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Abstract

The power generation of Bangladesh is being dominated by the private sector investors and has been burdened with huge capacity and energy payments to the private sector due to the higher purchasing price of electricity in the private sector. However, the purchasing price of BPDB is different in the public sector power generation companies. Though the public sector power purchasing price is administratively determined, the price of private sector power generation determines by the fiscal, monetary, and other forms of incentives mandated by the laws for private sector companies. The study aims to analyze the purchasing price of public and private sector power generation companies and identify the reasons to suggest accordingly. This study is quantitative and desk-based review has been conducted.

Keywords: purchasing price, electricity tariff, public and private sector, capacity payment

INTRODUCTION

The power sector of Bangladesh plays an important role in terms of thriving our economy. It has contributed largely to achieving sustainable annual economic growth over the last decade. An adequate and reliable supply of electricity is a prerequisite for socio-economic and human development. Therefore, to sustain the growth, the demand and supply of electricity increased at a thumping rate. However, the government could not meet the deficit on its own due to the lack of resources and the diverse requirements of those financial resources. In addition, there were other priority sectors that the government needed to finance. Hence, to ensure the supply of electricity, the government encouraged the participation of private sector power companies with a number of special provisions for easing their fixed and varied cost burden. However, to ease the burden on the private sector, the government is being burdened with fiscal pressure due to the increased price of purchasing electricity from the private sectors. Aside the provisions and incentives that are being provided to ease the burden of the private sector, there are a number of factors that are responsible to induce upward purchasing price of electricity from the private sector.

Background of the Study

BPDB, as the only buyer of electricity, purchases power from power generation companies in public and private sectors. Over the last ten years, rise in purchasing price has added additional pressure on BPDB resulting in a continuous loss in every fiscal year. BPDB is selling electricity at a price that is mandated by BERC and lower than their purchasing price resulting in losses. The cumulative losses of BPDB for the last ten years is BDT 51575.5 crore. This loss is largely incurred (more than 70 per cent) due to purchasing electricity from power generating companies. During FY2021, the 85 per cent operating cost has been made for

purchasing electricity from public (spent 14 per cent) and private (spent 71 per cent) companies.

Table 1: Share of Operating expenses of BPDB under different head of accounts

Fiscal Year	Fuel Cost	Generation Expenses*	Purchase from IPP	Purchase from RENT AL	Purchase from Public Plant	Purchase from India	Wheeling Charge to PGCB	Distribution & Coml . cost	General & Administrative cost
FY11	15.5	8.5	26.2	35.6	6.5		1.1	4.2	1.2
FY12	13.8	5.4	19.1	48.7	5.3		0.9	3.1	0.9
FY13		21.9	18.1	50.0	5.2		0.8	3.0	0.9
FY14	17.1	6.5	18.2	39.8	9.3	4.7	0.8	2.8	0.8
FY15	13.6	5.8	23.2	33.2	12.7	7.2	0.8	2.8	0.9
FY16	12.8	6.7	28.4	24.2	15.0	7.4	1.0	3.4	1.2
FY17	11.7	7.1	29.2	20.1	17.9	8.7	0.9	3.2	1.3
FY18	16.6	6.5	28.3	17.1	19.8	7.6	0.5	2.5	1.0
FY19	10.7	6.2	39.8	12.7	17.3	9.4	0.5	2.4	1.0
FY20	8.6	7.5	43.9	8.1	16.7	10.1	0.6	3.4	1.1
FY21	5.9	5.7	55.0	6.6	13.7	9.3	0.5	2.3	0.9

Source: BPDB; Note: * (Excluding fuel cost for all year except for FY13)

Despite the private sector's substantial growth in the power generation process, the financial implication of the government is at large due to the energy payment and capacity payment to the private investors in the power sector. The amenities like payment for energy and capacity charges (including debt service, return on equity, insurance, covering operation, and maintenance cost), the allocation for project/plant site and provision of fuel, security against force majeure risk, and changes in certain duties and taxes have attracted private sector to invest in the power sector, however at a cost of the large financial burden on the government. The amenities have been mandated by the Private Sector Power Generation Policy 1996 with revisions in 2004 and 2018. It is high time to evaluate the amenities mandated under the "Private Sector

Power Generation Policy of Bangladesh” also known as the favourable investment policy for private investors. Therefore, the study will be discussed based on this law and the amenities mandated under this law to analyse whether the provisions are influencing the electricity tariff at bulk sales to BPDB.

Objective of the Study

The key objectives of the study are:

- a. To analyse and compare the purchasing price of power in public and private sectors of Bangladesh during the last ten years along with their power generation capacities
- b. To identify the reasons for the higher power purchasing price in the private sector’s power plants.
- c. To suggest a sustainable pathway to the policymakers to redesign their existing policies for private sector investment and electricity generation with a lower financial burden.

Methodology

The study is quantitative. Context analysis and Secondary data has been reviewed to achieve the aforesaid objectives. Besides, the statement of this study will be supported with information and data collated from government sources.

OVERVIEW OF POWER GENERATION STRUCTURE

The generation of power and its supply are being contributed largely by the public sector power companies. The power generation capacity of the public sector companies is higher than the private sector companies, though the number of public sector power plants is lower. The number of public sector plants has increased 18.2 per cent in the last 11 years whereas the number of private-sector plants has increased by 24.5 per cent. In terms of the growth of power plant establishment and growth in the generation capacity, the private sector has surpassed the public sector plants. Compound annual growth rate with five years intervals during

FY2000 to FY2021 illustrates that the private sector has contributed significantly to improving their generation capacity.

Table 2: Summary of the public and private sector power plants, capacity, and growth

Fiscal Year	Public		Private	
	No of Plants	Installed Capacity	No of Plants	Installed Capacity
2010	20	3889	23	1928
2011	20	3503	39	2940
2012	32	4329	44	3545
2013	36	4819	44	3492
2014	37	5230	47	4340
2015	41	5440	54	5248
2016	41	5930	59	5840
2017	43	7063	60	5858
2018	52	8845	74	7108
2019	56	9567	87	10279
2020	54	10339	81	10044
2021	60	11,390	85	10641
Annualised growth from FY2010-2021	18.2%	17.5%	24.5%	41.1%

Source: Author's calculation based on compiling the data from annual reports of BPDB FY2010-21

The private sector investment in the power sector has drawn a lot of attention from FY2000 to FY2005, right after 10 years of the formulation of the private sector power generation policy. Though for the last decade, the investment of the private sector has been rather slower than the public sector due to the huge investment of the government in infrastructure development related areas where the power sector receives proper allocation. The lower investment of the private sector during the last ten years can also be explained by the inverse relationship between public and private sector investment. However, the total investment of the public sector for

the last 21 years is not satisfactory, especially if the government aims to be financially solvent. Only six (06) per cent growth in terms of the investment of the public sector power generation during FY2000 to FY2021 is not commensurate enough to ensure the adequate and reliable power supply as well as financially viable power generation. The sudden increase in private sector participation has enriched the generation capacity which has led the sector to reach its peak of up to 166 per cent.

Table 3: Five years interval annualized growth of net power generation by ownership

Regimes	Public sector	Private sector*
FY2000-2005	-1.5	68.3
FY2005-2010	2.8	13.6
FY2010-2015	11.0	12.1
FY2015-2020	13.1	5.5
FY2000-2021	6.5	166.3

Source: BPDB, 2021; Note: * including REB net

Compared with the installed capacity and number of power plants, the comparison of the net energy generation of the public and private sectors are surprising since the net energy generation of the private sector is higher than the public power generation companies where the total capacity is lower in the private sector and higher number of power. Thus, it leads to the question regarding the efficiency of the public power plants in terms of power generation plants belong to the private sector.

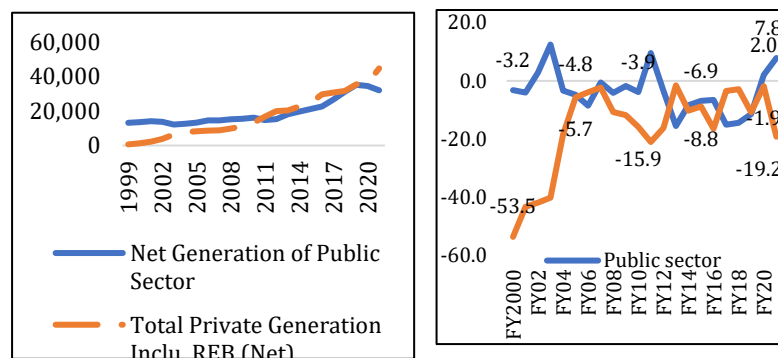


Figure 1: Net energy generation of the public sector, total private generation including REB (Net) (left) and percentage change over the Preceding Year (right) Source: Author's illustration based on calculating the data compiled from annual reports of BPDB, 2021.

DIFFERENCE IN PURCHASING PRICE IN PUBLIC-PRIVATE SECTOR

The cost of power purchase by BPDB has been increasing at a thumping rate. In FY2020 the cost of power purchase from IPP increased by 11 per cent whereas in FY2021 the rate became more than 5 times higher (58 per cent). On the other hand, the cost of power purchase from rental increased at a moderate rate of 3 per cent between FY2020 and FY2021 which can be explained by the underutilization of the rental power plants in the recent past because of their very high-power generation costs including the recent retirement of a few quick rentals.

Table 4: BPDB's purchase of electricity from public and private sector power generation companies

Electricity purchase from	FY2019	FY2020	FY2021	% Change in FY2020	% Change in FY2021
IPP	15749	17519	27737	11	58
Rental	5014	3216	3328	-36	3
Public	6839	6672	6917	-2	4

Source: Author's analysis based on the data collected from annual reports of BPDB FY2019-20

The purchasing price of electricity has been decreased for the public sector plants due to the cheap energy mix in the public sector plants. Oil and diesel-based plants are always costly, hence the purchasing price of private sector power plants are higher. The bulk purchasing price of gas-based power plants are less than the other fuel based power plants. In addition, zone-wise price variation is also notable due to the T&D coverage across the zones. East zone has a better infrastructure of electricity where cost reduces. However, to fulfil the government agenda to reach electricity to every people of the country, the government is implementing projects to reach the grid-based electricity at Char and Haor areas. Therefore, the T&D cost gets added to the overall cost of electricity, thus, raising the price of private as well as the public sector power prices. The private sector power generation policy has a provision which indicates that the cost of T&D can be adjusted at the consumer level.

Table 5: Electricity purchase of BPDB (in %Δ)

Fiscal Year	BPDB's Generation	Purchase from IPP	Purchase from Rental	Purchase from Public Plant
2011	25.0	27.1	352.8	0.3
2012	14.4	8.0	102.4	24.1
2013	25.4	8.1	17.1	10.1
2014	28.1	19.0	-5.7	109.9
2015	-10.0	37.4	-10.0	48.1
2016	3.7	23.4	-26.5	18.7
2017	9.9	15.4	-7.0	33.7
2018	52.5	19.2	4.7	36.5
2019	-18.9	51.3	-20.2	-6.2
2020	-2.4	11.2	-35.8	-2.5
2021	-9.7	58.3	3.5	3.7
FY2011-2020 (Annualized)	14.3	90.7	22.3	70.5

Source: BPDB, 2010-2021

Surprisingly, the BPDB's purchase from public sector plants decreased by 2 per cent in FY2020 over FY2019 and increased by 4 per cent in FY2021. Akin to the IPPs and rentals, public sector plants also require operating and maintenance costs and the total generation capacity is slightly higher than the private sector plants. Despite having fixed costs and higher generation capacity, public sector plants are generating power at a low cost. The cost differences between the public and private sector power generation process raise questions regarding the level of efficiency of the private sector entities. It is worthy to note that the private sector plants are smaller and have lower capacity per plant whereas the scenario is the opposite for the public sector plants. The cost for the establishment of these small-scale power plants is also costly. Besides, the government is approving short term projects which are costly and is influencing the price of electricity of the private sector plants. Despite having the higher cost of purchasing electricity, still, a lot of power plants are in the pipeline

for implementation under the private sector. If these projects are going to be completed, the country will have more than double of overcapacity than its demand for electricity. These plants will raise the financial pressure on the government.

Table 6: Generation Projects to be Completed, under construction, singing process (LOI & NOA), under tendering Process, and in retirement process by FY2022-25

Ownership	To be completed	Under Construction	Under LOI & NOA	Total	Will retire
Public	8998	4338	438	13774	1535
Joint Venture	5160	3731	100	8991	
Private	5321	4898	2866	13085	2455
Power import	1496			1496	
Total	20975	12967	3404	37346	3990

Source: BPDB, 2021; P-29, 42

Factors and Reasons for Different Prices

Energy Mix

The power generation of both the public and private sectors are fossil fuel based as encouraged in the private sector power generation policy. The encouragement regarding the establishment of power plants with fossil-fuel-based is well defined in the laws whereas no explanations have been made in terms of power generation from renewable sources. In addition, the materials and equipment are costlier than the conventional plants. Therefore, gas, being the cheapest source of power generation, the private bidders invested in gas, high-speed fuel (furnace oil), and HSD or diesel based power plants. The private sector plants having a total capacity of 9029.3 MW, power plants having a capacity of 5443.4 MW are generating electricity based on HFO and HSD based fuel plants.

Table 7: Capacity of power plants by fuel type and ownership (in MW) (excluding imported power)

Fuel type	Public	IPP	SIPP	RPP	QRPP
Coal	1146				
Gas	7682	2597	350	412.9	226
Gas/HSD	225				
HFO	1178.5	3605.4			757
HSD	290	1000			
Hydro	230				
Solar	7	81			
Total	10758.5	7283.4	350	412.9	983

Source: BPDB, n.d.

The power generation is heavily based on gas due to the abundance of this natural endowment. Besides, gas is cheaper and less pollutant. However, after identifying the actual reserve of gas, the government took initiatives to divert to other fossil-fuel-based power generation including renewables. The share of gas started to reduce from FY2011 when the policy of the government was shifting to another source of power generation. During this time, the private sector, especially the local investors invested in the oil-based power plants at a large scale. Currently, coal is a major fuel for power generation. From the utilisation of natural gas to locally extracted coal and imported coal have been using for power generation.

Table 8: Number of power plants by fuel type and ownership
(Source: BPDB, n.)

Fuel type	Public	IPP	SIPP	RPP	QRPP
Coal	4				
Gas	30	11	13	9	3
Gas/HSD	1				
HFO	15	32			9
HSD	4	6			
Hydro	1				
Solar	1	4			
Total	55	53	13	9	12

Fossil fuel based power generation is costly, it is even more costlier when the incentives are being provided at every stages from plant development to power generation. The fiscal incentives, monetary benefits, technical assistance, energy payment are being provided to the private sector power investors whether they produce the electricity or not. A minimum amount of capacity payment is payable by the government.

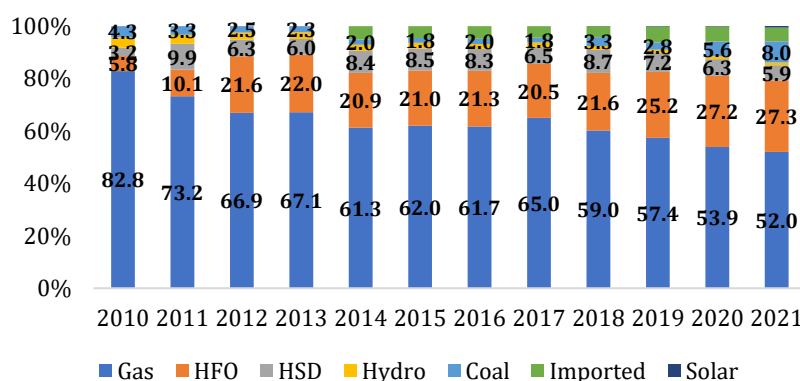


Figure 2: Share of the energy mix by fuel types from 2010 to 2021[Source: Author's calculation based on the compiled data from the annual reports of BPDB FY2010-2021]

Annual Plant Factor

The annual plant factor of public and private sector plants indicates that the utilisation of public and private sector power plants is almost similar throughout the years. This can be assumed that the demand for electricity is being supplied by the public and private sector collaboration with little fluctuation of power generation. The figure indicates that over the course of time, the public sector plants are gradually being reduced from the utilisation of power generation. It can be explained historically since the plant factor of public sector plant in FY2010 was more than 57 per cent and now in FY2021, it has been reduced to 38.9 per cent.

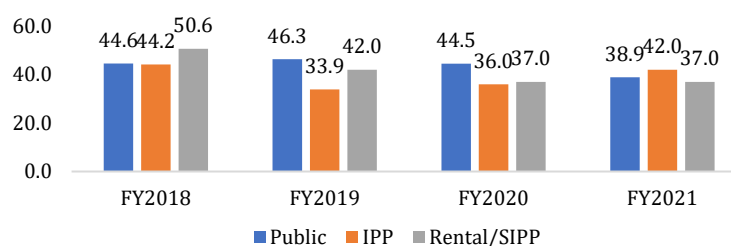


Figure 3: Annual Plant Factor by ownership of power plants (in %)
[Source: Author's illustration from the data compiled from annual reports of BPDB, FY2018-21]

The equal utilisation of public and private sector plants raises questions regarding the transparency in the power generation process as well as the reasons behind the huge financial burden on the government. Despite having the excess capacity and higher number of power plants, the equal utilisation of the public and private sector power plants cannot be done due to the huge financial obligation of the government.

Table 9: power plants remain idle due to various reasons for failure

Own-ership	Full/partial shut down	Total Plant	Reason to Shut down	Public Plant	Reason to Shut down	IPP Plant	Reason to Shut down	QRPP/RPP Plant
IPP	27	49	FGMO	8	FGMO	3	Reserve	2
QRPP/RPP	10	20	Gas shortage	9	Low demand	8	Engine problem	5
Public	52	78	Reserve	9	Reserve	8	Contract expired	1
Total	89	147	Under maintenance	11	Engine problem	4		

Source: Author's calculation based on the data compilation from the annual reports of BPDB, 2021

A number of public sector plants remain idle due to maintenance-related issues which raise questions regarding the transparency of the public sector power generation companies or the monitoring bodies in terms of ensuring power generation within a rationale price framework. The table identifies that most of the public sector power plants remain idle particularly partial shutdown or for reserve purposes. Even the table shows that due to the low demand, IPP plants remain shut down or idle. This indicates that the existing demand for electricity can be supplied by the public sector power generation companies which are located across the country.

Subsidy/capacity payment

The government is allocating a hefty amount of subsidy each year through budgetary allocation under capacity and energy payment. Due to the prioritisation of government in short term costly projects, the cost of these projects is being increased, thus, the average cost of electricity generation. This increase in cost ultimately increases the cost burden of BPDB since BPDB purchase electricity from the private sector at the bulk tariff rate which leads to higher subsidies in each budget year. In addition, the retail price of electricity is cheaper than the supply price of electricity at the bulk level.

The capacity payments have been increased by 44.3 per cent in the last 9 years. A total of 522.6 billion BDT has been provided as the capacity payment from 2010 to 2019. The incentivised amount triggered the rise in the purchasing price of electricity. It is going to be doubled by the end of FY2025 since the government has a lot of power plants under the implementation process which will also remain inactive.

Table 10: Capacity payments for idle power capacity (in billion BDT)

Fiscal year	Capacity payments
2010	17.9
2011	23.79
2012	50.01
2013	54.9
2014	47.14
2015	50.43
2016	53.76
2017	56
2018	62.41
2019	89.29

Existing Pricing Policies and Purchasing Price

In order to encourage the private sector's participation in the power generation process, the GoB established Power Cell with a mandate to support the private investors at all stages and to address the concerns of project sponsors like securing necessary approval and consents from GoB where needed. Power Cell is the designated institution in terms of developing private sector power projects including the solicitation and evaluation of proposals, negotiation, awarding contracts, and finalizing the agreements that are related to the projects as well as representing the interest of the government to the private sector. During the issuance of RFP from Power Cell will determine the power purchasing organisation of the private sector company.

Minimizing Risks

Agreement in terms of power purchase and fuel supply is in place to exclude the requirement for lengthy negotiations between the government and private sector projects sponsors. The agreement in terms of power purchase will be guaranteed by the government for the performance obligations of the concerned utilities. Similar will be followed in terms of the fuel supply agreement. The government is obligated to provide standard

protection against *force majeure* risk as well as changes in certain taxes and duties.

Project sites and required types of fuel for the projects will be determined by the government focusing on indigenous resources (natural gas, coal) and other fossil fuels including imported fossil fuels. However, investors may be asked to bid for renewables and sun, wind, biomass-based energy where the agreement in terms of implementation and power purchase will be different.

Tariff for Bulk Purchase

The tariff structure will be applied in terms of capacity payment and energy payment. The capacity payment will cover debt service, ROE, fixed costs in terms of operation, maintenance, and other costs, including insurance. Besides, the capacity payment will be made in denominated BDT to pay domestic loans and investment, and fixed costs. In terms of repaying foreign loans and fixed costs, the capacity payment will be paid in denominated dollars. The amount of payment will be determined subject to the availability of the power plant which will be notified by GOB to the bidders during the time of RFP issuance. The variable costs of operation and maintenance and the cost of fuel are regarded as the energy payment. These costs will be paid in BDT.

The bidders will offer bulk power tariffs based on the capacity and energy payment including equivalent levelized tariff based on the discount rate. The same is applicable to the SPP 30 MW installed capacity. The year-wise tariff profiles have to be matched with their annual debt service requirements. A mechanism will be in place to adjust the exchange rate fluctuations, prices of fuel, and inflation rates.

The cost related to connecting the power to the outgoing terminal will be borne by the private sector power investors where the transmission line for the connection with the national grid will be provided by the appropriate agency.

Power Pricing Framework

The end-user electricity tariff will be set differently for each customer class to cover the reasonable cost of supplying electricity and to generate a surplus to expand the services in future and improve the quality of services.

The government will provide subsidies from the budget if the government decides to subsidise the capital or operating cost in terms of serving a particular customer class. End users will bear the generation cost where incentives will be incorporated in tariff to gain efficiency both commercially as well as technically.

The tariffs will be reviewed quarterly and adjusted annually to reflect and incorporate the changes. In case of adjusting quarterly, the variation has to be more than 10 per cent than the recognised cost.

The cost of electricity in terms of peak and off-peak consumption will be maintained in two parts tariff rate, one part for capacity payment or fixed costs and the part other for energy payment or variable costs.

Incentive Structure

Financing

- a. Approval to the private sector power investors in terms of issuing corporate bearer bonds and registration of those power generating firms at SEC with the consent from SEC. In addition, the investors can avail the facilities to issue their shares at discounted prices with a maximum 10 per cent limit on the face value.
- b. The foreign banks can facilitate underwriting the issue of shares and bonds of private sector companies subject to the recognition of the SEC.
- c. Tax facilities for instruments similar to those are available to the non-banking financial institutions.
- d. Amendment to the 80:20 debt ratio is allowed if necessary.

Fiscal Incentives

The private sector companies will enjoy a rebate of corporate income tax for 15 years. In addition, the private sector companies can import equipment and other necessary parts up to ten per cent equivalent value of the total plant without paying any CD, VAT, other surcharges, and import permit fee up to twelve years of commercial operation. The incentives are not applicable for domestically manufactured equipment.

Tax exemptions are applicable for the following issues-

- a. Interest on foreign loans.
- b. Foreign investors can avoid double taxation through bilateral agreements.

CREATING FAIR AND APPROPRIATE INCENTIVE STRUCTURE-WAY FORWARD

It is important that the government address the challenges that have been found with proper guidelines mandated by the laws and policies alike to the Private Sector Power Generation Policy. Since the provisions mentioned in this policy are not fiscal friendly, the government can reform the provisions considering the demand for power and global shift in energy mix for power generation.

One of the major challenges that have been found is the incentives the government is providing to the private sector power generation companies. Therefore, the government should revise the incentive structure in the private sector power generation policy and should encourage the private sector to invest more on the Transmission and Distribution (T&D) coverage and supply system to provide quality electricity supply to the consumer so that the maximum utilisation of power plants can be ensured.

In addition, the government should introduce 'No Electricity, No Payment' for IPPs alike to the RPP/QRPP. The provision is not

applicable for the IPPs as mandated by the law rather the government provides subsidies and capacity and energy payment to the private sector power generation companies whether those produce the electricity or not. It is important that the government adopt this policy since the purchasing price of IPPs is way higher than the rental/quick rental power plants. In line with this, subsidy in the power sector should be rationalised so that the fiscal pressure can be lessened which is also important to adjust in terms of reducing the operational cost of BPDB, reducing the burden of capacity payment, and introducing effective cost management strategies.

A number of public sector plants remain idle which induces power generation from the private sector. Since public sector plants are inefficient compared to the private sector, the government should retire the inefficient and idle plants to reduce its operation cost. On the other hand, utilisation of IPPs or rentals during low demand generate huge cost as these plants are mostly oil-based. The government should expire or retire lower utilised private-sector plants to reduce the capacity payment of the government. Besides, a proper estimation of electricity demand should be made so that the supply side can be adjusted accordingly.

Additionally, the energy mix should be revised by prioritising non-fossil fuel-based power plants, especially for the private sector power plants. An appropriate incentive structure can be developed in this regard. The current policy does not emphasise renewable or non-fossil fuel-based power generation which is rather tacky considering the government commitments in various national documents including the power sector master plan and Eight Five Year Plan. Hence, the private sector power generation policy should be revised with other national documents.

The government promoted private sector power generation through fossil-fuel based power plants whereas considering the climate issues and Bangladesh's commitments at both national and international platforms targeting climate challenge related issues,

the government should divert this law to promote renewable energy-based power generation policy which would reduce the variable cost or energy payment of the government and could create some fiscal space.

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SUPPLY SIDE IMBALANCE IN THE POWER SECTOR OF BANGLADESH - LOOKING BEYOND THE INSTALLED SUPPLY CAPACITY

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Abstract

Bangladesh Power sector is facing double trouble as there is overcapacity of supply and outstanding electricity demand. It has been stated that there is not sufficient power demand leading to underutilization, but even that much of the demand is not being met. None of the influencing factors can explain the situation except that there is a divergence between the documented power supply capacity and actual power supplied. There are inconsistencies among the data, information and statistics recorded in the different sources. A good number of public and private power plants are operating at much lower level of efficiency than minimum threshold. After taking all the factors into account it can be concluded that the actual power supply capacity is actually much lower than the derated capacity. Data accuracy and transparency, along with a strong and efficient transmission and distribution (T&D) system can pave the way out of the imbalance.

INTRODUCTION

There was a time when the supply of power or electricity was not adequate but over the past few years, the power supply capacity has become more than sufficient. The overcapacity of power generation has become an alarming issue and seems to be out of

control. Quite a few power plants remain idle as there is not much of the power demand. Despite having a pretty big number of unutilized electricity, it is often observed that there are still irregular load shedding and power cuts. Load-shedding is frequent not only in the rural areas but also inside Dhaka. The transmission and distribution system are held accountable for the inconsistent electricity supply, but it is not applicable inside Dhaka metropolitan area. Therefore, the focus has been shifted from power generation to transmission and distribution. The twin trouble of Bangladesh's power and energy sector, supply overcapacity and underutilization of the present generation capacity is causing a massive loss.

Bangladesh's Power and Energy Sector is currently running in an unbalanced state. The statistics seem to be misleading as it states both shortage and surplus of supply at the same time. Simultaneously, there is excess supply and demand surplus. This surplus phenomenon from both of ends appears to be anomalous. Therefore, this study explores the reasons and factors causing the supply side imbalance. The study considers the power sector's installed and effective generation capacity and attempts to find the existing gap and the underlying reason for the supply-demand mismatch. The study is conducted based on the secondary literature and data from different Bangladesh's power and energy sector sources. This study will assess the supply surplus and shortage both in terms of installed and derated capacity with the help of data and statistics of the Bangladesh Power Development Board (BPDB).

As the drafting of the new Integrated Power and Energy Master Plan (IPEMP) has already begun and is now at the preliminary stage, it is high time to look beyond the installed capacity and focus on the efficiency of the generation sector to solve the existing puzzle of demand and supply. This study attempts to put an end to the power sector dilemma regarding overcapacity of electricity generation and availability of electricity.

State of Power Generation

As per Bangladesh Power Development Board (BPDB) annual report 2021, total installed capacity was 22,031 MW, which includes 10,146 MW Public, 1,244 MW JV, 8,141 MW IPP/SIPP, 1,089 MW Rental Power Plant, 251 MW under REB (for PBS) and 1,160 MW power import from India. The maximum peak generation was 13,792 MW, which is 8.27% higher than 2020. In the case of power generation, the ratio of public and private ownership is almost equal. The publicly-owned power plants supply about 46 per cent of the total power, whereas the private sector supplies 43 per cent of the total power, and 6 per cent of the supply comes from joint ventures. Therefore, players from both the public and private sectors are important while ensuring power generation efficiency.

Though the government of Bangladesh is taking more initiatives regarding power transmission and distribution, there are still some newly initiated projects to further expand the generation plan by adding 19,802 MW by 2025. A good sum of power plants will be obsolete by 2025, reducing generation capacity by 3,990 MW. Hence the predicted power generation capacity in 2025 will be 37,835 MW. As per the projection of the Power System Master Plan (PSMP) 2010, the demand in 2025 will be over 25,000 MW and the PSMP 2016 projects the demand to be almost 20,000 by 2025¹.

Overall the projection pattern of PSMP 2016 shows a lower trend than the previous PSMP, still the power demand prediction seems to be overestimated. The methodology was not much appropriate as it was only based on GDP and didn't focus on the micro-level sectorial analysis (Moazzem & Preety, 2021).

¹ See Annexure 1

Table 1: Present Installed Generation Capacity (MW) as of 30 November 2021

Ownership Wise	No of Power Plant	Installed Generation Capacity (MW)
Public Sector		
BPDB	38	6013
APSCL	5	1444
EGCB	3	957
NWPGCL	7	1401
B-R Power gen	1	149
RPCL	3	182
Subtotal	57	10,146 (46%)
Joint Venture		
BCPCL (JV of NWPGCL & CMC, China)	1	1244
Subtotal	1	1244 (6%)
Private Sector		
IPPs	59	8042
SIPPs (BPDB)	4	99
SIPPs (REB)	9	251
15 YR. Rental	4	169
3/5 YR. Rental	12	920
Subtotal	88	9481 (43%)
Power Import		
Bheramara HVDC		1000
Tripura		160
Subtotal		1160 (5%)
TOTAL	146	22,066*

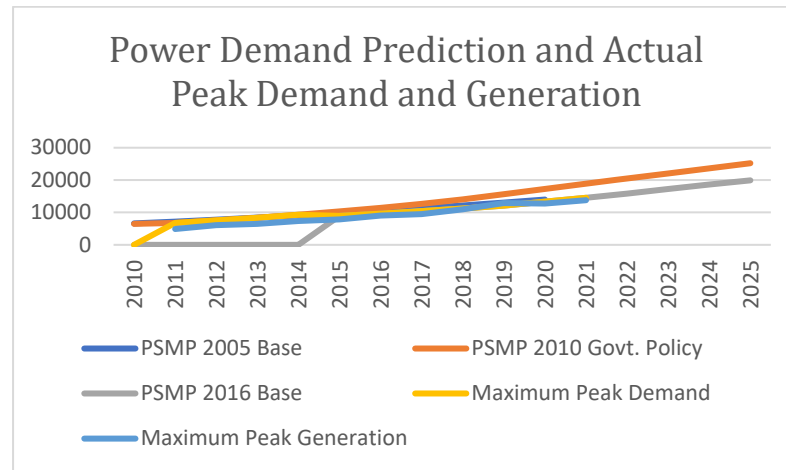
Source: Bangladesh Power Development Board (BPDB) Website.

*Including Captive Power & Off Grid Renewable Energy

Total Installed Capacity (22,031+2,800+404) =25,284MW

It can be observed that the power demand prediction in PSMP 2010 was the highest among all of the three forecasts. Both maximum peak demand and generation lie much lower than the PSMP 2010 forecast (Figure 1). The forecast of PSMP 2016 seems to be almost accurate as it aligns with the maximum peak demand. Even if the actual demand reaches out to be equal of the forecasted

demand, there will still be an excess capacity of 17,835 MW by 2025.



Source: Author's Illustration from PSMP and BPDB Data.

Figure 1: Forecasted Power Demand in different PSMPs and Actual Peak Demand and Generation

The assessment of the efficiency level at which a power plant is operating is vital while arguing about the efficient generation capacity. The level of efficiency in the private sector is said to be more than that of the private sector as the massive improvement in the power sector was achieved after including the power sector in generation. The efficiency level in the IPPs is the highest, 42 per cent, whereas the efficiency level of public power plants is 38.9 per cent. Annual plant factor of the SPPs & QRRs is less than the national power plants, 37 per cent². The high level of annual plant factors in the IPPs signals that the national power plants are not fully using their capacity. That ultimately backs the logic that much of the capacity is being idle in the public power plants.

² See Annexure 3

The total installed capacity and the derated capacity are not found to be the same in the power plants. The gas-based power plants have lower derated capacity than any other fuel-based power plants. In addition to this, the efficiency level of public power plants in terms of derated capacity is lower than the private ones.

Power plants with the highest installed generation capacity are situated in the Dhaka zone. Strong transmission lines are also mostly around and near the Dhaka zone. So the power supply in the Dhaka zone should be of good quality and reliable. To strengthen the T&D (transmission and distribution) system, plans are being prepared to construct an additional 5,346 ckt km transmission line 46,604 MVA capacity-based grid sub-station, 85 thousand km new distribution line, and related distribution substation by 2025. The constructed transmission lines should be enough to supply the generated electricity by 2025.

THE IMBALANCE BETWEEN POWER DEMAN AND SUPPLY

Mismatch between Power Supply and Demand

Even though 99 per cent of the country's total population has been brought under electricity coverage, the demand of people is being unmet. As per the BPDB annual report data, the maximum generation in 2021 was 13,792 MW, whereas the maximum demand was 14,500 MW. The need for electricity surpasses the availability of electricity by 708 MW. The existing installed capacity and derated capacity both are much higher than the peak demand of 2021. The scenario is similar for the previous year too. The mismatch between demand and supply of electricity is crucial to look at. Despite of the power supply capacity remaining much more than the power demand, those are not fulfilled. The paradox of power supply must be observed for a more clear picture.

Table 2 represents the present overcapacity situation from 2010 to 2021 and how much of the power demand remained unmet throughout that time. A substantial increment in the per cent of the share of overcapacity in terms of installed capacity has been observed in the last decade. The other side of the table tells a

different story. As the per cent of overcapacity increases with time, so does the gap between power demand and power supply. The demand for power remains higher than the power supply at all costs. If the derated capacity is considered instead of the installed capacity, the conclusion remains the same in almost all cases.

Table 2 : Demand Supply Situation on Power Sector of Bangladesh

Year	Total installed capacity (MW)	Maxim. Demand Served (MW)	Over-capacity (as per max. generation) (MW)	Maximum Peak Demand (MW)	% Of the share of over-capacity of installed capacity	Demand Unmet (MW)	Demand Unmet (In terms of Derated Capacity)
2010-11	7,264	4,890	2,374	6765	32.68%	1,875	-126
2011-12	8,716	6,066	2,650	7518	30.40%	1,452	582
2012-13	9151	6,434	2,717	8349	29.69%	1,915	188
2013-14	10,416	7,356	3,060	9268	29.38%	1,912	553
2014-15	11,534	7,817	3,717	10283	32.23%	2,466	656
2015-16	12,365	9,036	3,329	11,405	26.92%	2,369	-235
2016-17	13,555	9,479	4,076	12,644	30.07%	3,165	127
2017-18	15,953	10,958	4,995	14014	31.31%	3,056	1,396
2018-19	18,610	12,893	5,717	13044	30.72%	151	5,394
2019-20	20,383	12,738	7,645	13,300	37.51%	562	6,592
2020-21	22,023	13,792	8,231	14500	37.37%	708	6,780

Source: Author's calculation from BPDB data.

The question still prevails in the mind that if there is surplus both with respect to installed capacity and derated capacity, then why the demand surpasses the supply.

The power sector is not operating at supply surplus state; more accurately, it is operating at supply overcapacity. Therefore, the surplus that is always referred to is the supply capacity surplus, not that the power has been distributed over the demand or even equal to the demand.

Supply Side Imbalance of Power Sector

The demand-supply mismatch is being discussed, but the mismatch within the supply side of the power sector can be quite interesting. The deviation between the power supply capacity and the power supplied is uncanny. On the one hand, the capacity is 22,023 MW (without captive power); on the other hand, the peak generation was 13,792 MW. Data inconsistency among the data revealed in the public documents is also quite appalling (Table 2).

The Table 3 postulates how many faults have occurred in previous years, which hampered the uninterrupted power supply. The partial failure of power supply due to the trouble in power generation is highest throughout the years. Despite having a relatively higher number of faults, the duration of the interrupted power supply is recorded to be zero in 2020 and 2021. In 2019, the power supply was interrupted for only 53 minutes. Partial Power failure due to the lightning on transmission line/thunderstorm remains zero in all the years even though there are power cuts experienced outside and inside Dhaka.

In simpler words, there should have been no power cuts during the rain or thunderstorm, which contrasts with the actual scenario. As the table reflects, the total time of all load shedding or power cuts was 167 hours 4 minutes in 2021 all over Bangladesh. The data doesn't seem to represent the reality faced on a regular basis. Anomalies within the BPDB data also exist, as the daily power generation report shows no

load shedding or power cuts. It is hard to believe any statistics when anomalies are found among the data itself.

Table 3: Interruption of National Grid for FY 2019, 2020 & 2021

Type of faults	Total Number of Faults			Total Duration		
	FY 2019	FY 2020	FY 2021	FY 2019 Hours/Minutes	FY 2020 Hours/Minutes	FY 2021 Hours/Minutes
Partial Power failure due to trouble in generation	171	162	256	0/53	0	0
Partial Power failure due to trouble in grid S/S Equipment	55	29	98	45/43	33/15	146/29
Partial Power failure due to fault in transmission line	17	11	11	31/37	14/45	13/39
Partial Power failure due to the lightning on transmission line/Thunderstorm	00	00	00	00/00	00/00	00/00
Partial Grid failure	02	02	03	1/14	00/44	06/56
Total Grid failure	00	00	00	00/00	00/00	00/00
Total	245	204	368	79/27	48/44	167/04

Source: BPDB Annual Report 2020 & 2021.

Factors Influencing the Supply Imbalance

The imbalance of the electricity supply can occur due to various reasons. The high level of reserve margin can be one of those as the reserve margin of the power sector of Bangladesh seems to be above 25 per cent. While discussing the power supply paradox, the difference between installed and actual power generation capacity

(derated capacity) is often referred to. The installed capacity is not always the efficient (derated) capacity, so the disparity may have been one factor. This is not the case for the power sector of Bangladesh. Even if the derated capacity is considered, there should be no power demand surplus.

Insufficiency of natural gas is the reason why the highest number of unutilized capacity is at the gas based power plants. Those power plants were established keeping in mind that natural gas will be the dominating fuel for power generation. But later on, Bangladesh faced a huge natural gas shortage and those power stations started to remain idle.

Due to the maintenance issue, power plants are being shut down at some point. Total six power stations were under maintenance in 2020-21. Four of those have already started, and only two power stations with the capacity of 250 MW are still under maintenance (BPDB Annual report, 2020-21). So, the maintenance should not be an issue if not the power plants under running maintenance are more than what is mentioned in the annual report.

Usage of captive power in the industrial area is increasing with time as the reliable supply of electricity cannot be ensured. The generation capacity without captive power is 22,033 MW whereas the peak demand was 14,500 MW. So again, the demand should have been easily met by the existing electricity supply excluding the captive power.

The insufficient numbers of transmission lines have been causing the supply shortage for quite some time. With the increasing power generation capacity, transmission problems seem to waste the generated electricity as those remain idle. Payra power plant is a good example of this. Though the Government of Bangladesh (GoB) has started to pay more attention to the transmission and distribution sector than generation, the transmission and distribution have improved over time. Current transmission and distribution system loss is 11.11 per cent. And a total 12,835 km (Circuit Km) transmission lines and 6,12,310 Km distribution lines have been connected to power system network.

Low efficiency level of the public power plants compared to the IPPs seems to be responsible for the supply imbalance. The high level of annual plant factors in the IPPs (42 per cent) than public power plants (38.9 per cent) signals that the national power plants are not fully using their capacity.

There seem to be some data-driven anomalies in the power sector particularly in the power supply. The supply capacity that is mentioned in the official documents may not be there in reality. More precisely, 21,280 MW (derated capacity) of electricity is not in operation. Deducting the capacity of the power plants under 15 per cent annual plant factors, roughly 17,528 MW are in operation³.

The factors mentioned don't really seem to explain much the supply mismatch problem except the insufficient and inefficient transmission and distribution system, and low efficiency level of power plants. If not these factors, something else is creating dubious circumstances in the power sector. There seem to be some data-driven anomalies in the power sector particularly in the power supply. The supply capacity that is mentioned in the official documents may not be there in reality. More precisely, 21,280 MW (derated capacity) of electricity is not in operation. If the power sector had been operated with the 100 per cent capacity, the total power demand should have been met by the total power supply.

Way out to handle the Imbalance

The inconsistency of the power sector supply side may not be solved at once but can be balanced gradually. The power demand has been flat and doesn't seem to increase in near future as Covid pandemic may fuel the demand shortage further.

Data transparency and accuracy need to be ensured. The provided statistics don't seem to align with the reality. In addition to this, the inconsistency among the national data and statistics from different sources appeared to be a matter of concern. 100 per cent accurate data and transparency of those data are crying need

³ See Annexure 4

to understand how much of the efficient generation capacity exists and how plans should proceed further.

The efficiency of the public power plants requires further improvement. In order to improve the efficiency of the whole power sector, the national power plants must perform more efficiently. Therefore, the regulations that are applied for IPPs should also be applicable for public power plants.

Strengthening T&D system should have been the main priority as it is said to be the main reason for the unmet power demand. Already plans are being prepared to construct an additional 5,346 ckt km transmission line 46,604 MVA capacity-based grid substation, 85 thousand km new distribution line, and related distribution substation by 2025. But it is needed to keep in mind that by 2025 much more generation capacity will be added and the T&D systems have to be enough to support the generation capacity.

The transmission lines should be built where the power plants are so that the nearby power plant can fulfil the power need of that area. The lengthy and heavy transmission lines built to transport the generated electricity should be omitted. This will reduce the cost of BPDB and make the T&D more efficient.

The extended speedy energy supply act should be abandoned. The supply capacity is being underutilized, the speedy energy supply act under the quick enhancement of electricity and energy supply has been extended. The revision of the act further when the **Speedy Supply of Power and Energy Act** needs to be discontinued immediately.

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ANNEXURE**Annexure Table 1: Power Demand Forecast and Actual Peak Demand and Generation**

Yr.	PSMP 2010			PSMP 2016			Maximum Peak Demand	Maximum Peak Generation
	Low	High	Govt. Policy	Base	Low	High		
2010	6454	6454	6454	-	-	-	-	
2011	6756	6869	6765	-	-	-	6,765	4,890
2012	7083	7329	7518	-	-	-	7,518	6,066
2013	7436	7837	8349	-	-	-	8,349	6,434
2014	7819	8398	9268	-	-	-	9,268	7,356
2015	8232	9019	10283	8920	8920	8920	8,920	7,817
2016	8680	9705	11405	9584	9600	9600	9,600	9,036
2017	9165	10463	12644	10400	10400	10400	10,400	9,479
2018	9689	11300	14014	11200	11200	11200	11,200	10,958
2019	10255	12224	15527	12100	13300	12100	12,100	12,893
2020	10868	13244	17304	13300	13300	13300	13,300	12,738
2021	11,442	14,249	18,838	14,500	14,500	14,500	14,500	13,792
2022	12,056	15,344	20,443	15,800	15,800	15,800	-	-
2023	12,713	16,539	21,993	17,200	17,200	17,200	-	-
2024	13,416	17,840	23,581	18,600	18,600	18,600	-	-
2025	14,167	19,257	25,199	19,900	19,900	20,000	-	-

Source: PSMP 2010, 2016 & BPDB Annual Reports.

Annexure Table 2: Present Installed and Derated Capacity of Power Sector

Name of plant	Unit Nos	Installed capacity (MW)	Derated capacity (MW)
Public			
Sub-Total (PDB)	34	4202	3874
Sub-Total (APSCL)	21	1459	1367.4
Sub-Total (EGCB)	6	957	599.7
Sub-Total (NWPGL)	8	1064	994
Total in Public Sector	68	7682	6835.11
Private			
Sub-Total (IPP)	79	2597	2589
SIPP (PDB)			
Sub-Total SIPP(PDB)	28	99	99
Sub-Total (RPP)	132	412.9	377.7
Sub-total (QRPP)	112	226	226
Total in private sector	351	3334.9	3291.74
Grand Total	419	11017	10127

Annexure Table 3: Plant-wise Annual Plant Factor

Name of power plant	Generation Capacity Installed (MW)	Net Energy Generation (GWh)	Annual Plant factor (%)
PUBLIC			
Total (Grid)	10,146	31,912	38.90%
JOINT VENTURE			
Total Joint Venture	1244	3,811.92	36.80%
PRIVATE			
A. Total IPP	8042	29358.86	42%
B.Total RENTAL & SIPP	1,188	5463.08	37%

Source: BPDB Annual Report 2020-21.

Annexure Table 4: Actual Generation and Unutilized Capacity in the Power Sector

Name of power plant	Generation Capacity Installed (MW)	Annual Plant factor (%)	Actual Generation in 2020-2021	Unutilized Capacity in 2020-2021
PUBLIC				
b) Ghorasal Repowered CCPP Unit-3	260	2.30%	5.98	254.02
Hathazari 100 MW Peaking PP	98	0.10%	0.098	97.902
Kaptai Solar	7	15.90%	1.113	5.887
Titas 50 MW Peaking PP	52	10.40%	5.408	46.592
Shahazibazar 100 MW GT	100	5.20%	5.2	94.8
Khulna 225 MW (NWPGL)	230	14.40%	33.12	196.88
Bheramara GT unit-3	20	0.00%	0	20
Faridpur 50 MW Peaking PP	54	3.70%	1.998	52.002
Gopalganj 100 MW Peaking PP	109	0.70%	0.763	108.237
Modhumoti 105 MW NWPGL	105	1.50%	1.575	103.425
Baghabari 100 MW /GT	100		0	100
Sirajgonj 210 MW CC (NWPGL) Unit-1	210	12.20%	25.62	184.38
Bera 70 MW Peaking RE	71	5.20%	3.692	67.308
Santahar 50 MW PP	50	10.00%	5	45
Katakhali 50 MW PP	50	12.00%	6	44
Barapukuria Coal based S/T (unit 1,2)	250	7.80%	19.5	230.5
Saidpur 20 MW /GT	20	1.30%	0.26	19.74
Rangpur 20 MW /GT	20	0.90%	0.18	19.82
Sub- Total (Grid)	1,806	38.90%		1690.493
PRIVATE				
United Power Co. Ltd. 200 MW Exp	195	9%	17.55	177.45
Nutan Biddyt 220MW Bhola	220	14%	30.8	189.2

Sinha Peoples Energy Ltd.Katpatti 52.5 MW Exp	51	5%	2.55	48.45
CLC Power Co. Ltd. 108 MW Bosila Keranigonj	108	0%	0	108
Lobonchora Orion Power Rupsha Ltd. 105 MW	105	0.40%	0.42	104.58
Karnaphuli Power Ltd.	110	9%	9.9	100.1
Anlima Chattogram 116 MW	116	12%	13.92	102.08
Bhairab Power 54.5 MW	54	15%	8.1	45.9
United Payra PP Patuakhali Imp	150	3%	4.5	145.5
APR Energy 300MW	300	3%	9	291
Daudkandi 200MW(Bangla Trac)	200	2%	4	196
Noapara100MW (Bangla Trac)	100	14%	14	86
Aggreko, Aourahati 100MW	100	4%	4	96
Aggreko, Brahmangaon 100MW	100	3%	3	97
Paramount Baghabari BanglaTrack	200	1%	2	198
Sharishabari 3 MW Engreen Solar Power Plant	3	15%	0.45	2.55
50 MW HDFC Solar Power Plant	50	15%	7.5	42.5
Manikganj 35MW Spectra Solar Park Ltd.	35	10%	3.5	31.5
Sub-Total IPP	2,196	42%		2061.81
				3752.30

Source: Authors' calculation from BDDDB Data.

ESTIMATION OF HYDROGEN DEMAND FOR A SUSTAINABLE ENERGY MIX IN BANGLADESH REPLACING THE TRADITIONAL FUELS BY 2040

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Abstract

Due to environmental deterioration, fossil fuels are no longer preferable energy sources. Among other alternatives, hydrogen is a potential candidate to replace fossil fuels. Some countries have already developed the hydrogen economy and policy to achieve the sustainable energy mix. Many East Asian countries are to deploy the policy within 2040. Bangladesh has already started research for the use of hydrogen in various applications. The demand projection of hydrogen and a policy is required for the development of a sustainable energy sector in Bangladesh. In this paper, performed analysis shows the potential of hydrogen demand by Bangladesh in 2030. The analysis is based on the methods and criteria adopted by several international agencies, research institutes and laboratories. There are three scenarios, each having a specific percentage of different fuel mix. These three scenarios are modified and set for Bangladesh. For scenario1, Bangladesh would require about 2.98 MTOE of hydrogen in 2041, whereas for scenario 2 and 3 the amount would be 6.05 and 9.12 MTOE. The Power sector would consume about 70% whereas industries and transport would consume 23% and 6%, namely. Technology transfer and locally developed low-cost systems may facilitate more accessible and low-cost production of hydrogen in Bangladesh because of the penetration of Renewable energy sources and technologies. Technology transfer would be

challenging for Bangladesh. As neighbouring countries have already completed, and about to start making hydrogen policy, Bangladesh should commence on it. This research would contribute to the hydrogen economy and policy in Bangladesh.

Keywords: demand estimation, hydrogen economy; fuel mix, technology transfer, sustainable development.

INTRODUCTION

Hydrogen is being considered as the cleanest fuel for the future. It has the potential to take over fossil fuels. However, much research and development are still required to establish general purpose use of hydrogen as a fuel. Many countries have already made policy on the hydrogen economy, GOB (2019). England, USA, Canada, Australia, Germany, Ireland, Japan, South Korea and China has accounted on hydrogen and invested millions of dollars on establishing the hydrogen economy, CDP (2019). Among them, Australia, India, China, Japan, and Korea has completed the formulation of hydrogen policy, ERIA (2018). India and China are the close neighbours of Bangladesh. In contrast to them, sufficient research are yet to be facilitated in Bangladesh.

Argonne National Laboratory performed a hydrogen demand analysis in USA for the year 2050. The analysis is focused for fuel cell vehicles, synthetic hydrocarbon production, bio fuel production and injection into natural gas pipeline. For fuel cell the assumption is the reduced cost at H₂ filling station that is 8\$/kg to 5\$/kg. For synthetic hydrocarbon production the assumption is made to produce 100 m MT of CO₂. For bio-fuel production the assumption is that the 50% of total demand of jet fuel will be replaced by H₂ based bio fuel by 2050 and 20% of natural gas in gas pipeline will be replaced by injection H₂. The estimated demand for FCEVs is 16.9 MMT, Synthetic Methanol 14 MMT, Biofuels production 8.7 MMT and Injection into NG pipelines is about 16 MM, Amgad et.al. (2020).

Another study conducted for European countries, states the similar approaches of assumption to estimate hydrogen demand. For medium temperature applications 5% of current natural gas

demand is assumed to be replaced by hydrogen in 2030, 20% by 2040 and 30% by 2050. For high temperature application it is set to replace natural gas by 15% using hydrogen in 2030, 40% by 2040 and 50% by 2050, Anthony et.al. (2021).

A study conducted by NREL, national laboratory of the U.S. Department of Energy, estimated the demand by 4 scenarios. It identifies the transport sector as the biggest hydrogen market opportunity within 2050. Transportation sector is divided into light, medium and heavy vehicles among which 27% are to be replaced by FCVs. The study assumes economic potential scenarios which includes the lowest-cost electrolysis scenario at which 15% petroleum would be replaced by H₂. In The Aggressive Electrolysis R&D scenario, Steam Methane Reforming (SMR) is assumed to be 22% reduced and nuclear falls about 43%, Mark et.al. (2020). Another demand potential estimation is conducted for East Asia region by Economic Research Institute for ASEAN and East Asia (ERIA). The estimation is based on three sectors by three scenario up to 2040. Sectors are Power Industry and Transport. The assumptions are quite straight forward. The conventional fuels like Coal, Natural Gas, Petrol and diesel are to be replaced partly by hydrogen. For scenario 1 it is 10%, 20% for scenario 2 and 30% for scenario 3, ERIA (2018).

For East Asian Summit (EAS) region countries like Srilanka, it is set that 20% of new coal-fired electricity generation would be converted to natural gas and H₂ mixed fuel-fired generation within 2040, Govt. of Sri Lanka (2017). 20% of new natural gas-fired electricity generation would be converted to natural gas and H₂ mixed fuel-fired generation. 20% of natural gas consumption for industrial purposes would be replaced by natural gas and H₂ mixed fuel. For transport, a percentage of Gasoline demand would be converted into H₂ by introducing new vehicles that consume hydrogen. Similarly, Diesel demand would be converted to H₂ and Diesel consumption for rail transport would be converted to H₂. The target is set for 2040, SAARC (2018). Table 1 shows the categorized assumptions and fuel mix scenarios for EAS countries,

Considering the methods and assumptions taken by the NREL, ERIA, Argonne etc. the assumptions and methods are composed for

Bangladesh. In Bangladesh, the pattern of fuel usage varies within a few numbers of sources. Electricity production is mostly dependent on natural gas. Here, the transport sector uses imported petroleum products. The indigenous natural gas reserve is depleting quickly. Bangladesh has started importing LPG to support increasing demands. So, the country is mostly dependent on energy imports other than for natural gas. In future, it has to reduce the usage of natural gas (NG) to save the NG reserve as well as reduce the petroleum usage to mitigate climate issues, Ally and Pryor (2016).

Like some other Asian countries, Bangladesh needs to step on finding reliable new energy sources and making proper policy to achieve sustainable development goals (SDGs). The demand and supply potential of East Asian countries are showing that this part of the world is revising energy policy and choosing hydrogen as a new fuel mix, Cockroft and Owen (2017). Though most of the countries are yet to complete the policy, Spendelow and Papageorgopoulos (2012), it is high time for Bangladesh to start on it. It is because green hydrogen would be key factor in world energy economy in next few decades.

In recent years, Bangladesh government has initiated 41 solar park projects which have altogether 2175 MWp capacity. From these, 7 projects are completed and producing power, eight are being implemented, and 26 are in planning phase. Beside these there are ten wind power plants are initiated, having 259.9 MWp total capacity. From wind projects three plants are in live operation, one is in implementation, and the rest is in planning stage. These initiatives depicts a keen interest of the government to maximize the RE penetration in energy mix within 2030. Notably, Bangladesh Council of Scientific Research (BCSIR) in Chittagong has started research on hydrogen production and refuelling for Fuel Cell Vehicles (FCVs). The project is funded by Bangladesh Government, GOB (2016) and Rahman (2009). Study shows that due to the geographical location and locally developed low-cost electrolyzers, the green hydrogen production cost might get reduced in Bangladesh. This may help introduce the use of green hydrogen in the energy mix of the country, Mazumder et. al (2021).

To make a proper hydrogen policy, Bangladesh needs to exercise on its future demand. This research aims to calculate hydrogen demand projection in 2041 for Bangladesh perspective.

METHODOLOGY

In this research, the current scenario of energy usage in Bangladesh has been analysed. The method of the analysis and calculation process has been composed from various assumptions and approaches used by several international research institute, agency and laboratories. The data used for the analysis is sourced from the various document and reports published by the respective regulatory or government bodies like Hydrocarbon Unit, Energy and Mineral Resources Division, Ministry of Power, Energy and Mineral Resources and Bangladesh Power Development Board (BPDB).

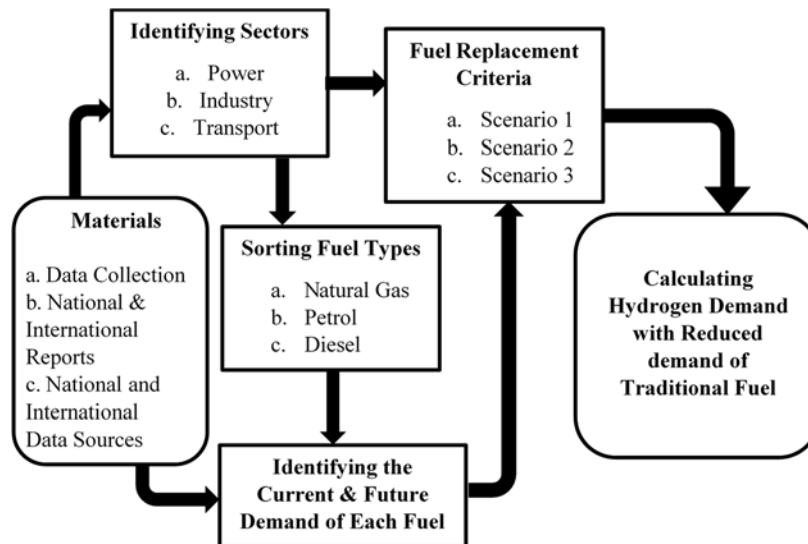


Figure 1. Flow of hydrogen demand determination

Such reports are Energy Demand Potential 2030 and Power System Master Plan 2040. In first phase of this research, major fuel consuming sectors are identified according to the published data. Replaceable traditional fuels are sorted along with the current and future demand. In this research future demand has been calculated in two stages. One is up to the year of 2030 and another is for 2040. Three replacement scenario are set to estimate the hydrogen demand. Finally the traditional fuel demand is replaced by hydrogen according to the parameters set in respective scenarios for each sectors. The flow of the analysis is shown in figure 1.

SECTOR-WISE CURRENT DEMAND OF TRADITIONAL FUEL

In Bangladesh, fossil fuels are the major components for meeting energy demands. It includes petroleum products like octane, petrol, diesel, kerosene, coal, liquid petroleum gas (LPG), natural gas and biomass. A small portion is sourced from Renewable Energy (RE) sources like solar, wind, hydro. In recent years, Bangladesh has started importing electricity. Here, Fossil fuels are mainly managed by import though it has natural gas and coal mines. In the 2017-2018 fiscal year, estimated usage of energy was 47 metric ton oil equivalent (MTOE), Holladay et.al. (2009). Bangladesh has the lowest per capita energy usage among the South Asian countries; 293 kgOE. Per capita generation of electricity is 446 kWh, Ogden (1999).

In table 1 biomass is presented though is it not considered as the commercial energy. It presents the overall demand and usage including commercially available and non-commercial form of energy sources. The total commercial energy usage in 2017-2018 is 33.4 MTOE, GOB (2019).

It has been observed that, nearly 65% commercial energy usage is natural gas and 21% is fossil fuel oil. Indigenous natural gas resources are depleting. It has been projected that natural gas production would be 63.69 Bcf in 2040 whereas about 960.77 Bcf has been produced in 2017-2018, Bangladesh and ADB (2010). The rate of depletion is alarming. So Bangladesh need to reduce the use of its own natural gas reserve to slower the depletion rate. LPG has

come into the scene recently as a substitute of natural gas. New fuel mix technology is a must to help the situation.

Table 1. Energy calculation for 2017-18. (MTOE) source: (Energy Scenario Bangladesh 2017-18 published by Hydrocarbon Unit, Energy and Mineral Resources Division, Ministry of Power, Energy and Mineral Resources)

Name of Fuel	Unit	MTOE
Oil (Crude, Refined, LPG) in K ton	6948	6.9
LPG	554	0.5
Natural Gas in Bcf	961	22.3
Coal (Imported) in K ton	3395	2.1
Coal (Local) in K ton	923	0.6
RE (Hydro) in MW	230	0.2
RE (Solar) in MW	350	0.3
Electricity (Imported) in MW	625	0.5
Sub- total		33.4
Biomass		13.6
TOTAL		47

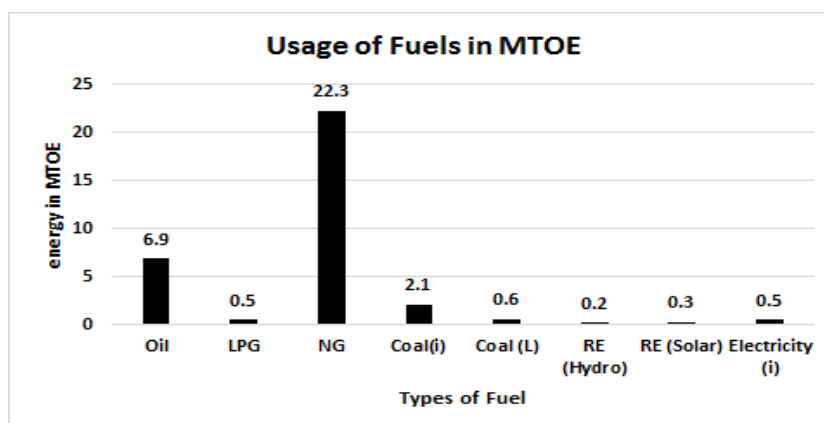


Figure 2. Total usage of commercial energy in 2017-2018

There are four major sectors identified that hold the capital share of gross energy demands of the country. Power generation, transport, agriculture and industrial sectors are the main consumers. The focus of this research is on the petroleum and natural gas demands. Table 2 shows sector wise usage of petroleum and natural gas in the year of 2017-2018.

Table 2. Petroleum and natural gas usage in 2017-18

Sectors	Fuel Type	Unit	%
Power Sector	Petroleum	1871756 MT	26.94%
	Natural Gas	384.4 Bcf	40%
	Natural Gas (Captive Power)	153.76 Bcf	16%
Transport	Petroleum	3432239 MT	49.40%
	Natural Gas (CNG)	48.05 Bcf	5%
Industries	Petroleum	337903 MT	4.86%
	Natural Gas	163.37 Bcf	17%
Agriculture	Petroleum	1090903 MT	15.70%
	Natural Gas (fertilizers)	48.05 Bcf	5%
Household	Petroleum	156756 MT	2.26%
	Natural Gas	153.76 Bcf	16%
Other	Petroleum	58779 MT	0.84%
	Natural Gas	9.61 cf	1%

Power sector is the major user of natural gas. About 64% is consumed here, BPC (2008). After power sector, use of natural gas in industries and households are remarkable. Though new gas line connection towards home users are not being facilitate still it has 16% share whereas industries having 17%. Petroleum products are mainly used in transport sector having 50% of its national demand, GOB (2016).

CHANGE IN TRADITIONAL FUEL DEMAND IN 2030 AND 2040

Energy Scenario Bangladesh 2017-18 published by Hydrocarbon Unit Energy and Mineral Resources Division, Ministry of Power, Energy and Mineral Resources on January 2019 presents the Energy demand potential on 2030 and Power system master plan

presents for 2041, Rahman (2009). It has predicted that natural gas demand will be about 8000 MMscfd in 2030 which is nearly 2920 Bcf. On the other hand total petroleum demand will be 10 M metric Tonnes. Considering the current percentage share of each fuels, sector wise future demand is obtained and presented in Table 3.

Table 3. Sector wise demand by fuel type in 2030

Sectors	Fuel Type	Unit	%
Power Sector	Petroleum	2694000 MT	26.94%
	Natural Gas (domestic)	1284.8 Bcf	44%
	Natural Gas (captive)	292 Bcf	10%
Transport	Petroleum	4940000 MT	49.40%
	Natural Gas (CNG)	146 Bcf	5%
Industries	Petroleum	486000 MT	4.86%
	Natural Gas	554.8 Bcf	19%
Agriculture	Petroleum	1570000 MT	15.70%
	Natural Gas (fertilizers)	146 Bcf	5%
Household	Petroleum	226000 MT	2.26%
	Natural Gas	467.2 Bcf	16%
Other	Petroleum	84000 MT	0.84%
	Natural Gas	29.2 Bcf	1%

Accepting that there would be no major changes within 10 year time period. Bangladesh government is planning to reduce the supply of natural gas toward captive power plants and increase supply to public and private power plants along with industries. It is assumed that about 6 % will be reduced in captive and 4% will be increased in domestic and 2% in industries within 2030. For industry and transport sector the annual average growth will be 6.3% up to 2041. The natural gas use for 2041 would be nearly 62% less and oil in same sector will increase about 16% from the year 2018 as indicated in master plan. In Bangladesh among other

petroleum products furnace oil and diesel is used in power production.

Table 4. Projected fuel demands in 2030 and 2041

Sector	Fuel	Demand in 2017-2018 (in MTOE)	Demand in 2030 (in MTOE)	Demand in 2041 (in MTOE)
Power	Diesel + Furnace	1.86	2.6	2.15
	Natural Gas	12.49	39.42	7.79
Transport	Diesel	2.3	3.31	5.60
	Gasoline	1.1	1.63	2.76
	Natural Gas	1.12	3.65	6.18
Industries	Natural Gas	3.79	13.87	23.48

In 2018 fuel oil demand of power sector is about 1.86 MTOE which might reach up to 2.6 MTOE in 2030. Natural gas demand would be nearly 39 MTOE. In transport sector 1.01 MTOE would be increased from current requirement. In table 4 sector wise demand projection is presented by fuel type. Demands in 2041 is present in table 4 also.

SCENARIOS AND ESTIMATION PARAMETERS

The demand is estimated based on three scenarios for 2030 and 2040. Each scenario is parameterized by the percentages of traditional fuel mixed with hydrogen as the replacement of that fuel. Scenario 1 is the lowest target of replacement in each sector like 5% replacement of any fuel by hydrogen for 2030. Scenario 2 is the medium target of 10% and scenario 3 is the highest target assumed for 15% replacement. For 2040 the targets are half increased for each scenario of 2030. Table 5 presents the category wise parameterized scenario for the year 2030 and 2040.

Table 5. Estimation parameters for Bangladesh for 2030 and 2041

Sector	Fuel	Scenario 1		Scenario 2		Scenario 3	
		2030	2041	2030	2040	2030	2040
Power	Gasoline	H ₂ : 5%	7.5%	H ₂ : 10%	15%	H ₂ : 15%	22.5%
		Pet:95%	92.5%	Pet: 90%	85%	Pet: 85%	77.5%
	NG	H ₂ : 5%	7.5%	H ₂ : 10%	15%	H ₂ : 15%	22.5%
		NG: 95%	92.5%	NG: 90%	85%	NG:85%	77.5%
Industry	NG	H ₂ : 5%	7.5%	H ₂ : 10%	15%	H ₂ : 15%	22.5%
		NG: 95%	92.5%	NG: 90%	85%	NG: 85%	77.5%
Transport	Gasoline	H ₂ : 0.5%	0.75%	H ₂ : 2.5%	3.75%	H ₂ : 5%	7.5%
		Pet:99.5%	99.25%	Pet:97.5%	96.25%	Pet: 95%	92.5%
	Diesel	H ₂ :0.0125%	0.025%	H ₂ : 0.025%	0.05%	H ₂ : 0.05%	0.1%
		Pet: 99.99%	99.975%	Pet: 99.975%	99.95%	Pet: 99.95%	99.9%
	NG	H ₂ : 5%	7.5%	H ₂ : 10%	15%	H ₂ : 15%	22.5%
		NG: 95%	92.5%	NG: 90%	85%	NG: 85%	77.5%

RESULTS AND DISCUSSIONS

In 2030 and 2041 the energy demand is assumed to be supplied from several mix of fuels. In power sector fuel oils will be mixed with hydrogen gas to reduce its consumption alone. In data analysis furnace oil and diesel is considered together and mentioned as oil in table 7.

Demand potential of Hydrogen in 2030 and 2041

Based on the estimation parameters and projected demand of traditional fuels in 2030 and 2040 the demand potential of hydrogen is calculated. The categorical data is shown in table 6.

Similarly the natural gas consumption would be reduced by hydrogen mix. In transport sector according to EAS assumption all diesel vehicles will be replaced by gasoline and hydrogen mix.

In Bangladesh CNG is used in transport sector. To reduce the use of natural gas in transport sector it has been considered for replacing a part by fuel cell vehicles and maximum by the gasoline vehicles. Some part of existing gasoline vehicles will be replaced by FCVs also. There are three scenarios in EAS assumptions. By scenario 1 total demand of hydrogen would be 2.98 MTOE which is the lowest among all other scenarios. The third scenario results 9.11 MTOE. Hydrogen demand will be highest in power sector and it is expected to be 70%, industries approximately 23% and transport nearly 6% of the gross (Fig.3).. There might be other commercial and non-commercial aspects of hydrogen but exempted from this research.

Table 6. Demand potential of Hydrogen in 2030 and 2041

Sector	Hydrogen Demand in 2030						Hydrogen Demand in 2041					
	Scenario 1		Scenario 2		Scenario 3		Scenario 1		Scenario 2		Scenario 3	
Power	Oil	H2	Oil	H2	Oil	H2	Oil	H2	Oil	H2	Oil	H2
	2.47	0.13	2.34	0.26	2.21	0.39	1.99	0.16	1.83	0.32	1.67	0.48
	NG	H2	NG	H2	NG	H2	NG	H2	NG	H2	NG	H2
Trans- port	37.44	1.971	35.478	3.942	33.507	5.913	7.21	0.58	6.62	1.17	6.04	1.75
	Diesel	H2	Diesel	H2	Diesel	H2	Diesel	H2	Diesel	H2	Diesel	H2
	3.309	0.001	3.309	0.001	3.308	0.002	5.602	0.001	5.601	0.00	5.59	0.00
	Gasol.	H2	Gasol.	H2	Gasol.	H2	Gasol.	H2	Gasol.	H2	Gasol.	H2
	1.622	0.008	1.589	0.041	1.549	0.082	2.739	0.021	2.656	0.10	2.55	0.21
	NG	H2	NG	H2	NG	H2	NG	H2	NG	H2	NG	H2
Indus- tries	3.468	0.183	3.285	0.365	3.103	0.548	5.72	0.46	5.25	0.93	4.79	1.39
	NG	H2	NG	H2	NG	H2	NG	H2	NG	H2	NG	H2
Total	13.17	0.694	12.483	1.387	11.789	2.081	21.72	1.76	19.96	3.52	18.20	5.28
		2.986		5.996		9.014		2.982		6.04		9.12

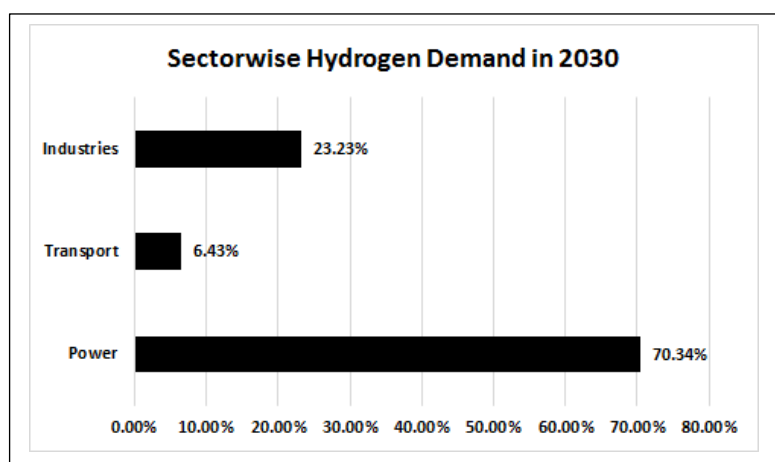


Figure 3. Hydrogen demand potential in 2030 by sector

The demand will be based on technology transfer at user end. In power sector, Hydrogen and natural gas mixed fuel gas turbine will replace the conventional gas turbines. Hydrogen and natural gas mixed fuel would be used in large- and small-scale boilers various industries as well as in power plants. Passenger fuel cell vehicle and Fuel cell buses will be used in transport sector. These technologies will create the demand for hydrogen in future.

Scopes and Challenges

Due to the climate issues the entire world is facing, fossil fuels are no more the noble choice. Most advanced countries are rushing toward the green fuel solutions. Above all hydrogen is the most prominent solution up to date. But there are some technological barrier towards establishing the hydrogen economy for any country. First of all it requires energy input to produce. There are some technical issues for the storage also. There are several established methods of hydrogen production each of these has different categories of issues however electrolysis and bio-mass gasification might be suitable for Bangladesh, Salam et.al. (2018).

In Bangladesh solar photovoltaic technology is being exploited in the form of small and large scale applications. Availability of solar radiation is useful here. The price of renewable electricity has

been lowered by government policy. Electricity can be used to produce hydrogen to store energy as well for various commercial and non-commercial use of hydrogen. Price of hydrogen is a barrier to expand its use. Large scale photovoltaic technology based hydrogen production might result a market competitive price of hydrogen which may help Bangladesh becoming a green hydrogen producer. To full fill that low price locally developed electrolyzers can play a vital role. Japan imports hydrogen from other countries currently from Australia. Likewise Bangladesh may also export green hydrogen to other countries.

To use hydrogen domestically current technologies need to be changed, added and modified. Using natural gas and hydrogen mix fuels in boilers and gas turbines shows prospective results. It has a safe range of mix ratio which is 8:2. Research is going on to increase it up to 7:3. In this ratio NO_x formation has been identified and mitigation method is also developed. However, the technology is still in development phase. In transport sector FCVs can be launched but in that case hydrogen filling station to be established first.

CONCLUSION

Having potential in renewable energy sector especially in solar, Bangladesh could become a prominent producer of green hydrogen in Asian region. As many neighbouring countries in the same region are trying to establish the hydrogen economy Bangladesh should step forward to achieve the same. A very few countries have already completed the documentation for the hydrogen policy like India and China but most of cases it has not yet been started. However, most of the countries have set the time line and had the hydrogen demand projection for 2040. If technology transfer and adaptation toward the hydrogen economy is accepted here, power sector would require the most of it as the form of commercially available hydrogen. Along with this the industrial and transport sector will experience a demand of this clean fuel as a fuel mix in 2030. Hydrogen will reduce the gross usage of fossil fuels and help fighting the climate issue more firmly. The demand projection is based on some specific assumptions and some future plans of the

government. However, the approach can be taken into account and many sectors other sector specific consideration can be incorporated to it for a closer projection. Still this work can contribute to make hydrogen policy in Bangladesh and provide some information based on specific scenarios on the demand in 2030 and 2041.

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ROOPPUR NUCLEAR POWER PLANT: HOW MUCH SAFE AND VIABLE THE SCHEME IS FOR BANGLADESH?

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“There’s a fragment of some conversation, I’m remembering it. Someone is saying: “You have to understand: this is not your husband anymore, not a beloved person, but a radioactive object with a strong density of poisoning. You’re not suicidal. Get a hold of yourself.” And I’m like someone who’s lost her mind: “But I love him! I love him!” He’s sleeping, and I’m whispering: “I love you!” Walking in the hospital courtyard, “I love you.” Carrying his sanitary tray, “I love you.”

— **Svetlana Alexievich, Voices from Chernobyl: The Oral History of a Nuclear Disaster.**

‘Q. There is much material to choose from when you direct a disaster film. Why did you particularly choose Fukushima?

A. There are many disasters currently threatening us such as hurricanes, massive earthquakes and heavy snowstorms. But the size of damage and the number of victims in the explosion of a nuclear power plant is something different. Radiation leaks are seen in our eyes as side effects and are not caught immediately. At the same time, some countries such as Korea and China are increasing the number of their nuclear power plants and many countries such as the United States depend on nuclear power. I wanted to stop this.’

(South Korean Director Kim Ki Duk on an interview about his movie on the Fukushima nuclear disaster: http://www.koreatimes.co.kr/www/art/2018/08/689_220178.html).

THE ROOPPUR NUCLEAR POWER PLANT: A BRIEF AND INTRODUCTORY SKETCH

The Rooppur Nuclear Power Plant will be a 2.4 GWe nuclear power plant in Bangladesh. The nuclear power plant is being established at Rooppur (Ruppur), adjacent to Paksey, in the Ishwardi Upazila of Pabna District, on the bank of the river Padma, 87 miles (140 km) west of Dhaka, in the northwest of the country. It will be the country's first nuclear power plant, and the first of two units are anticipated to start its activities in 2023. The VVER-1200/523 Nuclear reactor and critical infrastructure are being constructed by the Russian Rosatom State Atomic Energy Corporation. "Non-critical" infrastructure is being erected by Bangladeshi and Indian construction companies such as the MAX Group of Bangladesh and the Hindustan Construction Company of India.

The plan to construct a nuclear power plant in the then East Pakistan was built in 1961. In 1963, the Rooppur village of the Pabna district was chosen for the planned plant and 254 acres (103 ha) of land was undertaken for this purpose. The plan was to establish a 200MW nuclear power plant in the selected site. Discussions were held with the Government of Canada from 1964 to 1966. Discussions with the governments of Sweden and Norway were also being continued on in those years. However, no actual advancement took place. In 1970, the project was thrown away.

After the independence of Bangladesh, the Government of Bangladesh commenced conversation with the Soviet Union in 1974, but no agreement could be made. In 1976–77, the French company *Sofratom* carried out a feasibility study and established the project at Rooppur workable. In 1980, a 125 MW nuclear power plant project got approval. However, this endeavour could not also be implemented. In the 1987-88 period, another feasibility study was carried out and the decision was undertaken to build a 300 to 500 MW nuclear power plant. In 1998, steps were taken to build a 600 MW power plant. The *nuclear action plan* was granted approval in 2000.

In 2005, Bangladesh signed a nuclear cooperation accord with China. In 2007, the Bangladesh Atomic Energy Commission (BAEC) offered two 500 MW nuclear reactors for Rooppur by 2015. In

2008, China offered funding for the project. In lieu of it, the Bangladesh government began conversation with the Russian government after a year and on 13 February the two governments scribbled a Memorandum of Understanding (MOU). Rosatom said they would start construction by 2013.

In 2011, International Atomic Energy Agency carried out *IAEA Integrated Nuclear Infrastructure Review (INIR)* mission in Bangladesh. Then IAEA permitted a technical assistance project for the Rooppur nuclear power plant. In 2013 a group of Bangladeshi scientists and the global diaspora conveyed their grave concern over the security and financial feasibility of the plant. Several distinct issues were put on the table for discussion ranging from the impropriety of the site to the antiquity of the VVER-1000 model offered, contentious economic arrangements and a shortage of agreement with Russia over nuclear waste disposal.

In 2015 the proposal was slowed down for a year. Rosatom proposed a two VVER-1200 reactor power plant, enhancing output to 2.4 GWe. By December 2015 *The Daily Star* published a report saying that the approximate cost of the plant had shot up to US\$13 billion, from narration of near about US\$4 billion earlier in the very ear. German based Transparency International conveyed its disquiet on 28 December 2015 regarding the security of the proposed plant.

CONSTRUCTION

In 2016 ground preparation work started. The \$12.65 billion contract is 90% sponsored by a loan from the Russian government. The two units generating 2.4 GWe are planned to be operating in 2023 and 2024. Rosatom will operate the units for the first year before giving it to the Bangladeshi operators. Russia will furnish the nuclear fuel and retract paid out nuclear fuel.

On 4 November 2017, Bangladesh Atomic Energy Commission obtained, from Bangladesh Atomic Energy Regulatory Authority, the design and construction license of Unit 1, leading the way for the nuclear island first concrete pour.

The nuclear reactor and critical infrastructure are being made by Russian companies. Atomenergomash is the engineering

division of Russia's state nuclear corporation, Rosatom. This company is the dealer of all the equipment for the reactor compartment of Rooppur Nuclear Power Plant and a vital part of the equipment for the machine room. Over 70 tenders have been supplied for 'non-critical' works where Bangladeshi and Indian construction companies can take part.

On 14 July 2018, the first concrete was spouted for Unit 2. The next month, Rosatom started lodging a 200-tonne sole captor as the first colossal piece of equipment in the reactor building of Rooppur 1, depicting it as "a unique protection system".

When the COVID-19 pandemic did hit Bangladesh in early 2020, many projects such as the Dhaka Metro Rail were thwarted, but the Rooppur Nuclear Power Plant persisted on track to be finished by 2023. Advancement in this period comprises Rosatom's engineering company Atom mash finishing hydraulic tests for Rooppur unit 1.

Safety/Security:

VVER-1200/523 is one of the latest Generation III+ nuclear reactor. Design feature of the nuclear reactor is layered safety barriers preventing escape of radioactive material. The reactor has five layers:

1. Fuel pellets: Radioactive elements are retained within the crystal structure of the fuel pellets.
2. Fuel rods: The zircaloy tubes provide a further barrier resistant to heat and high pressure.
3. Reactor shell: a massive steel shell encases the whole fuel assembly hermetically.
4. Core catcher: A core catcher is a device provided to catch the molten core material (corium) of a nuclear reactor in case of a nuclear meltdown and prevent it from escaping the containment building.
5. Reactor building: A concrete containment building is the last line of defence. It prevents escape of radiation. It also protects from external damages.

The nuclear part of the plant is housed in a single building acting as containment and missile shield. Besides the reactor and steam

generators this includes an improved refuelling machine, and the computerized reactor control systems. Likewise protected in the same building are the emergency systems, including an emergency core cooling system, emergency backup diesel power supply, and backup feed water supply. A passive heat removal system had been added to the VVER-1200. The system is based on a cooling system and water tanks built on top of the containment dome. The passive systems handle all safety functions for 24 hours, and core safety for 72 hours.

Other new safety systems include aircraft crash protection, hydrogen recombiners, and a core catcher to contain the molten reactor core in the event of a severe accident. Russia's arms manufacturer Almaz-Antey to install cooling systems for Rooppur Nuclear Power Plant.

Table 1: Planned nuclear power reactors

<i>Unit</i>	<i>Type</i>	<i>Capacity (gross)</i>	<i>Construction started</i>	<i>Operation (Expected)</i>
Rooppur 1	VVER-1200/523	1200 MWe	30 November 2017	2023
Rooppur 2	VVER-1200/523	1200 MWe	14 July 2018	2024

RESEARCH

Bangladesh's development strategy discerns the country being a middle-income nation by 2021, widely highlighting on its science and technology sector to steer economic growth. The ministry of science and technology (MoST) reckoned in 2014 that US\$6.2 billion will be required in the coming decade to attain the objectives of Vision 2021. The Science and Technology Act 2010 is aiding to improve this, and MoST is now allotting over \$150 million per year to nuclear technology development as gas reserves become exhausted. The power plant will also foster the local economy of Rooppur, Pabna.

The country has had a TRIGA 3 MW research reactor operational since 1986.

Assessing the Feasibility of ‘Rooppur Nuclear Power Plant’ and how much it can really contribute to our future energy sector?

Antu Biswas (student of Department of Automation, National Research Nuclear University MEPhI, Moscow, Russia) and Md. Shivly Mahmood (student Department of Nuclear Science and Technology, Harbin Engineering University, Harbin, China), in a joint paper entitled ‘*Feasibility of “Rooppur Nuclear Power Plant” & Its Contribution to the Future Energy Sector,*’ (*World Journal of Nuclear Science and Technology* > Vol.10 No.1, January 2020) published in the ‘Scientific Research: An Academic Publisher,’ analyses all the pros and cons of the Rooppur Nuclear Power Project.

This paper duly observes that digital Bangladesh is one of the tough decisions by the Bangladesh government to change the country to be a middle-income country by 2021. That’s why the government materialized a huge number of projects pertaining to digital technology. Rooppur Nuclear Power Plant (RNPP) project is one of them.

In the current past, the country faced a massive electricity shortage with a huge energy gap between peak demand and maximum energy generation. In Bangladesh, the present government pledged to ensure the electricity to all the citizens by 2021. That’s why the world’s most profitable Nuclear advanced technology is being carried out under Power Sector Master Plan (PSMP)-2016 (Vision 2041). It is to upgrade the safety system of nuclear power, the bilateral project is not totally transparent for the public, which is comprehensible. That creates some political conflict with the anti-nuclear agenda. As a result, the general concerns are also involved in this project.

Rooppur Nuclear Power Project is one of the dream projects for Bangladesh. With the aid of this project, Bangladesh will be the 33rd country having a nuclear power profile. That can contribute 2400 MW power in the grid system to meet up the energy demand. The complex nuclear technology is being supported by the financial and technological help of ROSATOM.

In Bangladesh, Ministry of Power, Energy & Mineral Resource (MoPEMR) deals with the electricity business. Power is supplied through Power Grid Company of Bangladesh's (PGCB) power transmission facilities to customers in local cities by BPDB, in the metropolitan area by Dhaka Power Distribution Company Ltd. (DPDC) and Dhaka Electric Supply Distribution Company (DESCO), and in rural areas by Palli Biddyt Samities (PBS)..

CONTRIBUTION OF DIFFERENT POWER GENERATION SECTORS: ENERGY SCENARIO

Contributions of Public & Private Sector

In the present situation, both public and private power generation is equally important. Here is an overview by Figure 1. In Bangladesh private sectors offers around 50% of the total power generation.

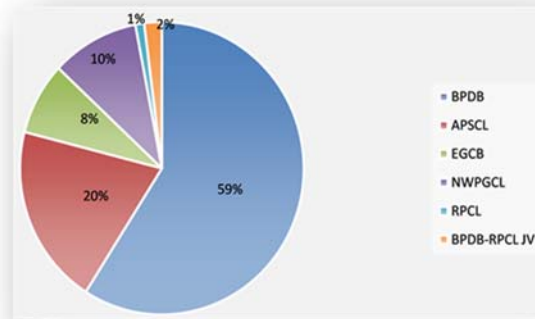


Figure 1 : Energy scenario of Bangladesh.

Among the public sectors BPDP alone provides almost 4402 MW and privates sectors IPPs provides 3245 MW. It is clear that the public sector does not generate sufficient load to meet the public demand. Approximately 3/5 years Rental plants are providing about 55% load from private sector generation which is very expensive.

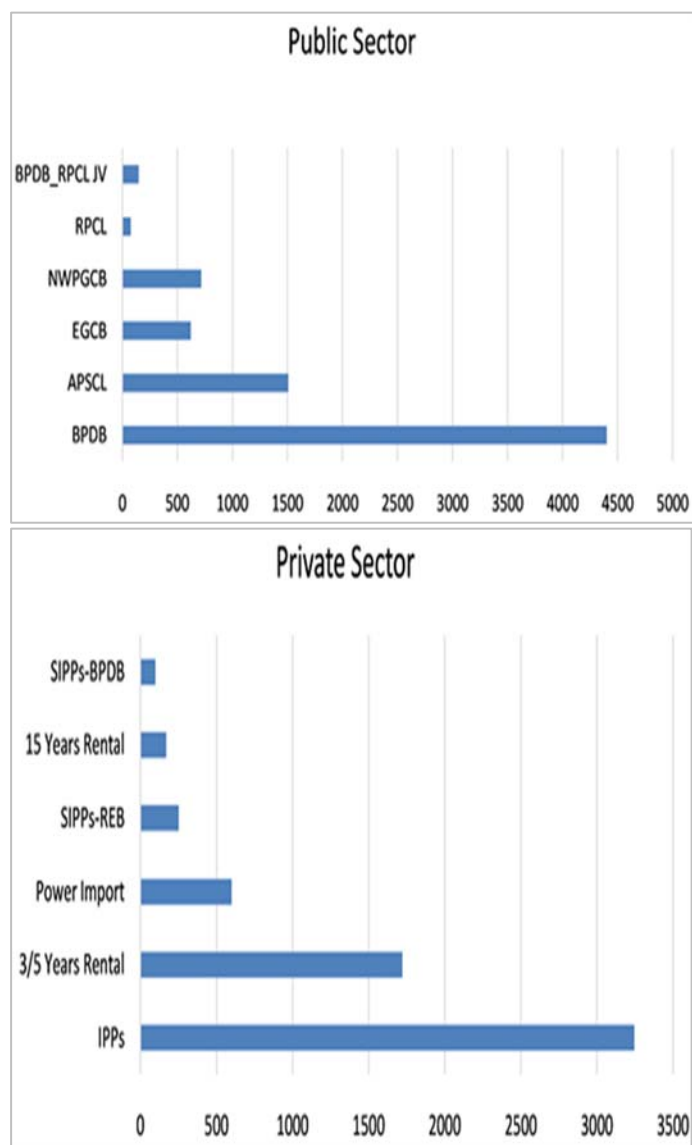


Figure 2: Public & private sector contribution in national grid.

POWER STATIONS IN BANGLADESH

Bangladesh is largely dependent on its traditional energy technology and it is led by the natural gas (62.39%). Besides, furnace oil (20.49%), diesel (7.97%), coal (2.33%), hydro (2.15%) too play a vital role in energy generation. Until the mid-1990s demand for fertilizer was the top priority. But, now-a-day's demand for the gas power generation has risen. The fastest-growing demand is from the industry, with 13% annual increase shown in the Gas. Power contributions and the National energy statistics are also ascribed succinctly in Table 2:

Table 2 : Average annual growth rate of demand of Gas in different sector

Sector	Average annual growth rate
Power	8.2%
Fertilizer	3.9%
Industry	12.6%
Domestic	12.0%
total	7.7%

Table 3: Capacity of Power Plants 1991-2007.

Fuel Type	Capacity of Running Power Plants		
Gas Turbine	Meghnaghat	450	
	Ashuganj	146	
	Haripur	360	
	Golpara	265	
	Mymensingh	210	
	Siddhirganj	240	

Gas Engines	Baraka Power Ltd.	51	
	Dhaka	7	
	Gazipur	53	
	Gopalganj	100	
	Maona	35	
	Raozan	240	
	Ghorashal Regent	108	
	Baghabari	50	
Hydroelectric	Karnafuli	230	
Plant Under Construction			
Power Stations	Capacity (MW)	Expected Operations	
Matarbari	1200	2024 [8]	
Payra Thermal	1320	1st unit in August, 2019 [10]	
Rampal	1320		
Feni Lanka Power Limited	114	September, 2019	
Manikganj Power Generations Limited	162	January, 2020	
Bhairob Power Limited	55	January, 2020	
Payra LNG Power Plant	3600	1 st phase- December, 2022 2 nd phase- December, 2023	

Table 4 : Electricity production and consumption summary. (1980-2014)

Year							Average annual growth rate (%)
Capacity of electrical plants (GWe)	1980	1990	2001	2008	2012	2014	2001 to 2014
Thermal	0.91	2.29	3.48	4.972	7.88	9.60	8.12
Hydro	0.08	0.23	0.23	0.23	0.22	0.22	-0.34
Nuclear	0	0	0	0	0	0	
Wind					0	0	
Geothermal	0	0	0	0	0	0	
Other Renewable					0	0	
Total	0.99	2.35	3.711	5.202	8.100	9.82	7.78
Electricity Production (TWh)							
Thermal	2.07	7.17	14.48	23/361	34.341	41.607	8.46
Hydro	0.58	0.88	1.08	0.949	0.776	0.588	-4.57
Nuclear	0	0	0	0	0	0	
Wind					0	0	
Geothermal	0	0	0	0	0	0	
Other Renewable					0	0	
Total	2.65	7.73	15.56	24.31	35.118	42.195	7.98
Total Electricity consumption (TWh)		4.704	14.002	22.622	30.098	40.296	8.47

Electricity production & installed capacity.

Electricity Access across the Population

Bangladesh has achieved considerable advancement in having access to electricity as its electrification coverage reached 88% in 2017. The World Bank mentioned that among the countries with the largest population without access to electricity Bangladesh, Kenya, Myanmar, and Sudan have made the most progress. World Bank, Sustainable Energy for all database shows the progress in the following Figure.

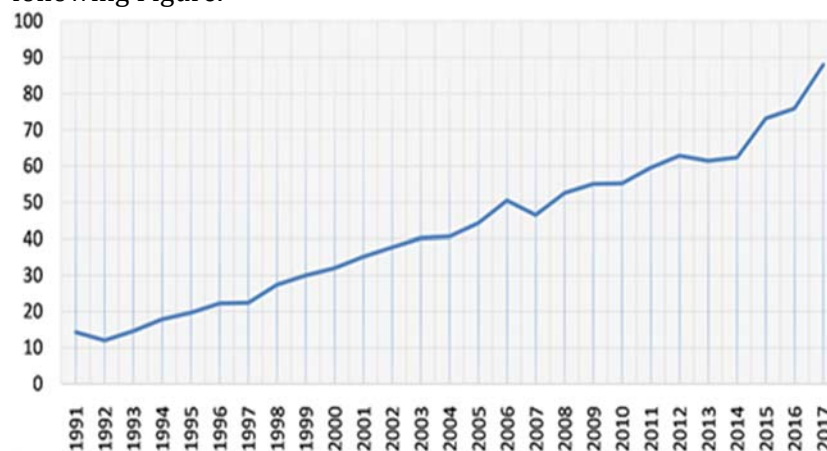


Figure 3: Electricity access across the population (%) corresponding to year.

Energy Preservation

Energy conservation is one of the most pertinent issues of the sector due to economic and environmental causes. However, until a very recent past no serious attempts were made to take up and implement energy conservation programs which have been given due importance in the National Energy Policy of Bangladesh (1996).

Specifications System Loss

System loss of more than 4% in power generation is not acceptable. It has been stated that the average system loss of power

generation by the PDB is 6.35%. The government will plan to reduce system loss to a specific limit.

Generation Lag

Even in the recent past Bangladesh had faced a huge electricity scarcity that impacted non-agricultural employment. So, there was a great energy gap between peak demand and maximum energy generation. Those gaps are said to be the generation lag. In Bangladesh, the present government promised to ensure the continued supply of electricity to all the citizens by the year 2021. According to the Power System Master Plan (PSMP) 2010, the forecasted demand for the power based on 7% GDP growth rate shows the only Nuclear Power Plant can full fill the demand of the nation, that is illustrated in [Figure 4](#) by showing the exponential increase of peak demand (MW).

Energy Import

In order to fill up the gap in between demand and generation, every year Bangladesh imports power from neighbour country which is really too expensive. The import of electricity from India and Bhutan are worth exploring. Myanmar has satisfactory gas reserves. Bangladesh could negotiate for import of gas from Myanmar.

Government Vision: Brief Story

Bangladesh has lots of well-written policies but the problem begins with the implementation processes and procedures.

Some of the policies of recent years are mentioned below :

- National Energy Policy-2004,
- Renewable Energy Policy of Bangladesh-2008,
- The Sixth Five-year plan of Bangladesh (2011-15)-2011,
- Perspective plan of Bangladesh (2010-2021) Vision 2021-2012,
- The National Sustainable Development Strategy-2013,
- Intended National Determined Contributions-2015,
- The Seventh Five Year Plan (2016-2020)-2015,

- Energy Efficiency and Conservation Master Plan up to 2030-2015,
- Power System Master Plan-2016.

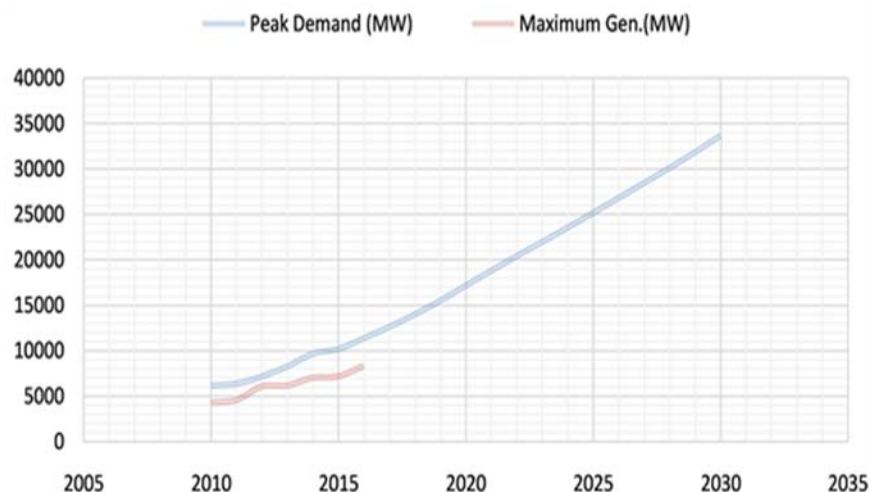


Figure 4: *Difference in between peak demand & maximum generation.*

The Power Sector Master Plan (PSMP)-2016 (Vision 2041)

The PSMP is a document that aimed to assist the Bangladesh Government in formulating an extensive energy and power development plan up to the year 2041. It highlights the country's wish to be a high-income country by 2041, so the quantity and quality of the power infrastructure must also reflect that status. The plan further mentions five major objectives of the vision 2041 :

- Augmentation of imported energy infrastructure and its flexible operation.
- Skilled Development and materialization of domestic natural resources (gas and coal).
- Building of a colossal, high-quality power network.
- Optimization of green energy and promotion of its introduction.

- Upgrading of human resources and mechanisms related to the stable supply of energy.

Energy Mix Concept

Owing to the present low situation of primary energy resources, our national demand is not being met. Against this backdrop, the Government is formulating the “Five-Fuel strategy,” of which the priorities are noted below.

- Undertake immediate exploration of hydrocarbon and identify additional reserves that can meet the growing demand of gas by all consumer sectors.
- Develop alternative commercial energy supplies suitable for power generation, especially coal, to ease the burden of fast-growing electricity demand on gas resources. Thus, a two-fuel (gas and coal) strategy is required for both resource diversification and energy security.
- Guarantee efficient use of energy by using energy-saving appliances, plants and equipment to effectively enhance the stock of available energy supplies.
- The resource potential of renewable energy is significantly larger than its present consumption and is a promising source of clean, convenient energy supply, particularly in rural areas.
- Taking into consideration the limitation of fossil fuel supplies, nuclear fuel could be a potential energy option for the country, as it is a proven technology for economic, reliable and sustainable electricity generation.
- At present, almost 88% of the country’s power is dependent on gas and almost 50% of the consumed commercial energy is used for power generation. To ensure energy security more balance is needed#

Electricity Supply Expansion Plan

In order to decrease the pressure on natural gas, oil and biofuel it is wiser to develop alternative plan so that the efficient use of different energy sources can be ensure. That’s why their Power System Master Plan-2016 suggests a projection of energy supply.

Table 5: Comparison of Bangladesh and Global projection of energy sources

Sources of Energy	Bangladesh	Global		
	Current (%)	2021 (%)	Current	2030
Gas	87.5%	30%	18%	28%
Oil	6%	3%	10%	5%
Coal	3.7%	53%	37%	38%
Hydro	2.7%	1%	17%	4%
Nuclear	0%	10%	17%	19%
Renewable	0.5%	3%	1%	6%

Table 6 : Projection of primary energy supply

Primary Energy Sources	2014	2041		Annual growth rate (2014-2041)	
	kote	(Share	kote	(Share	
Natural Gas	20,726	56	50,149	38	3.3%
Oil	6263	17	32,153	25	6.2%
Coal	1361	4	26,273	20	12.7%
Nuclear Power	-	-	11,942	9	-
Hydro, Solar, Wind Power and Others	36	0	197	0	6.5%
Biofuel and Power (Import)	8449	23	4086	3	-2.7%
Total	36,888	100	130,82	100	4.8%

Projection of primary energy supply

ROOPPUR NUCLEAR POWER PLANTS

History

Bangladesh is in the stage to become the 33rd Nuclear Power producing nation. The Rooppur Nuclear Power Plant (RNPP) is expected to generate 2400 MW of power, helping the nation to address the expanding demand for electricity. The project is done by the financial and technical support of the Russian State Energy Commission (ROSATOM). The idea of building a nuclear power plant was developed in the year 1961. Only after the chosen primary site, Pakistan government shifted the nuclear power plant project to Karachi. After independence, the government of Bangladesh again took over the project and decided to set up a nuclear power plant that has a capacity of 200 MW. Some of the key milestones of Bangladesh national Power program is given below (IEAE, 2016).

1963: Rooppur site selected for implementation of Nuclear Power Plant (NPP).

1971-78, 1987-88: Feasibility studies for site and first NPP conducted. Further feasibility studies for site and first NPP conducted.

1996: National Energy Policy identifies nuclear power as an option.

2000: BANPAP approved by the government.

2010: National Parliament approves first NPP project and new structure for NP program development (equivalent NEPIO) were formed (National Committees, Technical Committee, Working Group).

2011: IGA with Russian federation signed for the first NPP with two VVER units, each of 1000 MW.

2012: Bangladesh Atomic Energy Regulatory Act 2012 was passed in the National Parliament on 19th June 2012.

2013: Bangladesh Atomic Energy Regulatory Authority was formed as a separate entity on 12th February 2013.

2015: General contract was signed with Russian Federation for main stage construction of Rooppur NPP.

2016: Inter-Government State Credit Agreement for financing the main stage construction of Rooppur NPP.

Why Nuclear Power?

Heating Value

Bangladesh needs a stable and powerful alternative energy source to produce electricity. Alternative energy source means the type of source which is alternative to fossil fuel. Among all Nuclear Energy is the most effective and powerful. At this energy source is capable of producing enormous power ensuring the least fuel consumption. A comparison between heating values of different fuels are given below in [Table 7](#) (Sabhasachi, et al., 2018).

CO₂ Emission

Greenhouse gases (Carbon dioxide, nitrous oxide, methane) surround the Earth like a blanket. As we use to burn more coal, natural gas, and oil, the blanket becomes excessively thick, dense, and less likely to allow heat to escape. Heat gets trapped inside the blanket of greenhouse gases and the Earth becomes too warm. Nuclear power is a much better choice than conventional gas or coal-based power plant. Where Nuclear power plants emit greenhouse gases less than any other, [Figure 5](#) gives a clear idea about this statement.

Table 7 : Comparison of heating value of different fuels.

Fuel	Heating Value (MJ/kg)
Fire Wood	16
Brown Wood	9
Black Coal (Lower grade)	13 - 20
Black Coal (Higher grade)	24 - 35
Natural Gas	40
Crude Oil	45
Uranium	500,000

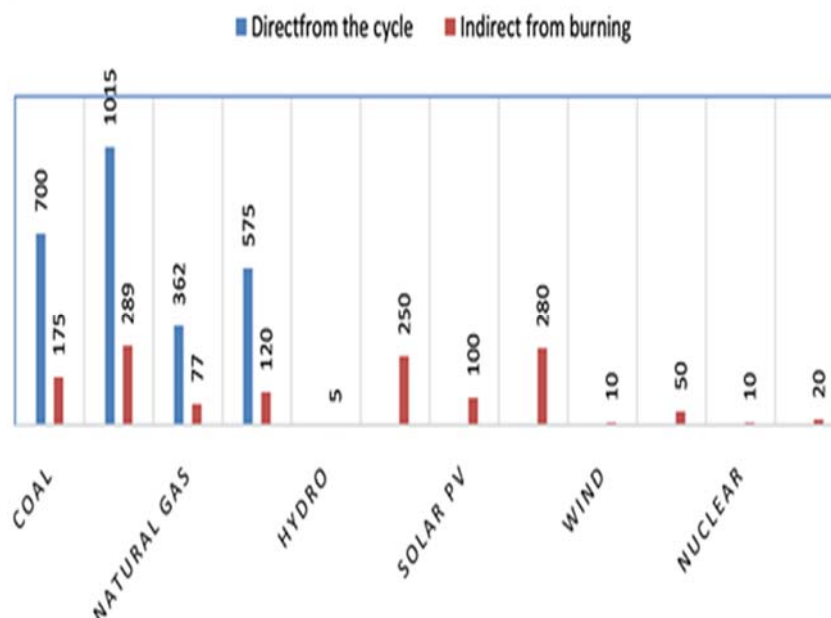


Figure 5. Greenhouse gas emission from different energy sources (Sabhasachi, et al., 2018).

The nuclear power plant is relatively a good choice when we only consider emission of CO₂ emission and heating value produced by burning the nuclear fuel. But Nuclear power plants are relatively expensive to build. Especially it takes 75% cost only for machinery, setup and capital cost. So the nuclear power plant is cheaper to run. Table 8 shows a comparison among different methods of energy generation technologies.

Nuclear Power Development Strategy

Bangladesh is evolving an energy mix diversification, where nuclear is one of the best choices. Right now the Government of Bangladesh has the plan to set up 2 units of Rooppur Nuclear Power Plant, described by the Table 8. On 2 November 2011, the Government of the Russian Federation and the Government of the People's Republic of Bangladesh signed an agreement on cooperation for the construction of an NPP on the territory of the

People's Republic of Bangladesh (Table 1). An agreement was signed on 15 January 2013 between the Government of the People's Republic of Bangladesh and the Government of the Russian Federation on the extension of a state export credit to the Government of Bangladesh for financing of the preparatory stage for construction of an NPP in the People's Republic of Bangladesh. The credit shall be used by Bangladesh during 2013-2016 [2]. Bangladesh Atomic Energy Commission (BAEC) has been appointed as the owner organization of NPP by:

- The prudential order 15, 1973,
- Bangladesh Nuclear Power Action Plan, 2000,
- Inter-Government Agreement (IGA) between Russian Federation and Bangladesh, 2011,
- Nuclear Power Plant Act, 2015 and

.

Table 8 : Comparison among different methods of energy source

Technology	Time (Unit)	Time (lead)	Cost (Capital)	Cost (Operational)	Fuel Necessity	Sustain ability
CCGT	Medium	Short	Low	Low	High	NO
Nuclear	Huge	Long	High	Low	Low	OK
Coal	Large	Long	High	Low	Medium	NO
Hydro	Huge	Long	Very High	Very Low	N/A	OK
Wind	Small	Short	High	Medium	N/A	OK

Nuclear Power Company of Bangladesh Limited (NPCBL) is the operating organization which clearly reflects in NPP Act 2015.

VVER-1200 (Generation III+ Design) & Safety

The VVER is a pressurized water reactor (PWR), the commonest type of nuclear reactor worldwide, employing light water as coolant and moderator. However, there are some significant differences between the VVER and other PWR types, both in terms of design and materials used. Distinguishing features of the VVER include the following :

- Use of horizontal steam generators,
- Use of hexagonal fuel assemblies,
- Avoidance of bottom penetrations in the VVER, Vessel,
- Use of high-capacity pressurizers.

VVER Generations

VVER is one of the oldest type reactor technology used in nuclear technology by Russia. Beginning from 1964 (Gen I), VVER now is in nuclear market with its new technology which is called generation III+ VVER-1200 with lots of improvement.

VVER-1200

Main principles of VVER-1200 (AES-2006) design are :

- Optimum use of proven technologies,
- Lowest cost and construction times,
- Balanced combination of active and passive safety system in general to manage beyond basis accidents,
- Reduction in the influence of human factors on overall safety.

Table 9. VVER generations (Biswas and Mahmood, 2020 Citing The VVER Today: Evolution, Design, Safety, ROSATOM)

Gen I (1964 -1966) VVER	Gen II (1966- 1980) VVER-440	Gen II/Gen III (1980-2006) VVER-1000	Gen III+ (2006-) VVER-1200
V-210 Russia, Novovoronezh 1	V-179 Russia, Novovoronezh 3- 4	V-187 Russia: Novovoronezh 5	V-392M Russia, Novovoronezh II 1-2
V-365 Russia, Novovoronezh 1	V-230 Russia, Kola 1-2 East Germany, Greifswald 1-4 Bulgaria, Kozloduy 1-4 Slovakia, Bohunice 1-2 V-213 Russia, Kola 3-4 Ukraine, Rovno 1- 2 Hungary, Paks 1-4 Czech Rep., Dukovany 1-4 Finland, Loviisa 1-2 Slovakia, Bohunice II 1-2 Mochovce 1-2 Mochovce 3-4	V-302 Ukraine, South Ukraine 1 V-338 Ukraine, South Ukraine 2 Russia, Kalinin 1-2 V-320 Russia, Balakovo 1-4, Kalinin 3-4, Rostov 1-2, Rostov 3-4 Ukraine, Rovno 3-4, Zaporozhe 1-6, Khmelnitski 1-2, South Ukraine 3 Bulgaria, Kozloduy 5-6 Czech Rep, Temelin 1-2	V-491 Russia, Baltic 1-2 Leningrad II 1-2 Belarus, Belarus 1
	V-270 Armenia, Armenia-1 Armenia-2	V-428 China, Tianwan 1-2, Tianwan 3-4 V-412 India: Kudankulam 1, Kudankulam 2 V-466 Iran: Bushehr 1	

Fundamental Safety Functions

- 1) Control of Reactivity
 - Resisting unchecked reactor power increase.
 - Ensuring fast safe shutdown of the reactor when required.
- 2) Decay Heat Removal
 - Cooling of the shutdown reactor.
 - Cooling of used nuclear fuel.
- 3) Containment of Radioactive Material
 - Preventing significant radioactive releases to the environment.

Electric Grid Development

PGCB manages the gridline of Bangladesh, where different power generation company contributes their power either in 230 kV or 132 kV line. At present 10,000 MW is the maximum load that can be handled by the grid line. According to the plan, a 400 kV line is going to be hooked up in order to import power from India. At present, the dependable generation capacity of the country will be about 12,000 MW against a maximum demand of about 11,000 MW in 2017. But the contribution of nuclear power will be about 2000 MW by the year 2020 and will be increased by about 5000 MW in 2030. So the erected capacity is projected to increase about 33,000 MW by 2030. So, PGCB needs to upgrade the national grid.

Public Concern: Fuel Cycle & Waste Management

Bangladesh believes that a healthy market exists at the front end of the fuel cycle. Currently, all reprocessing plants are state-owned and any guarantee from a supplier would have the implicit or explicit agreement with the corresponding government. Based upon the prevailing nature of the nuclear business worldwide, Bangladesh is considering a long-term contract and transparent suppliers' arrangements with supplier(s) through backing of the respective government in order to ensure the availability of fuel for the nuclear power reactor of the country at present, there is no international market for spent fuel disposal services.

Earthquakes

The number of earthquakes (magnitude between 4 and 6) happened in the last decade inside the country or near the borders. That has raised awareness among the general public and the government. But the good news is these earthquakes are located far away from the Rooppur site.

Security of the Nuclear Materials

Nuclear materials will be strictly supervised by the government of Bangladesh. However, there remains a certain concern due to the increasing terrorist or extremist activities in the region. However, the government of Bangladesh has not made any clear statements on the issues of non-proliferation policy and measures from the part of the government.

Scarcity of U Resources

The world has around 5.47 million tU of uranium resources, costing approximately US\$130/kgU to produce. Among them, just 30% are in Australia, about 14% in Kazakhstan, followed by 16% in Russia and Canada, and in South Africa, China, Niger, Brazil all of them have 5% in Uranium resources. By comparison, Bangladesh's share is only 0.25%.

Cost of Electricity

It shows that the purchase, operation, and maintenance of plants at the generation stage, will lead to increased spending on the generation and consequent higher cost of power supply. Ultimately, the price per unit of electricity needs enhancement. Strong Energy Regulatory Commission will have to address these issues.

Water Supply

The Rooppur NPP site was chosen even before the creation of Bangladesh. At that time the Padma (Ganga) river was selected for the water supply source of the power plant. But when in 1975 India completed the Farakka barrage, it affected Bangladesh's water

supply, including the river level in the area of the Rooppur NPP. Water supply is a really serious technological challenge for the Rooppur NPP, that likely to be resolved via a protected water-catchment area in the Padma River.

Cyber Threats

The digital security system of Bangladesh is not safe enough. On 1st February 2017 a seminar was organized named “Entering the world of Nuclear Energy” about the cyber-security where Dr. Petr Topychkanov stated ‘Digital security must be guaranteed. Generally, there may be a tremendous hazard. In the event, there is no activity taken and it ought to be taken as right on time as possible.’

Table 10: Five Worst Nuclear Disasters in History:

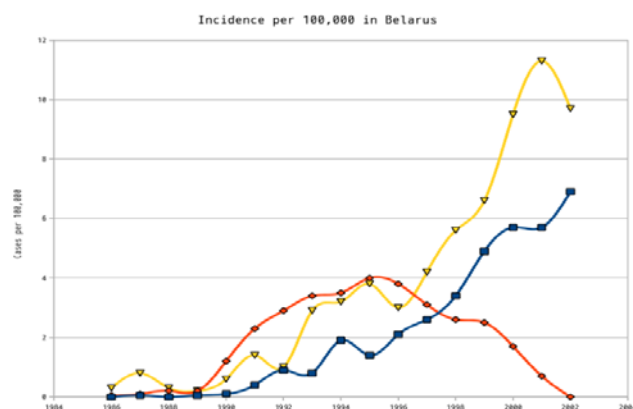
Name of the Nuclear Disaster	Place and Date of the Nuclear Disaster	Fatalities Involved
<i>Three Mile Island Nuclear Accident.</i>	Pennsylvania, USA 1979 (INES Level 5)	The Three Mile Island Unit 2 (TMI-2) reactor, near Middletown, Pennsylvania, suffered a partial melt down on March 28, 1979. The most serious accident in U.S. nuclear power plant history was caused by a relief valve failure, after an unplanned shutdown, causing severe damage to the core. Better instrumentation, training programs and public information would have vastly improved matters but luckily there were no injuries or discernible health impacts.

<i>Windscale Fire Nuclear Disaster</i>	Sellafield, UK 1957 (INES Level 5)	On 10 October 1957 a raging inferno swept through the core of Unit 1 nuclear reactor at Windscale, Cumberland (now Sellafield, Cumbria) for three days. The Level 5 accident dumped radioactive contamination across Europe and it is thought that traces of isotope iodine-131 may have caused several hundred cancer diagnoses. Windscale's two piles had been hastily built during the British atomic bomb project. It was the UK's worst ever nuclear accident.
<i>Kyshtym Nuclear Disaster</i>	Russia 1957 (INES Level 6)	The third most serious nuclear accident in history happened at the secretive Mayak plant, near the Russian town of Kyshtym – part of the Soviet Union's attempt to match the US for weapons-grade plutonium production. After a faulty cooling system was left to disrepair, rising temperatures resulted in an explosion with the equivalent force of 70-100 tons of TNT. Nuclear fallout reached more than 300 kilometres away and, due to the classified nature of the plant, it was only a week later that 10,000 locals were evacuated from the area.
<i>Fukushima Nuclear Disaster</i>	Japan 2011 (INES Level 7)	On Friday 11 March 2011 the Great East Japan Earthquake, which measured 9.0 on the Richter scale, caused a 15-metre tsunami that disabled the power supply and prompted three reactor meltdowns at the Fukushima Daiichi plant. Official figures suggest that more than 1,000 deaths occurred as a result of an evacuation process that displaced more than 100,000 people. Subsequent investigations have suggested that the infrastructure and risk forecasting were inadequate for such a devastating

		natural disaster. It was only the second accident in history to receive the most severe Level 7 rating.
Chernobyl Nuclear Disaster	Ukraine 1986 (INES Level 7)	The Chernobyl Nuclear disaster is widely considered to have been the worst power plant accident in history, and is one of only two classified as a level 7 event on the International Nuclear Event Scale (the other being the Fukushima, Daiichi disaster in 2011). The battle to contain the contamination and avert a greater catastrophe ultimately involved over 500,000 workers and cost an estimated 18 billion rubles. The official Soviet casualty count of 31 deaths has been disputed and long-term effects such as cancers and deformities are still being accounted for. Abortions as consequence of radio activity: Worldwide, an estimated excess of about 150,000 elective abortions may have been performed on otherwise healthy pregnancies out of fears of radiation from Chernobyl, according to Robert Baker and ultimately a 1987 article published by Linda E. Ketchum in the <i>Journal of Nuclear Medicine</i> which mentions but does not reference an IAEA source on the matter. The available statistical data excludes the Soviet-Ukraine-Belarus abortion rates, as they are presently unavailable. Cancer assessments A report by the International Atomic Energy Agency examines the environmental consequences of the accident. The <i>United Nations Scientific Committee on the Effects of Atomic</i>

		<i>Radiation</i> has estimated a global collective dose of radiation exposure from the accident "equivalent on average to 21 additional days of world exposure to natural background radiation"; individual doses were far higher than the global mean among those most exposed, including 530,000 primarily male recovery workers (the Chernobyl liquidators) who averaged an effective dose equivalent to an extra 50 years of typical natural background radiation exposure each. The Chernobyl Forum predicts that the eventual death toll could reach 4,000 among those exposed to the highest levels of radiation (200,000 emergency workers, 116,000 evacuees and 270,000 residents of the most contaminated areas); this figure is a total causal death toll prediction, combining the deaths of approximately 50 emergency workers who died soon after the accident from acute radiation syndrome, 15 children who have died of thyroid cancer and a future predicted total of 3,935 deaths from radiation-induced cancer and leukaemia. In a peer-reviewed paper in the <i>International Journal of Cancer</i> in 2006, the authors expanded the discussion on those exposed to all of Europe (but following a different conclusion methodology to the Chernobyl Forum study, which arrived at the total predicted death toll of 4,000 after cancer survival rates were factored in) they stated, without entering into a discussion on deaths, that in terms of total excess cancers attributed to the accident:

		The risk projections suggest that by now [2006] Chernobyl may have caused about 1000 cases of thyroid cancer and 4000 cases of other cancers in Europe, representing about 0.01% of all incident cancers since the accident. Models predict that by 2065 about 16,000 cases of thyroid cancer and 25,000 cases of other cancers may be expected due to radiation from the accident, whereas several hundred million cancer cases are expected from other causes. Two anti-nuclear advocacy groups have publicized non-peer-reviewed estimates that include mortality estimates for those who were exposed to even smaller amounts of radiation. The Union of Concerned Scientists (UCS) calculated that, among the hundreds of millions of people exposed worldwide, there will be an eventual 50,000 excess cancer cases, resulting in 25,000 excess cancer deaths, excluding thyroid cancer. However, these calculations are based on a simple linear no-threshold model multiplication and the misapplication of the collective dose, which the International Commission on Radiological Protection (ICRP) states "should not be done" as using the collective dose is "inappropriate to use in risk projections". Along similar lines to the UCS approach, the 2006 TORCH report, commissioned by the European Greens political party, likewise simplistically calculates an eventual 30,000 to 60,000 excess cancer deaths in total, around the globe.



Adults, ages 19 to 34 ; Adolescents, ages 15 to 18 ; Children, ages up to 14
 Figure 6: [Thyroid cancer](#) incidence in children and adolescents in Belarus

Rooppur Nuclear Power Plant: How much safe and viable it is?

On July 2013, around 25 scientists, engineers, doctors, surgeons, political economists, social scientists, academics, activists, authors and intellectuals of Bangladeshi origin living overseas and several conscious foreign nationals like Dr. Peter Custer and Mr. Satish Kapoor and other dignitaries voiced their concerns over the safety and viability in the Rooppur Nuclear Power Plant in a post-editorial in the 'BD News Opinion.'

This article was entitled 'Rooppur Nuclear Power Plant: Unsafe, not viable!' The main concerns raised by them in the article are summarized below:

1. The site at Rooppur, by the river Padma, was selected more than 50 years ago for a 10MWe prototype nuclear power plant on utterly political grounds by the then Pakistani Junta (in 1961). No site selection procedure or environmental impact assessment was carried at all, but the present government wishes to construct not just one but two 1000 MWe units on the same site. The river Padma is now heavily clogged over the course of time and also partly due to the Farakka barrage. The rest amount of water is deplorably insufficient to fulfil the plant cooling need for even one 1000MWe plant! This would enhance the risk of nuclear accident

as in Fukushima (loss of coolant accident) to an unsupportable extent!

2. The Bangladesh government seems to have been too much satisfied at the Russian proposal to construct a nuclear power plant and furnish the loans for it. No consideration has been given to the appropriateness of the offered plant its safety standards.

3. Bangladesh has no technical specialisation or expert and skilled manpower to take the onus of such a complex and high-tech project. Moreover, the country has no industrial infrastructure, and the transport system is still at its elementary stage. Most of the materials to be used in the plant such as the quality assured high grade stainless steel, pipes, valves, pumps and other components will need to be imported and the cost will simply be skyrocketing for a country like us.

4. Bangladesh has no institutional and regulatory framework to accept a complex project like this and as a result the safety standards will be really jeopardized. The Minister in Charge asserted that Russia has ensured Bangladesh of the safety of the plant; whereas the Russian state owned company, Rosatom (reactor vendor) has justly affirmed that the duty of endorsing safety lies with the licensee (Bangladesh government). The Bangladesh authorities seem to be unconscious of the legal effects of the licensing regime.

5. It appears that no consideration has been provided to technical issues relevant to the storage, transportation and disposal of radioactive material and radioactive waste. The government demands radioactive waste materials will go to Russia but Russia has mentioned that no such agreement has yet been confirmed.

CONCLUSION

So whatever we may do or our government may decide, all the concerns of public security, technological details, environmental-ecological-social and economic impacts should be taken into consideration.

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BANGLADESH IS NOT OVER CAPACITY IN POWER GENERATION

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Abstract

*The big difference between total installed capacity of power generation and peak load gives a feeling that the power generation sector is over capacity. This is surprising to many that despite higher power generation capacity, load shading is a common feature in many places of Bangladesh. This paper shows that the power plants in Bangladesh operate at the lower range of **capacity factor** due to inherent weakness of the power generation system. In fact, at the present **utilization factor**, the system is under capacity. Procurement and installation of energy efficient plants and uninterrupted fuel supply can substantially reduce the difference.*

Key Words : Capacity factor, Utilization factor, Peak load, Reserve capacity

INTRODUCTION

It is a general conception that the generation sector is over capacity as there is a big difference between peak load and the total installed capacity. The difference is nearly 8,000 MW which apparently seems to be surplus but actually we cannot consider it as surplus or reserve capacity because the major portion of this capacity is used to offset the weakness of the system. For example, a daily report dated 18.10.2020 recorded a power loss of capacity 4,500 MW due to fuel limitation and shut down maintenance. This article will analyse a daily report and try to assess where our generation system stands in terms of capacity utilisation. The evaluation result

of a daily report chosen at random will be representative to that of yearly performance.

EVALUATION OF GENERATION DATA

The daily generation report lists the name of the plants, the fuel type and their installed capacity or the 'nameplate' capacity. The next column shows the present capacity i.e. de-rated (reduced) capacity which is the actual maximum capacity (obtained from performance test). Then a column shows the day's peak load and the following column the evening peak load.

It is a fact that a plant or a group of plants cannot operate at 100% capacity all the time. As a result in a grid system the peak load demand is always less than the total installed capacity due to cumulative effect of de-rating of plant capacity, shortage of fuel, plant shut down for maintenance and poor performance of aged plants. In generation industry there is a term called **capacity factor** to account for this difference. The ratio of the actual energy generated over a period to the ideal generation at installed capacity for that period is called the **capacity factor** which reflects the utilisation ability of the generation system. Capacity Factor of 50 to 60% is considered as an acceptable range for utility scale electricity generation. The following computations of capacity factors are made based on the daily generation data for 18.10.2020 in the report on PGCB web site.

Capacity Factor of Total Power Generation

Total installed capacity = 20,383 MW

Actual total generation of the day = 257.283 MKWh

Ideal generation at rated capacity for the day (24 hrs) =
 $20,383 \times 24 = 489.192 \text{ MKWh}$

The Capacity Factor = $257.283 \text{ MKWh} / 489.192 \text{ MKWh} = 53\%$

It is evident that the Capacity Factor of our generation system is at the lower side of the acceptable range. The present total capacity is just adequate to meet the load demand and cannot be said it is over capacity. How can it be so when 22% capacity is lost

on a day due to outage and another 15% due to de-rating! The grid is under pressure and has to go for load shed at different places. Transformers get overloaded and few transformers got burnt in the year 2020 in grid substations.

Capacity Factor of gas power plants

The total installation capacity of gas base plants = 10,979 MW

Generation at rated capacity for the day = $10,979 \times 1000 \times 24 = 263.496$ MKWh

Actual generation for the day = 139.3003 MKWh.

Capacity Factor = $139.3003 / 263.496 = 53\%$

Capacity Factor of coal-based plants

The total capacity of coal based plants = 1,146 MW

Generation at the rated capacity for the day = $1146 \times 1000 \times 24 = 27.504$ MKWh

Actual generation for the day = 13.903 MKWh

Capacity Factor = $13.903 / 27.504 = 50\%$

Capacity Factor of solar plants

The total capacity of grid connected solar plants = 38 MW

Generation at rated capacity for the day = $38 \times 1000 \times 24 = 912$ MKWh

Actual generation of the day = 0.184 MKWh

Capacity Factor = $0.184 / 912 = 0.0002 = 0.02\%$

The Capacity Factor is unbelievably too low. The Capacity Factor of PV solar sector in Germany is 10% which is even lower than that in some other countries.

Capacity Factor of oil-based power plants

The total capacity oil-based power plants = 6,716 MW

Ideal generation at rated capacity = $6,716 \times 24 \times 1000 = 161.184$ MKWh

Actual generation of the day = 76.04 MKWh

Capacity Factor = $76.04 / 161.184 = 47\%$

Capacity Factor of hydro plant

Installed capacity = 230 MW

Actual generation of the day = 2.819 MKWh

Ideal generation at rated capacity = $230 \times 1000 \times 24 = 5.52$ MKWh

Capacity Factor = $2.819 / 5.52 = 69\%$

GENERATION FORECAST AND REALITY

The daily report shows maximum generation forecast of 14,726 MW for the next day. Power generation of such a figure had never occurred in the past and will not be achieved by this generation fleet for technical limitation. There is a term called **utilisation Factor** which is the ratio of peak demand and rated capacity. The **utilisation factor** of our generation system is (peak demand 12,512 MW / rated capacity 20,383 MW) 62% and good it falls in the acceptable range of 60 to 65%. With the existing utilisation factor the total rated capacity of $(14,726 \text{ MW} / 0.62)$ 23,750 MW would be required for generation of 14,726 MW. It means that there is a deficit of $(23,750 - 20,383)$ 3,367 MW in the rated capacity. Therefore, we cannot say the present generation system is over capacity. In reality it is under capacity. As a demand to the extent of over 14,000 MW is recognised on the consumer side in the system, but that could be fulfilled if the installed capacity were enhanced by another 3,500 MW.

IMPACT OF GRID SOLAR POWER STATIONS ON THE SYSTEM

Grid solar power sector is showing a very poor performance. The main reason is that many of the plants were not supplying for some reason or other. The contribution of the solar power was found minimal on the day, only 0.184 MKWh as against 912 MKWh. The capacity factor is only 0.02% whereas the solar capacity factor in Germany is 10%. The grid solar sector is still in primary stage, and it is a high time to audit the performance to detect the inherent weakness of the sector and solve them before going for further expansion.

The solar plants are listed along with other plants of different fuel mixes in the daily generation report. There is a mismatch in the list. Because pv solar plants are part time power plants as they run for four hours per day, whereas all other plants run for twenty-four hours. This unused solar capacity will remain as a dead load on total installed capacity of the system. It will reduce the capacity factor of the overall system.

CONCLUSIONS

There will always be a difference between installed capacity and the peak load demand. The problem is to keep it in limit. The procurement of energy efficient plants and uninterrupted supply of fuel to the plants will substantially reduce this difference and then the controversy will go away.

**TOWARDS ENVIRONMENTAL SUSTAINABILITY: A
SPECIAL APPROACH FOR INTEGRATION OF RENEWABLE
ENERGY SOURCES INTO THE POWER GENERATION
SYSTEM OF BANGLADESH**

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Abstract

Bangladesh relies on non-renewable energy sources and is continuously increasing unplanned urbanization with its population growth, and uncontrolled development of diverse industries. Moreover, both the global and regional climate change including unabated use of toxic and harmful chemicals in agriculture and deforestation are making alarming impacts on the environment. These conditions push Bangladesh in the vulnerable zone for natural disasters and contribute to adverse impacts on human health, water resources, biodiversity, ecosystem, green economy, and the quality of life in general. The balancing of the demand–supply equation of primary fuel has been a massive challenge for power generation and power system of Bangladesh that should be revisited in order to minimize significant dependence on non-renewable energy sources. An innovative approach of restructuring the energy sectors with a special emphasis on integration of renewable energy sources should be investigated. There is an overwhelming consensus that the renewable energy sources can play an important role towards reducing dependency on fossil fuel; however, challenges of efficient implementation of renewable technologies in Bangladesh are

enormous, especially, the issues related to intermittency of both wind and solar energy sources. At the same time, even gradual transition to renewable sources of energy would cost enormous financial commitment. Despite the challenges, there are some encouraging trends of progress in utilizing the solar energy, especially in rural communities of Bangladesh.

This paper focuses on approaches that could be cost-effective with a significant contribution towards the integration of renewable energy into the power system. The approaches will also ensure stability, reliability, protection and control of transmission and distribution of power.

Keywords: Sustainable environment, Climate change, Carbon emission, Fossil fuel, Renewable energy, Natural disaster, Optimum Decision.

INTRODUCTION

The outcome of the 26th United Nations Climate Change Conference (COP26), held in Glasgow, Scotland, in November/December 2021, was characterized as “cautiously optimistic”. On one hand, the people of developing countries are enjoying some impressive progress, such as in empowering women, improving access to education, expanding access to technology and reducing infant mortality, and Bangladesh is playing an impressive role in that front; on the other hand, the most important question needing to be answered is whether the world is capable of making this remarkable progress a sustainable one. Numerous studies suggest that if the planet is to avoid the most catastrophic impacts of climate change, there might need to be an even bigger development priority which is directly related to environmental sustainability. Environmental Sustainability can be defined as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our

actions diminishing biological diversity [10]. It is, therefore, obvious that Environmental sustainability must find a balance with economic and social sustainability. An effective approach towards Environmental Sustainability should be the one that takes care of ecosystem, social and economic activities that are every day's needs of human being. It is our firm conviction that approaching the destination for a complete transition to renewable energy sources should be the path to prosperity not only for the people of Bangladesh but for whole humanity.

Bangladesh is considered one of the fastest growing economies in the world and the World Bank has recognized that it has an impressive track record of growth. Bangladesh also has a higher population growth rate close to 1% per year. Therefore, it is an undoubted fact that with the given power demands, Bangladesh is still in need of non-renewable energy sources. But transition to renewable energy sources by replacing the conventional ones is an urgent task for the policy and decision makers of Bangladesh. It must be underscored that the benefits of implementation of a transition goal towards environmental sustainability outweighs the cost of doing so by avoiding irreparable damages to the environment.

The goal of this paper is to share our exploration for the optimal approaches of integration of renewable energy into the power generation system of Bangladesh in order to avoid the damaging consequences of carbon emission. These approaches will also ensure stability, reliability, protection and control of transmission and distribution of power.

The rest of the paper is organized as follows: In Section 2, we paid attention on the emission of Carbon dioxide (CO₂), consumption of conventional fuel and its correlation with the economic development of Bangladesh. A brief overview of the present scenario of renewable energy prospect in Bangladesh was also presented with analysis.

In section 3, we have shared a mathematical model that we used in our earlier paper [7] based on Lotka–Volterra prey–predator system [7]. Here we have demonstrated the knowhow of Pontryagin Minimum Principle that can be an amazing tool to

determine Optimal Control (Decision) policy. We took advantage of this Principle to show how one can minimize energy generation from coal and diesel (liquid fuel) while meeting the targeted energy demand as closely as possible through gradual replacement of them by solar and wind energy sources.

For grid reliability and adequate control of integration of renewable energy into the power system, a specific example was illustrated in Section 4. In Section 5, we focused on implementation part of integration of renewable energy sources into power generation system from practical point of view and some of the examples are explained in details. Work on the effective Battery Energy Storage System (BESS) was also discussed. A special attention was given to exploring the ways of a robust and effective integration of renewable power and BESS to the grid. We end the paper with concluding remarks. Due to specific size limit requirements of the paper for this conference, we have limited our illustrations only with some examples and their explanations without demonstrating computational portions.

SECTION 2

Option of Renewable Energy for Bangladesh to Mitigate the Carbon Dioxide Gas Emission

Carbon dioxide (CO₂) emissions are the primary driver of global climate change. It is widely recognized that to avoid the worst impacts of climate change, the world needs to urgently reduce carbon emissions. But how this responsibility is shared between regions, countries, and individuals has been an endless point of contention in international discussions [4].

The significant concerns were 2021 global energy-related CO₂ emissions that are projected to rebound and grow by 4.8% as demand for coal, oil and gas rebounds with the global economic growth. The increase of over 1500 Mt (Metric ton) CO₂ which is 33 Gt (Gigatons) for 2021 that would be the largest single increase since the carbon-intensive economic recovery from the global

financial crisis more than a decade ago, it leaves global emissions in 2021 around 400 Mt CO₂, or 1.2%, below the 2019 peak [4].

Despite some progress, COP26 left some key issues unresolved. Countries, including Bangladesh, vulnerable to warming effects have higher adaptation costs compared to developed countries. CO₂ and Green House Gas emissions from fossil fuels and coal industry considerably record high in Bangladesh. In 2020, CO₂ emissions per capita for Bangladesh was 0.64 tons CO₂ emissions per capita of Bangladesh increased from 0.05 tons of CO₂ per capita in 1971 to 0.64 tons of CO₂ per capita in 2020 growing at an average annual rate of 5.48% [4].

The Government of Bangladesh announced, in its new policy “Vision 2041”, an important target of becoming one of the developed nations by 2041. Consequently, for the power and energy sector which receives quite dominant development budget, it has become newly necessary to secure the consistency between the economic development strategy of the country toward joining the developed countries and the master plan of the power and energy sector (PSMP) [4].

Environmental value of CO₂ emissions has been examined by adopting the vision 2041. CO₂ emissions in different scenarios are shown in the Fig. 1 below. CO₂ emissions in 2041 are the highest (0.55 CO₂ kg-C/kWh) in Scenario P1, with a high share of coal in the energy mix, and the lowest (CO₂ kg-C/kWh) in Scenario P5, with a low share of coal in the energy mix [4].

The distribution of emissions has changed significantly over time and rising CO₂ emissions have clear negative environmental consequences [4].

The Fossil-fuel and Gas based conventional energy production systems in Bangladesh have serious implications for the environment [4].

As Bangladesh increases the grid-connected renewable generation capacity, it is important that the leadership of the Power Sector of the country emphasizes on the network and operation capacity while continue to adjust with technical rules and regulations for grid-connected renewable energy generation. It is our hope that Bangladesh Sustainable and Renewable Energy

Development Authority (SREDA) can establish a robust, efficient, and reliable integrated grid system that can ensure the uninterrupted renewable power supply to the grid from renewable power sources.

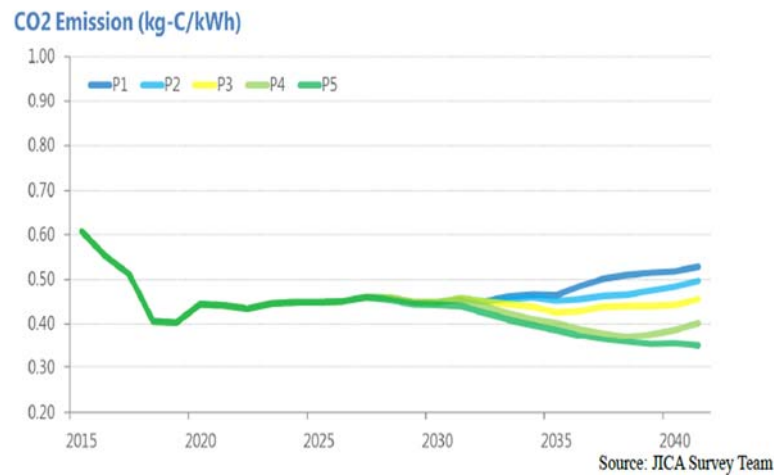


Figure 1: Scenario-wise CO2 Emission

Renewable energy power generation by 2021 and projected renewable energy in 2041 data are:

1. Domestic renewable energy power generation (cumulative): 2,470MW (by 2021), and 3,864MW (by 2041) [6]
2. Domestic biogas production: 790,000m³/day (including additional 600,000m³/day by 2031, 3 million m³/day by 2041) [6]

In Bangladesh, renewable energy deployment has been heavily concentrated on microscale off-grid solar home system (SHS). However, Bangladesh is planning to deploy utility scale (mega) solar power and wind power, accompanied with promotion policy and regulations. It's important to take an account that Bangladesh has also regulations on land usage for utility-scale solar PV (Photovoltaic). The government stipulates the policy prohibiting

private projects from using agriculture or cultivable land for a utility-scale solar PV project [4].

There is an enormous potential of harnessing waste to energy (energy from the waste) for power generation and for heating system given the large population of Bangladesh. This potential can be used as a win-win approach that allows resolving the problem of waste management and its utilization for power and heat generation [4].

SECTION 3

A Theoretical Approach to Optimum Decision (Strategy) Policy for Integration of Renewable Energy Sources into Power Generation System of Bangladesh

“Rapid emission reductions” over the coming decade to avoid dangerous levels of global warming was the single most important call of the 26th UN Climate Change conference COP26. To avoid unprecedented climate catastrophe that the planet earth is facing right now, one of the measures we must take is to limit our consumption of fossil fuels without delay. In this regard, one of the important steps would be to implement the policy for integration of renewable energy into power generation systems of Bangladesh by replacing polluting (or high carbon emitting) energy sources. The challenges of efficient implementation of renewable technologies are enormous, especially, the issues related to intermittency for both wind and solar energies (Macdonald, 2009). At the same time, any transition would need a tremendous financial commitment. But there is little doubt that the cost of implementation of transition goal is insignificant compared to the damaging environmental cost. Therefore, finding an optimal solution, that takes care of above-mentioned constraints remains appropriate for various reasons (Grafton and Silva-Echenique, 1997; Meadows and Meadows, 1973). This can be achieved by developing an optimal policy based on Modern Systems and Optimal Control Theory (Ahmed, 1988, Costello 2007, Pontryagin et al 1965) [7], [12]

In “Optimum Policy for Integration of Renewable Energy Sources into the Power Generation System” [8], the authors

proposed to use as a dynamic model of power generation involving only two sources such as Renewable and Conventional sources. Here we are offering the same dynamic model representing the temporal evolution of the levels of power generation (installed capacity) from two competing types but for four different specific sources, namely, Coal, Diesel (Conventional sources, and Solar and Wind energy (renewable sources). We propose to use the official data from Bangladesh Power Development Board to validate the model and then develop optimal generation policy based on the Pontryagin minimum principle (Ahmed, 1988). The Lotka-Volterra system of nonlinear differential equations (Ahmed, 1988, p24) can be used for modeling cooperative as well as competing agents. A brief description of the problem with its dynamic model is given at the next subsection. To find an optimum decision-making policy for our illustration, a system of 4 first-order nonlinear differential equations can be considered. The percentage penetration rates of renewable and non-renewable sources are considered as control or decision variables. We introduce an objective functional based on energy demand, production of pollution associated with usage of fossil fuels, and the cost of their systematic substitution by renewable sources. Pontryagin minimum principle is used to determine optimal control policy through minimizing energy generation from fossil fuels while meeting the energy demand as closely as possible through gradual replacement of non-renewable sources by renewable ones. For different choices of plan periods, optimal generation path along with the corresponding control policies can be presented [8].

A brief description of the problem and dynamic model of the system

Lotka-Volterra model is an effective model that describes the dynamics of competing (or/cooperating) in any given habitat. Our 4 first-order nonlinear differential equations can be introduced as follows:

$$\dot{x}_i = u_i x_i - \sum_{j=1, j \neq i}^4 \beta_{ij} x_i x_j \quad (1)$$

Where x_i , $i = 1 \dots 4$ denotes the level of power generated by the i th

source at any given time. In particular, $x_1(t)$ is the level of electric power generated from Coal at time t , $x_2(t)$ is the level of electricity generated from Diesel, $x_3(t)$ is the level of electricity generated by solar source and $x_4(t)$ is the level of electricity generated from wind [8].

The vector $x(t) = (x_1(t), x_4(t))'$, $t \geq 0$ denotes the state (level) of power generation from each of the sources as a function of time. In equation (1), u_i , $i = 1 \dots 4$ represents the percentage increase or decrease of generation from the i th source. The parameter β_{ij} describes the impact of generation level of the j th power source on the growth (or decline) rate of generation level of the i th power source, and similarly, β_{ji} is the impact of the generation level of the i th power source on the growth (decline) rate of generation level of the j th energy source. Note that in general, $\beta_{ij} \neq \beta_{ji}$. In other words, the matrix of interaction is not necessarily symmetric [8].

Brief explanation of Performance or cost function

The model that we are proposing has an outstanding ability that allows developing a methodology for gradual and optimal replacement of Coal and Diesel (Conventional) by Solar and Wind (Renewable) energy sources. The objective function to be chosen must incorporate the main concerns of the planner. For example, one may be interested to meet the target level of generation at the end of the plan period while reducing the cost of implementation and greenhouse gas emission during the plan period.

The Objective Functional that we mentioned earlier can be expressed as below:

$$J(u) = \int_0^{t_f} l(t, x(t), u(t)) dt + \Phi(x(t_f)) \quad (2)$$

The cost function given by equation (2) consists of two parts representing the running cost and the terminal cost. The running cost may include the implementation cost and the penalty for producing greenhouse gases during the plan. The terminal cost represents the mismatch between the desired level of generation and the actual level of generation reached by the system at the end of the plan period [9].

Determining the Control (Decision) policy u as a function of time is the main objective here by taking values from the set $U = \{u:$

$|u_i| \leq 1, i = 1 \dots 4\}$ so that it minimizes the cost function $J(u)$. To determine the optimum decision policy, we must use the relevant mathematical theory of optimal control and system identification problem details of which can be found in [13]. Because of time and relevant resource utilization constraints, we limit our exploration only with theoretical part of the problem. We aimed to illuminate a research pathway where our experiences are highlighted. The results that we achieved from our earlier research made us convinced that modern control theory can be used effectively to formulate optimal socio-economic policies [8], [11], [12], [14].

SECTION 4

Integration of renewable power into electrical power systems

Modern electrical power systems (the grid) developed in the late 19th century that has since been evolving; they take different forms around the world. As electrical power systems worldwide are different, there cannot be one recipe that fits all when examining the integration of renewable energy.

The robust and effective integration of renewable power to grid requires reliable protection and control. In this paper, the authors have suggested some measures and policy recommendations which would help achieve the goal of PV renewable energy integration for future generations.

Network Structure of PV Arrays

Solar PV power plants can greatly impact on GHG (Green House Gas) – emitting fossil fuels. To take the full advantages, we need to establish a reliable electrical network they are integrated into distribution grids. As a result, it is important to adjust the output of a solar plant (both real and reactive power) to minimize any effect the plant may have on grid reliability and other customers. Coordination of the PV plant and its intertie with the existing distribution and sub-transmission electrical system is essential for reliable operations. By using the Grid Connected information library, users can design and implement a control system that

seamlessly adjusts the equipment operational points in response not only to commanded set point changes but also to variable conditions. Feature sets that allow for this seamless operation include concurrent control of both real and reactive power [2].

A sample radial low voltage residential urban distribution network is considered for voltage imbalance investigations. The simplified equivalent single line diagram of one feeder of the network is illustrated in Fig. 2. A schematic diagram of a PV connection to grid is shown in Fig. 3. In this model, the PVs are all grid-connected such that the surplus of the electricity generated will flow to the grid. It has been assumed that all the PVs work at unity power factor based on IEEE (Institute of Electrical and Electronics Engineers) Recommended Practice for Utility Interface of Photovoltaic Systems. It is also assumed that the neutral conductor is making the path for unbalance current circulation and the analysis are based on the mutual effect of three phases [2].

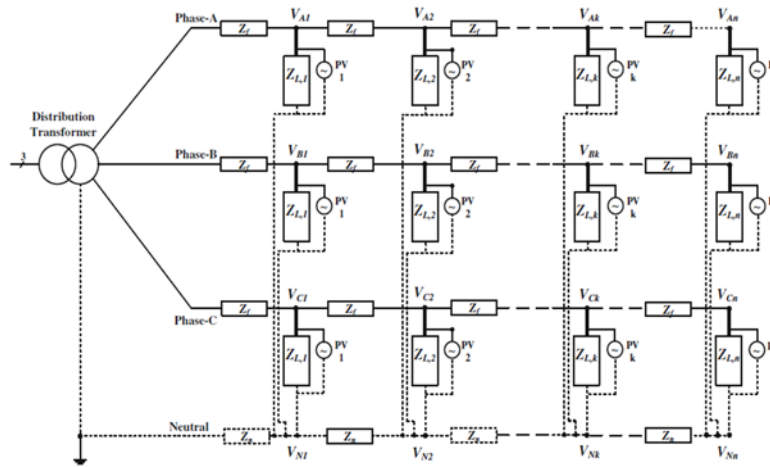


Fig. 2 Schematic single line diagram of the considered low voltage distribution network [2]

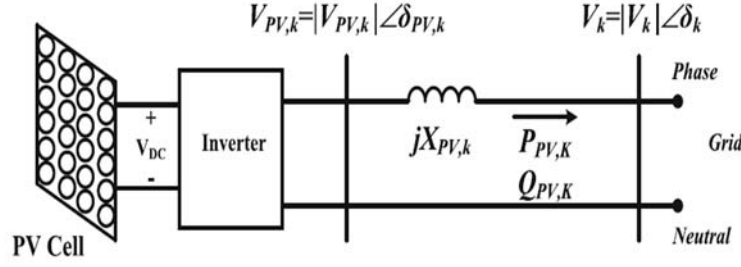


Fig. 3 Schematic diagram of a PV connection to grid [2]

Power Flow Analysis

For calculating the voltage imbalance, it is necessary that the network be analyzed and the voltages at the desired nodes be calculated. Based on the KCL (Kirchhoff's Current Law) on k th node of phase A, we have

$$\frac{\beta(V_{A,PV,k} - V_{A,k})}{X_{A,PV,k}} + \frac{V_{A,k-1} - V_{A,k}}{Z_f} + \frac{V_{A,k+1} - V_{A,k}}{Z_f} + \frac{V_{N,k} - V_{A,k}}{Z_{A,L,k}} = 0 \quad (1)$$

Where, Z_f is the feeder impedance between two adjacent nodes in phase lines, V_{Ai} ,

$i = 1, \dots, n$ is the single-phase voltage of the i th node of phase A, $Z_{A,L,k}$ is the load impedance connected to k th node of phase A and $V_{N,k}$ is the voltage of the neutral wire connected to k th node. $V_{A,PV,k}$ and $X_{A,PV,k}$ are the PV voltage and impedance connected to k th node of phase A. Similar equations are valid for phases B and C. In (1), the controlling constant β is equal to 1 when there is a PV connected to k th node, otherwise, it is zero. KCL for each node on the neutral line is

$$\frac{V_{N,k-1} - V_{N,k}}{Z_n} + \frac{V_{N,k+1} - V_{N,k}}{Z_n} + \frac{V_{N,k} - V_{A,k}}{Z_{A,L,k}} + \frac{V_{N,k} - V_{B,k}}{Z_{B,L,k}} + \frac{V_{N,k} - V_{C,k}}{Z_{C,L,k}} = 0 \quad (2)$$

Where Z_n is the feeder impedance between two adjacent nodes in neutral line.

The simplified diagram of the PV connection to the grid is shown in Fig. 3. Based on this figure, we have

$$P_{PV,k} = \frac{|V_{PV,k}| |V_k|}{X_{PV,k}} \sin(\delta_{PV,k} - \delta_k) \quad (3)$$

$$Q_{PV,k} = \frac{|V_k|}{X_{PV,k}} (|V_{PV,k}| \cos(\delta_{PV,k} - \delta_k) - |V_k|) \quad (4)$$

where $P_{PV,K}$ and $Q_{PV,K}$ are respectively the active and reactive power output of the PV connected to k th node. Assuming $P_{PV,K}$ and $Q_{PV,K}$ to be constant and $|V_k|$ and δ_k are known, $|V_{PV,K}|$ and $\delta_{PV,K}$ can be calculated. Please note that $Q_{PV,K}$ will be zero if the PV operates in Unity Power Factor (UPF) [2].

To calculate V_k from (1)–(4), an iterative method is required. Starting with a set of initial values, the entire network is solved to determine V_k .

Once the solution converges, the sequence components are calculated. IEEE recommended practice for monitoring Electrical Power Quality defines voltage imbalance as

$$VUF \% = \left| \frac{V_-}{V_+} \right| \times 100 \quad (5)$$

where V_- and V_+ are the negative and positive sequence of the voltage, respectively. The positive and negative sequence voltage components are obtained by resolving three-phase unbalanced line voltages V_{ab} , V_{bc} , and V_{ca} (or phase voltages) into two symmetrical components and V_n (of phase voltages or the line) [2].

Unbalanced systems indicate the existence of a negative sequence that is harmful to all polyphase loads, especially three-phase induction machines. For the utility, it is just a matter of repairing malfunctioning equipment or redistributing loads to reduce the unbalance. For the end-users, proper testing,

communication timely asset management with the utility would help locate and resolve the problems [2].

SECTION 5

Exploring an Innovative Approach of Integration of Renewable Energy and Battery Energy Storage System (BESS) Sources for Bangladesh Power Grid

Photovoltaic (PV) and Battery Energy Storage System (BESS) are two inverter-based resources that could be utilized as cost effective alternatives. The inverter-based distributed energy resources (DER) offer unique technical and economic opportunities to optimize electric power delivery. The decision makers of Power Development Board of Bangladesh may want to explore this innovative approach.

To take full advantage of these systems and to provide the maximum benefit to owners, operators, and the grid, the inverter-based DERs need accurate and reliable control. With appropriate control schemes, many use cases can be optimized by different ways such as:

- 1) Simply implementing inverters that connect to the grid, 2) Reducing peak demand or supplementing local energy demands, 3) Maximizing energy export, and 4) Providing services to reduce the operating costs of local loads for industrial or utility users [3].

A combined PV and BESS system offers an opportunity to meet various use cases, one of the cases is reducing peak demand, which reduces demand charge and enhances reliability schemes; however, to effectively utilize storage, assets typically need integration to be managed with other power system assets and DERs behind the point of common coupling (PCC). A controller that manages and coordinates with other resources allows optimization of use case and dynamic switching between operating modes. State of charge management, time-shifted generation, and peak demand reduction are a few applications with PV and BESS that require a controller between multiple DERs [3].

SEL (Schweizer Engineering Laboratories) developed an off-the-shelf control system that helps owners of renewable energy installations meet interconnection utility and regulatory requirements. SEL Grid Connect is an add-on feature available for the SEL Real-Time Automation Controller (RTAC) family. It is designed to simplify interconnection control and solve common interconnection issues, such as adapting for varying cloud cover, nonresponsive inverter controls, and unexpected voltage excursions. This control system contains pre-engineered function blocks for controlling the PCC between the utility grid and a power generation source. Using SEL's pre-engineered control system library helps get renewable projects online quicker and with reduced cost [3].

Based on the use case, the PCC operates within a defined range set by the user-configured parameters in Grid Connect. In this operating mode, when the PCC meter detects power flow exceeding the maximum allowable export, Grid Connect automatically curtails inverter production to account for the maximum allowable output and consumed energy via the loads. This allows a facility to cover energy usage and sell back the most amount of energy when conditions allow [3].

Alternatively, when paired with BESS and PV power supplies, Grid Connect will discharge energy from the storage assets to keep energy import at the current peak demand value, reducing any energy surcharge for peak consumption if Grid Connect detects import of more energy than the peak demand value for the billing cycle. In addition to providing peak demand reduction, battery assets also provide solar power supply smoothing, ensuring ramp rates at the PCC stay within the interconnection agreement specifications [3].

Grid Connect can be configured to either charge batteries from PV assets only or to import energy from the PCC. State of charge management includes an automatic charging algorithm that determines when the system is not using the battery to charge it for later use. The charging algorithm is configurable to keep the battery topped off between solar smoothing events during the day or to fully charge the battery after heavy discharge for peak

demand reduction or time-shifted generation when the system is at low utilization and energy is at a reduced price [3].

A Practical View of Integration of PV and BESS Energy to the Grid and P&C Monitoring by Utility SCADA System

The grid-connected PV systems are designed by the utilities and consumers to operate in conjunction with other DERs and the utility grid based on some benefits. The grid-connected PV systems consist of the bi-directional inverter, PV panels, battery system, smart meter, direct current (DC) bus system, and alternating current (AC) bus, as shown in Fig. 4, with their respective functions. A bi-directional interface is made between the PV system and the utility power output with the application of an inverter. The bi-directional interface or features introduced into the system allows the power generated by the PV panels to supply the loads directly to the connected AC bus system and sends the excess power to the grid whenever the power output of the PV system is more than the power required by the consumers. The opposite occurs whenever the power demand is more than the output of the PV system or if BESS system needs to charge from utility power during the off-peak time with lower prices. During the normal day consumer power demands, both PV and BESS discharge the power to the utility incoming system by EMS (Energy Management System Tesla Controller).

Some safety features are introduced into the grid-connected PV systems to prevent the system from feeding the grid whenever the utility grid is down due to faults or under maintenance.

As shown in Fig. 4 and listed in Tables 1 through 4, the main protection from internal faults within BESS and PV facility for Battery Energy Storage System (BESS) and Photovoltaic (PV) arrays shall be provided by SEL700G protection relay which will operate the vacuum contact DG-2. Breaker failure logic is configured in Relay A SEL-700G such that when DG-2 failure is detected, CB-2 breaker shall be tripped by Relay A SEL-700G.

1.
Table-1 Relay-A SEL-700G for Internal Faults within Load Facility
Summary Tripping Matrix

Description	Protective Element	Actuating Device
Phase instantaneous overcurrent current	50	DG-2
Neutral overcurrent	51N	DG-2
Phase time delayed overcurrent	51	DG-2

Additionally, there will be over current protection functions provided by fuse in feeder DG-1 .

2. Certain abnormal system conditions such as over / under voltage, over / under frequency

Relay-A SEL-700G shall have following protection functions for abnormal voltage and frequency conditions. The settings for each function shall follow IEEE-1547. [1]

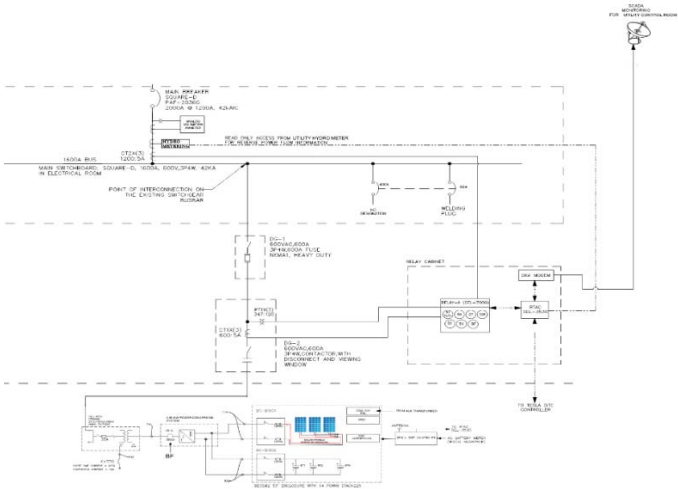


Fig. 4 Single Line Diagram (SLD) with P&C (Protection and Control) and with Metering system at PCC

Table-2 Relay-A SEL-700G abnormal condition Summary Tripping Matrix

Description	Protective Element	Actuating Device
Under voltage	27	DG-2
Over voltage	59	DG-2
Under frequency	81U	DG-2
Over frequency	81O	DG-2

Table-3 Relay-A SEL-700G Voltage protection settings

Description	Voltage setting range	Clearing time (s)
Under voltage-01	$V < 50\%$	Instantaneous to 0.16
Under voltage-02	$50\% \leq V < 88\%$	Instantaneous to 2.00
Under voltage-03	$106\% < V \leq 110\%$	0.5 s to 2 minutes
Over voltage-01	$106\% < V \leq 110\%$	1.00
Over voltage-02	$110\% < V \leq 120\%$	Instantaneous to 2.00
Over voltage-03	$137\% \leq V$	Instantaneous

Table-4 Relay-A SEL-700G Frequency protection settings

Description	Protective Element	Frequency setting range	Clearing time (s)
Under frequency-01	81U	$f < 57$	0.16
Under frequency-02	81U	$f < 58.8$	299
Over frequency-01	81O	$f > 61.2$	299
Over frequency-02	81O	$f > 62$	0.16

Additional Protection functions are available in Power conversion system (PCS) as well.

Table 5 shows the inverter default response to abnormal voltage and frequency which is compliant to the IEEE1547 standards.

Table-5 PCS voltage protection settings

Description	Voltage setting range	Clearing time (s)
Under voltage-01	$V < 50\%$	Instantaneous to 0.16
Under voltage-02	$50\% \leq V < 88\%$	Instantaneous to 2.00
Under voltage-03	$106\% < V \leq 110\%$	0.5 s to 2 minutes
Over voltage-01	$106\% < V \leq 110\%$	1.00
Over voltage-02	$110\% < V \leq 120\%$	Instantaneous to 2.00
Over voltage-03	$137\% \leq V$	Instantaneous

Table-6 PCS Frequency protection settings

Description	Frequency setting range	Clearing time (s)
Under frequency-01	$f < 57$	0.16
Under frequency-02	$57 \leq f < 58.8$	299
Over frequency-01	$f > 61.2$	299
Over frequency-02	$61.2 \leq f < 62$	0.16

3. Reverse power protection

The reverse power flow (32R) protection relay is used to prevent reverse power back feed to the distribution network.

The BESSs need to be sized such that the generation of the BESS will always be less than the system load during normal operation. However, in the condition when the load is not sufficient to absorb all the power generated by the BESSs, the additional power may flow back into the grid.

Reverse power protection shall be set at 10% of total load with time delay of 5 Sec. Reverse power function shall be performed by RTAC (SEL-3530) through Meter-A SEL-735. In case, reverse power flow occurs, DG-2 shall be operated as trip device. DG-2 can be reset manually after the event is cleared.

In order to accomplish protection and control design objectives, the following design criteria will be considered:

- Fault clearing time: It must be kept to minimum to mitigate the impact on utility network and to maintain system stability.
- Selectivity: It is necessary to isolate a fault while interrupting only the circuits directly involved. Coordination is required with adjacent protection schemes including breaker

failure, voltage transformer fuses and station services protection.

- c) Sensitivity: Minimum fault conditions, as determined by power studies, shall be sensed by protection relays without imposing limitations on circuit or equipment capabilities.
The settings shall be determined such that relays will correctly perform during transient power swings from which the system can recover.
- d) Reliability: The criterion has two requirements:
 - Protection relays shall be dependable thus tripping when required
 - Protection relays shall be secure thus system will not be subjected to nuisance trips
- e) External Fault: It is necessary to take an immediate action to isolate a faulty part while interrupting is not internal. There are several events can be considered for external fault. Here are below some common external interruptions:
 - Islanding, i.e. disconnecting/isolating the facility from the distribution network upon loss of grid
 - Breaker failure
 - Tele protection signal received
 - Loss of communication
 - Protection scheme failures

CONCLUSION

The solution of the Equation of Environmental Sustainability can be found in balancing human needs with ecosystem integrity. We have, therefore, emphasized the impact of human activities on the environment, which is directly related to a number of factors, namely, population of Bangladesh, consumption rate by the population and the deployment of technological innovations. An urgent action must be taken to make a significant reduction of CO₂ and Green House Gas emissions from fossil fuels. Our practical working experiences and the research work in the field of renewable energy sources and its application in Canadian Power

sector conclude that an optimum decision (Strategy) Policy for integration of Renewable Energy sources into Power Generation System of Bangladesh can be formulated for an Environmental Sustainability. It will be worthwhile to take advantage of renewable energy efficient technologies, and in parallel, circular economy that would allow recycling, reusing, and waste minimizing techniques to reduce pollution. The authors believe that the proposed approaches will have positive impact in making an environmentally sustainable Bangladesh. The authors, judiciously employing their work experiences in the power sector of Canada, analyzed the Power System of Bangladesh and offered their recommendations.

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RENEWABLE ENERGY FROM MUNICIPAL SOLID WASTE IN BANGLADESH

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Abstract

Energy is available from organic fraction of municipal solid waste (MSW) and a major part of the municipal waste is organic. The simple method of recovery of energy from MSW practiced all over the world is collection of methane from landfills known as landfill gas (LFG) which is used as fuel. LFG is produced by anaerobic decomposition of carbonaceous organic matters of MSW. The second method is thermal process, which include incineration, pyrolysis, gasification, and arc plasma. Incineration is the most common method of energy recovery and 11% of the world's MSW is incinerated for energy recovery while other processes are still in experimental stage. The least heating value (LHV) of MSW required for incineration is 4.00 MJ/kg but the LHVs of Dhaka and Chittagong MSW are 6.32 MJ/kg and 8.44 MJ/kg respectively. Thus, the MSW of the major two cities of Bangladesh are suitable for incineration but moisture content of the MSW all over Bangladesh is high in rainy season which sometime consume all the heat energy of the MSW for evaporation of water leaving no additional energy for use. In this paper, an attempt has been made to estimate the quantity of MSW, potential amount of LFG form landfills and heat energy by incineration of all MSW of Bangladesh.

Key Words: Municipal Solid Waste, Landfill Gas, Incineration, Clan Development Mechanism

INTRODUCTION

Landfill is the most popular method of solid waste disposal all over the world. About 70% of all solid waste is disposed of by landfill. The developed countries practice sanitary landfill and developing countries dispose of solid waste mostly in open landfills. Methane gas produced in the sanitary landfills by anaerobic decomposition of organic solid waste can be collected for use as a source of energy. Around 19% of solid waste is recycled in different forms. Heat energy is recovered from solid waste by incineration, gasification, pyrolysis and plasma methods. An estimated 11 percent waste is subjected to thermal processes for collection and use of energy. Incineration is the widely used method among thermal processes for energy recovery. Solid waste can be burned in oxygen starved condition to produce syngas which can be used as fuel. The use of this gasification process is limited. Another similar method is Pyrolysis in which the solid waste is burned in absence of oxygen to produce gas, liquid bio-fuel and char and all can be used as a fuel but use of the process is also limited. In Arc Plasma method atomization of organics takes place at high temperature but the process is still in experimental stage.

A summary of waste to energy presented by Islam (2016) from various sources shows the energy recovery by different waste to energy technologies. The input heating value and moisture content of the municipal solid waste are important parameters for conversion of solid waste into energy. Table 1 shows that between 0.15 and 0.9-MWh electricity can be generated from 1 ton of municipal solid waste depending on the characteristics of the waste and the technology adopted for conversion.

Table 1: Overview of Major Waste to Energy (WtE) Technologies

Waste to Energy(WtE) technology	Conversion efficiency (MWh/ton MSW)	Service life (year)	Typical MSW input heating value (MJ/Kg)	Max fuel moisture (%)
Waste incineration	0.5	30	8-10.5	40-50
Pyrolysis	0.3	20	-	10
Gasification	0.9	20	16.5	40-50
Anaerobic digestion	0.15	20	2.5	97
LFG gas recovery	0.22	30-50	-	40-80

Landfill is the method of ultimate disposal of Municipal Solid Waste (MSW) in all municipal areas in Bangladesh. The most common technique in practice is the open dumping of each day's wastes in low lying areas/ditches over the previous days' dumped wastes until the ditches are filled up. The Dhaka City Corporation compacts the wastes to a certain degree using bulldozers after dumping in designated landfill sites but rarely provides a soil cover after each day's deposition as recommended for well-designed sanitary landfills. The placement of a layer of soil after completion of all uncontrolled or partially controlled landfills ensures anaerobic decomposition of organic materials with the production of gases and leachate. A major fraction of gases produced in the landfills is methane and the leachate thus produced is known for its extremely high pollution potential. A part of the leachate is subsequently converted into methane by methanogenic bacteria. Methane being lighter than air tends to escape in the air through permeable landfilled materials. Thus, anaerobic biochemical reactions involving methanogenic bacteria, organic fraction of solid wastes in all landfills results in the emission of methane. The process of decomposition in all landfills is relatively faster in Bangladesh due to favorable temperature and high moisture content in solid waste. Methane can also be recovered from solid

waste by anaerobic decomposition in a reactor under controlled conditions.

In Bangladesh the organic fraction of solid waste varies between 60 to 70 percent. Incineration of organic fraction of the solid waste releases heat energy, which can be used for generation of electricity. In land scarce Bangladesh, availability of land for landfills is getting limited and Bangladesh has become more inclined to incineration of solid waste for final disposal after energy recovery. This paper describes the present status and future potential of energy recovery from solid waste as landfill gas (LFG) and heat energy from incineration.

QUANTITY AND QUALITY OF SOLID WASTE

Bangladesh is the 9th largest country in respect of population, and urbanization is increasing at high rate. The estimated solid waste in urban centers in Bangladesh was 23,688 metric tons/day in 2014 and it was projected to be 47,000 metric tons/day in 2025 by Waste Concern (Enayetullah et al., 2014). This estimation has been made by multiplying the population by the waste generation rate of the different category of urban centres. The annual growth rate of solid waste considering the projection by Waste Concern is computed as 2,100 metric ton/day. Considering this growth rate the solid waste generation per day in Bangladesh is estimated as 40,500 metric tons in 2022. The solid waste generation is distributed proportionally in different types of urban centres is shown in Figure 1.

The materials present in typical solid waste in Bangladesh are shown in Fig.2. It may be observed that 71.7% of the solid waste is organic, the other constituents include plastic (7.45%, paper (6.84%), wood (3.72%), and textile (3.56%). About 20% of MSW is recyclable

It has been estimated that that about 68% of the solid waste in Dhaka city and 72% in all urban areas are organic matters. The larger Fraction of solid waste disposed of after recycling is organic. Solid waste having high organic matter produces more Landfill Gas (LFG) and heat energy on incineration.

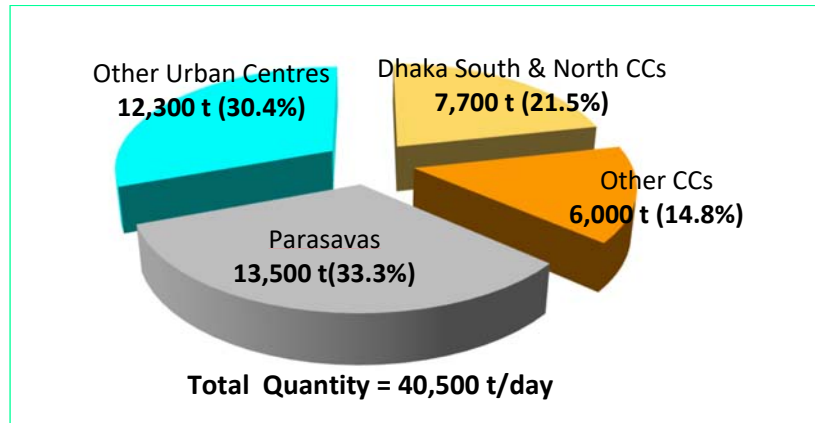


Figure 1: The quantity of solid waste generated per day in Bangladesh in 2022

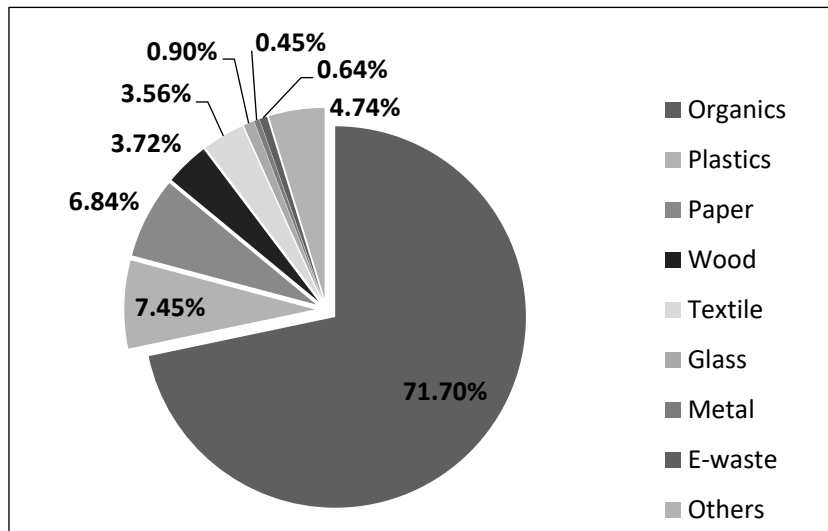


Figure 2: The constituents of solid waste in Bangladesh

WASTE TO ENERGY

Methane Collection from Landfill

The emission of methane from landfills can be estimated using one of the following methods:

Method 1 : An approach based on theoretical first order decay model applied in the Netherlands (Amstel et al, 1993).

Method II : An empirical model developed by USEPA (1995) using landfill gas recovery data from a large number of landfills in the USA representing a broad range of climate and waste composition.

Method III: Methane release potential based on mass (carbon) balance approach developed by Bingemer and Crutzen(1987).

Out of the above mentioned three methods, methods I and II require extensive data on number, size, quantity etc. for the estimation of methane emission (Bhide, 1994). The method III is based on carbon balance and requires minimum data for the estimation of methane. This method has been proposed by IPCC/OECD (1995) for the computation of methane from landfills. The theoretical CH₄ gas generation computed by this method is given by:

$$\text{CH}_4 \text{ Emission} = [\text{Total MSW landfilled}] \times [\text{Fraction DOC in MSW}] \times [\text{Fraction DOC degrades}] \times [\text{Fraction C-CH}_4 \text{ in C-biogas}] \times [\text{Methane/Carbon conversion factor, } 16/12]$$

Quantity of solid waste disposed of by landfill vary widely with the size of urban centre, extent of recycling and efficiency of collection of the municipalities. Data available on quantity and

quality of solid waste to estimate the methane generation are scanty. The data reported by a multidisciplinary team of experts organized by Goethe Institut (German Cultural Centre), Dhaka (1994) are the main source of information for the computation of methane from MSW. The chemical analysis reported by Ahmed (1994) is used as a source of chemical composition of waste landfilled in Bangladesh for estimation of methane. The quantities of solid wastes reported are based on the actual quantities of waste collected and disposed of by dumping trucks in natural wet condition. The computation of methane has been shown in Table 2.

Table 2: Methane emission from MSW produced in Bangladesh

(1) Urban Centres	(2) MSW t/day	(3) Dry Waste t/day	(4) DOC Land- filled t/day	(5)Methane Emission	
				t/day	10 ³ m ³ /day
DNCC & DSCC	8,700	4,437	1,003	514	717
Other CCs	6,000	3,060	692	354	494
Paurasava	13,500	6,885	1,556	797	1,112
OtherUrban Centres	12,300	6,273	1,418	726	1,013
Total	40,500	20,655	4,669	2,391	3,336

Notes : Col.5: Methane Emission t/day = [Col.2: MSW Produced, t/day] x [1- Moisture content in MSW, 0.49] x [Fraction DOC in MSW, 0.226 (Ahmed,1994)] x [Fraction carbon released as biogas, 0.77 (IPCC, 1995)] x [Fraction methane in biogas ,0.50(IPCC,1995)] x [Methane/Carbon conversion ratio, 16/12] Dividing weight of methane by density, 0.7167 g/l gives volume.

Recovery of biogas from landfills is known at 247 sites in 12 countries around the world (Bhide, 1994). It can be done by installation of wells in the landfill as shown in Figure 1. Gas collection begins when a portion of the landfill (a landfill cell) is complete. The well heads are connected to lateral piping, which transport the gas to the processing and storage facilities. Methane, being lighter than air and CO₂, tends to move upward. However, a

pump or blower is installed to create a negative pressure to pull the gas into the collection wells.

A compressor may be required depending on how the gas is used. Moisture and H_2S gas removal columns may be installed in the main pipeline to trap undesirable moisture and H_2S gas.

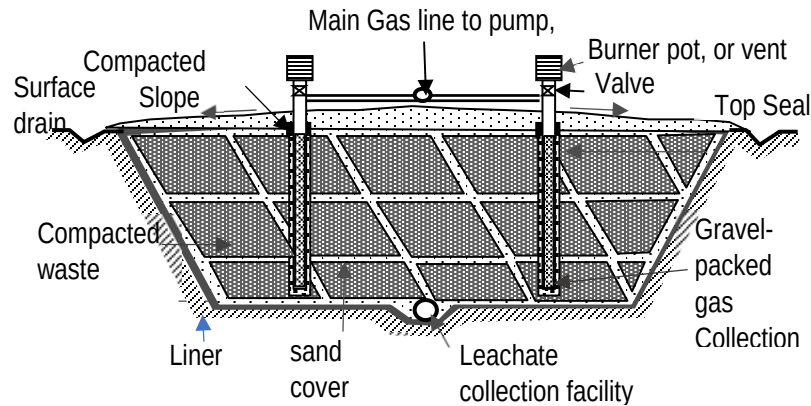


Figure 3 : Biogas collection facilities in a sanitary landfill

INCINERATION

Heating value and moisture content of the MSW are important for incineration and energy recovery. Least Heating Value (LHV) required for successful incineration is 4MJ/kg. LHV of Dhaka City Waste is 6.32 MJ/kg, and that of Chittagong waste is 8.44 MJ/kg (Islam 2016). The LHVs indicate high waste-to-energy potential and low GHG emission from Dhaka and Chittagong wastes at low moisture content.

Sustainable and Renewable Energy Development Authority, (SREDA, 2015) of Power Division, Ministry of Power, Energy and Mineral Resources conducted a study in 6 municipalities in

Bangladesh. The study showed that no additional energy was available from incineration of municipal waste. A relationship among moisture content (%), ash content (%) and combustible organic content (%) is shown in Figure 4. Solid waste is suitable for energy recovery by incineration if it falls in the pentagonal area touching the left bottom corner of the diagram. The European solid waste falling in red pentagonal area within the large pentagon is very suitable for energy recovery by incineration. A good solid waste for energy recovery as indicated in Figure 4 should have moisture content between 0 % and 55% and combustible organic content ranging from minimum 40% at very low moisture content to 100% at high moisture of about 55%. The SREDA study of solid waste in 6 Municipalities having moisture content between 58% and 68% falls in the yellow triangular area above the pentagonal boundary indicating unsuitable for incineration.

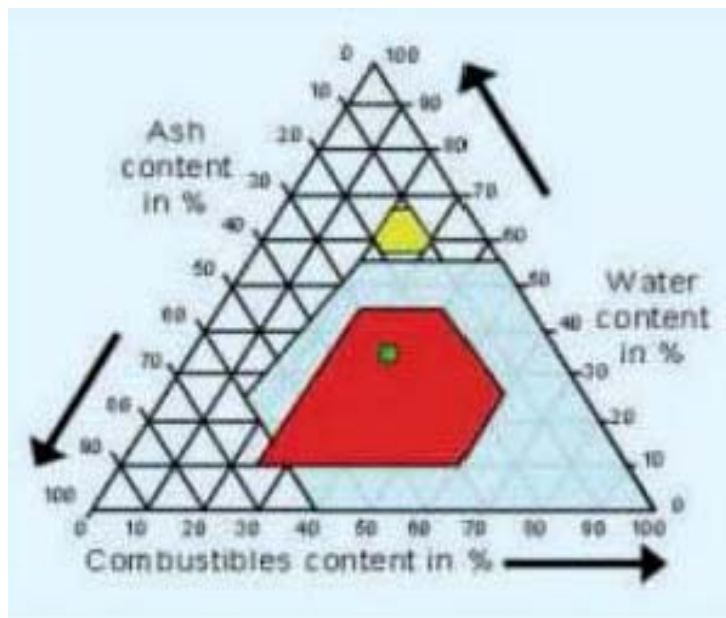


Figure 4 : A diagram showing the suitable areas for energy recovery from solid wastes.

The combustible organic content of Dhaka and Chittagong wastes are high enough but moisture content must be below 55% for energy recovery. Low moisture content of MSW in Bangladesh occurs in dry season only. However, moisture content of solid waste can be reduced if the waste is protected from rain in the secondary transfer stations. DNCC has taken initiative to establish 42.5 MW waste to energy power project in Dhaka by Incinerating 3000 tons MSW. China Machinery Engineering Corporation (CMEC) will set up the plant in 2 years on a build-own-operate basis. where Dhaka North City Corporation (DNCC) will supply MSW and 30 acres of land for incineration plant. Bangladesh Power Development Board (BPDB) will purchase electricity for a 25-year period at US \$ 21.78 cents (equivalent to Tk 18.295) per unit. A similar project is now being implemented in Narayanganj in collaboration with the Narayanganj municipality, which will generate 6 MW power. The success of DNCC and Narayanganj projects will show the way of energy recovery from MSW in Bangladesh by incineration.

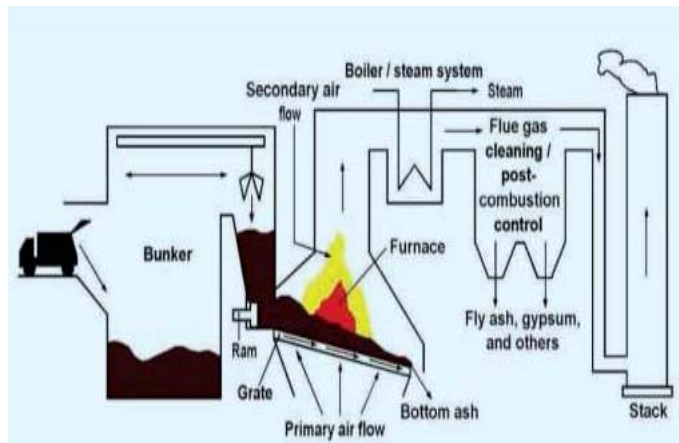


Figure 5 : A typical incinerator with energy recovery from solid wastes.

A typical incinerator is shown in Figure 5. Emission from incinerator needs treatment for removal of dust, dioxin, NO_x, SO₂ and heavy metal. If proper treatment facilities for the removal of

particulate matters toxic gases are not installed, severe air pollution will occur around incinerators.

CLEAN DEVELOPMENT MECHANISM (CDM)

The Clean Development Mechanism (CDM) as defined in the Kyoto Protocol provides for carbon reduction/ emissions trading schemes. Developing countries will implement carbon reduction and capture projects and generate CER (Certified Emission Reduction) and Developed countries will purchase CER at market price to compensate the emission they produce. China, India , South Korea , Brazil made the best use of CDM as shown in Figure 6.

Bangladesh has not yet implemented a single project for LFG collection, although 60-80 m³ of methane gas can be collected and around half ton of greenhouse gas (GHG) reduction is possible from each ton of MSW. LFG collection from Matuail landfill by West Concern with CER EURO 2.8 million was planned but could not implemented. The Department of Environment (DoE) planned to establish WtE plants in each Zilla but the plan was not materialized. Work order for construction of one incinerator for Dhaka North City Corporation (DNCC) and one for Dhaka South City Corporation (DSCC) was issued in favor of an Italian company but the company did not turn up to implement the project. The interest in implementation of WtE projects is lost probably due to fall of CER price in the international market.

A 700 t capacity Bhulta composting project of CER Euro 1.06 Million by Waste Concern is partly implemented. Presently only 130 t/d of solid waste is composted but this only CER project in Bangladesh is in implementation difficulties.

There is enough interest in establishment of WtE projects in Bangladesh. From a large number of bidders, 4 companies were short listed for installing an incinerator for DNCC. Finally, a Chinese company has been awarded the project to complete the project in 2 years as mentioned earlier. Another incinerator to produce 6 MW electricity by Narangonj Municipality is under implementation.

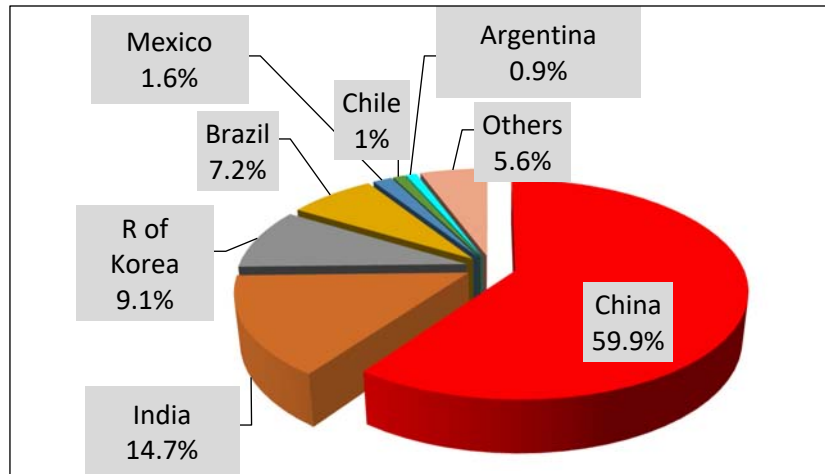


Figure 6: Global share of CDM projects

In addition to energy recovery, there is a hidden benefit from LFG collection and incineration of MSW. The certified emission reduction (CER) from these two process in developing countries can be sold to developed countries in the international carbon market under Clean Development Mechanism (CDM) as defined in the Kyoto Protocol (IPCC,2007). But unfortunately the international carbon market has been flooded with CER projects from China, India, Brazil etc. and the carbon price of \$20/M.Ton in the international market in 2008 has fallen to less than \$ 3 /M.Ton. The Bhulta Composting Project, the only CER project in Bangladesh by West Concern and Worldwide Recycling (WRR) of Netherland is in problem. The fall of carbon price has influenced the non-implementation of the other CER projects stated above.

CONCLUDING REMARK

In Bangladesh, recovery of biogas from well-designed MSW landfills has good potential. The multiple benefits from biogas recovery included a supply of substitute fuel, reduction of emission

of greenhouse gas, environmentally sound disposal of MSW and elimination of the risk of fire hazards and explosions at sites by gas build-up at dump site. At present, about 82 m³ methane gas per ton of solid waste can be recovered per day from the MSW dumped by the city corporations and the municipalities. The total methane generation from solid waste will increase when all the MSW is brought under collection and disposal systems. It is a land intensive option but filled land after exhaustion of gas can be used for alternative purposes like creation of artificial forest, park and recreational area.

Incineration is the alternative method of energy recovery. Incineration is a very costly option and requires highly skilled manpower. Extensive study for characterization of waste in all seasons is required to assess technical and financial viability. Exhaust from incinerator needs extensive treatment to eliminate air pollutants. The control of pollutants like Dioxin, oxides of Nitrogen, Sulphur dioxide, heavy metal, bad odor and dust produced during the process of incineration of the MSW will be a challenge for incineration.

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CURRENT STATUS AND APPLICATIONS OF RENEWABLE ENERGY IN AGRICULTURE: GLOBAL AND BANGLADESH PERSPECTIVE

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Abstract

By 2040, it is expected that building energy and agriculture would account for more than 30% of world energy use. The direct and indirect consumption of energy in agriculture makes it difficult to determine its worldwide share in agricultural application, and in the context of Bangladesh, an agro-based country, agriculture sector is one of the dominant energy sinks. The energy generation in Bangladesh still heavily depends on fossil fuels such as natural gas, coal, oil, etc. Renewable energy could be the substitute for traditional fossil fuel for agriculture application, which will alleviate the dependency on grid electricity and subsequently reduce the expenses of crop production. Out of different renewable sources, only solar energy got popular in household applications in rural areas. However, solar energy in agriculture has not yet become a standard practice. Whereas neighboring country, India places a premium on renewable energy generation with 20% of the overall electricity generated used in agricultural sector, mostly for irrigation. Other developing and developed countries are resolute in their efforts to wean themselves off fossil fuels. Bangladesh should also prioritize the use of renewable energy sources in agriculture. Bangladesh's

contribution to renewable energy is not as substantial as we anticipated in our 2008 renewable energy program. However, the Mujib Climate Prosperity Plan (MCCP) sets a target of 30% renewable energy use by 2030 in Bangladesh. To do this, the agricultural energy industry must be restructured to allow for a greater proportion of renewable energy. Bangladesh's active participation in the COP-26 climate change conference may have shifted the government's support for renewables, but other challenges such as underdeveloped physical infrastructure and logistics, a shortage of skilled labor, and insufficient access to institutional finance are all very real for Bangladesh. Policymakers and other renewable energy stakeholders must plan for these obstacles, especially for its utilization for the agricultural sector. We presented the current status and strategies as well as examined data pertaining to Bangladesh's solar and geothermal energy as well as other renewable energy types and their potential use in agriculture sector. Solar energy was addressed mostly using agrivoltaic cells, while geothermal energy was discussed provided that suitable geothermal energy extraction sites are discovered in the country. Lessons learnt in existing agrivoltaics systems will be shared. Additionally, we will examine the possibility of extracting suitable geothermal energy based on previous studies. Potential for other renewable energy use in agriculture for Bangladesh will be addressed as well through lesson learnt globally.

INTRODUCTION

In the past, industrial development, a rise in population, and increased living standards led to a significant increase in global primary energy consumption (Petroleum, 2018). While this trend is expected to continue in the future, global energy consumption could double by 2100 (Gulagi et al., 2020). Maintaining fast-paced economic growth at the same level as population increase, particularly in developing countries, together with climate change mitigation targets, has put tremendous pressure on governments to supply stable, uninterrupted, and sustainable power (Kamaludin, 2013). High dependence on domestic or imported

fossil fuels has environmental consequences and risks related to long-term energy security and cost competitiveness of electricity production. Energy generated from fossil or traditional fuel sources, such as natural oil, gas, coal, etc., causes negative impacts on our surrounding environment as they produce greenhouse gases (GHGs) responsible for climate change and global warming. Climate change has devastating effects and consequences on the existence and survival of human beings, biodiversity, and ecosystems on this earth. Therefore, the reduction of emission of GHGs in order to mitigate climate change has turned out to be an essential concern for almost everyone. The global community has proposed and adopted various policy initiatives which advocated shifting the energy production from fossil fuels to energy generated from renewable energy sources (RES), such as solar, geothermal, biomass, wind, biogas, hydropower, etc. since these are reported to be cleaner, more sustainable, and relatively more minor pollutant (Barua et al. 2018). Bangladesh's constant growth with an annual 6% plus Gross Domestic Product (GDP) for more than the last two decades and achievements in other socio-economic metrics in recent times is impressive and recognized by various global authoritative bodies. Bangladesh is frequently projected as an agricultural country that encounters catastrophic natural disasters yearly. However, in recent years, it has aimed to transform from an agro-based nation to an industrial one, and this is reflected through slow but massive industrial growth. The extent of overwhelming economic ventures and the government's commitments demonstrate Bangladesh's economic shift. The country is fortunate to have fossil fuel reserves on a limited scale, and these are not enough to run the ongoing massive-scale development activities, both in the private and public sectors. Thus, the constant and uninterrupted energy supply at an attractive price remains a severe concern for successive governments. Therefore, this issue has been gaining importance in the development agenda constantly.

Figure 1 shows the primary grid system of Bangladesh. Bangladesh Power Development Board (BPDB) started its operation with an install capacity of only 200 MW in 1972.

Recently, BPDB has taken a massive capacity expansion plan to produce electricity in Bangladesh. For this circumstance, on 29 May 2019, the installed capacity increased to 20,000 MW. However, with an install capacity of 20,000 MW, the maximum electricity produced was 12 893 MW against the demand of 14,796 MW in 2019. Recently, Bangladesh's electricity generation capacity reached 23,436 MW. Not all power generation in Bangladesh against demand is efficient, an obstacle to the country's development and advancement. Furthermore, it seems to be an exclusive approach for ensuring sufficient electricity supply and stimulating the country's economic progress. Bangladesh's national beauty has potential renewable energy resources: solar energy, hydroelectricity, wind energy, and biomass. Ahmed et al. (2013) presented the energy scenario, alternative energy sources, and prospects in the power sector of Bangladesh. The present study has discovered the factors essential to policymakers in the current power supply crisis. Finally, they recommended renewable and sustainable energy resources to fulfill the power demand in Bangladesh. Islam et al. (2006) discussed the effective utilization of renewable and sustainable energy resources in Bangladesh. The authors suggested that solar PV systems could gain more acceptance for providing electricity to small business enterprises and households in remote rural areas. Islam et al. (2008) have studied sustainable energy resources and technologies for development activities in Bangladesh. There is an electrical problem in the rural areas. The authors concluded that renewable energy could be used as a primary power source of energy in rural areas to overcome these problems. Khan et al. (2008) presented the energy conversion system's technical and economic feasibility progress, prospects, and challenges. They provided technological advancements in the relevant field. Sharif et al. (2018) investigated the opportunity of renewable energy resources in Bangladesh.

The government of Bangladesh is devoted to investment in both public and private sectors in renewable energy projects to substitute contemporaneous non-renewable energy resources. The authors recommended the contributions of renewable energy

based on electricity generation. Figure 1 represents the primary grid system of Bangladesh.

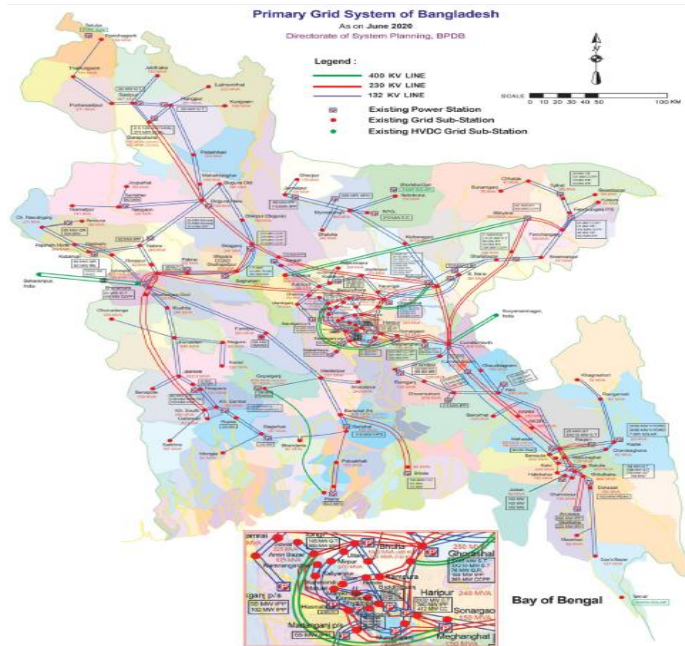


Figure 1: The primary grid system of Bangladesh (Hossain, 2020)

This country has many natural resources, such as natural gas, petroleum, and coal. In Bangladesh, the prime source of power and energy is natural gas. Sustainability trends in the power and energy sector play a pivotal role in achieving sustainable development in any country (Rezaei et al., 2013). Karim et al. (2019) evaluated Bangladesh's law and policy regarding renewable energy resources for sustainable development. Hossain et al. (2017) suggested that sustainability and commercial viability within the renewable energy program initiated by the government through the private sector and micro-finance institutions expand the solar energy program. The renewable and sustainable energies developing in Bangladesh will play a crucial impact on these issues. Compared with the world energy situation, the primary energy resource of

Bangladesh is not satisfactory. Reservation of natural resources is limited in Bangladesh. For this circumstance, the country must develop renewable and sustainable energy sources. Recently, Bangladesh has had many opportunities to generate electricity using renewable and sustainable energy resources. The key to Bangladesh's development has renewable and sustainable energy resources. By using these energy sources, the government has already made significant progress in distributing electricity to the country's population in urban and rural areas. The prospect of renewable and sustainable energy in Bangladesh is promising in the case of solar energy. Solar energy is a popular sustainable energy source used in Bangladesh's rural, hilly, and coastal areas (Ibrahim et al., 2002). Hoque et al. (2013) presented the status of Bangladesh's solar home and photovoltaic micro-utility systems. They recommend upgrading and expansion of rural electrification through renewable energy resources. The reservoir of water and dam is the primary purpose for generating hydroelectricity. Bangladesh has already established micro and mini-hydropower projects (Wazed et al., 2008).

Consequently, Bangladesh has adopted this fuel diversification program to extend its renewable energy (RE) industry and ensure ever-increasing electricity demand. In 2008, the government formulated the Renewable Energy Policy. Public-private investment is welcomed in promoting the RE ventures to replace the fossil fuel-based energy generation to the RE contributing to the national grid (Halder et al. 2015). The government's Renewable Energy Policy is presumed to generate 5% of energy from the RES by 2015 and increase 10% of the total electricity generation by 2020 (GOB, 2011). Meanwhile, the government has launched a new project, the "500 MW Solar Power Mission" to satisfy the escalating need for energy consumption (Sharif et al., 2018). Bangladesh signed the Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCCC) on 21 September 2016 and ratified the same on 4 November 2016. The Paris Agreement is not like the Kyoto Protocol, which puts an obligation on the advanced nations to mitigate GHG emissions. A bottom-up treaty obliges every country to undertake essential reports to protect the

environment and keep the climate stable [Karim et al. 2018]. Having ratified the Paris Agreement, the government has pledged to reduce GHG emissions by 5% below the 'business-as-usual' level by 2030 using domestic resources regardless of its GDP. In such a context, Bangladesh is also responsible for establishing, developing, and implementing the legal framework for addressing environmental concerns, formulating rules and policies for reducing GHG emissions, and realizing a sustainable economic strategy to generate electricity (Karim et al. (2018). Although the government wishes to expand a significant portion of RE contribution in the national grid, such expansion can only be achieved if fundamental challenges encompassing the RE projects are appropriately addressed. Despite executing comprehensive policies and development strategies, which eventually worked as the catalyst for RE penetration in power generation, RE projects and green technologies still face financial, technical, and even political barriers. Even though many scholars, researchers, bodies, and agencies from both public and private sectors have shown interest and significant concerns about the scientific and technical challenges encircling the expansion of RE in Bangladesh, there is a shortage of literature on this issue particularly from the legal point of view. This paper is primarily legal and purports to share the prospects of RES and problems in exploiting the RES in Bangladesh. In doing so, it has attempted to identify the critical obstacles within the existing legal and regulatory mechanisms and suggest solutions based on international best practices. In this review paper, as per the context of Bangladesh, the present status and prospect of renewable and sustainable energy resources to incorporate with various private and governmental projects planned to fulfill electricity demand in this country. It would provide advance advice about these sectors to the government's plan to finish successfully.

METHODOLOGY

Greenhouse Heating using Geothermal Energy

The proposed greenhouse heating system is shown in Fig 5. The greenhouse's heating system compensates for the greenhouse's

heat loss. The greenhouse's heat loss comprises two parts: heat transmission losses (via the walls and roof) and heat infiltration losses (due to the cold air from the outside). The overall transmission heat losses may be calculated as follows: (Ghosal and Tiwari, 2004; Fahmy et al., 2016; Kasapoğlu, 2003; El-Fiky, 2009).

$$q_t = (A_1 \Delta T_d U_1 + A_2 \Delta T_d U_2)$$

Where is the temperature difference (°C) inside and outside the greenhouse; A is the total surface area of the cover material, including the sides and roof. Infiltration heat losses are typically calculated using the air change method. The approach is based on the number of times per hour that chilly air escaping from outside replaces the air within the greenhouse. The heat losses due to infiltration are estimated as follows (Kasapoğlu, 2003; El-Fiky, 2009):

$$q_i = 0.018 * ACH * V_t * \Delta T_d$$

Where ACH ruffles, the number of times air is changed per hour and V_t . The total heat loss can be calculated by addition of transmission heat loss and infiltration heat loss as follows:

$$q = q_t + q_i$$

The greenhouse heating load variation during the year is given in Fig. Due to the difference in design temperature between inside and outdoors, the heating demand is greater in the winter season than in the summer. Geothermal heating may compensate for the heat loss in a greenhouse, which we designed using this mathematical model. The use of geothermal heating systems may be accomplished in several different ways. To heat our greenhouse, the present study used Soil Heating technology, in which underground heat pipes transport hot fluid.

Soil Heating

Using the greenhouse floor as a massive radiator, the soil heating system provides the greenhouse with the necessary heat supply. The greenhouse's bottom is covered with tubes that transport warm water throughout the structure. Using a tube, the

heated water's energy is dissipated into the soil and, ultimately, the greenhouse's atmosphere. Polybutylene is the most often used tube material since it does not have the corrosion and expansion issues that steel does. Ground surface temperature, greenhouse air temperature, and average unheated surface temperature influence the floor's heat production. There are two ways heat from the floor is dissipated: convection and radiation. The required floor surface temperature is calculated as (El-Fiky, 2009):

$$\frac{q}{A} = 0.472 * \left[\left(\frac{1.8T_f + 492}{100} \right)^4 - \left(\frac{1.8AUST + 492}{100} \right)^4 \right] + 2.186(T_f - T_a)^{1.32}$$

$$IST = IDT - (0.0756U\Delta T_d)$$

$$AUST = (A_1 * IST_1) + (A_2 * IST_2) / (A_1 + A_2)$$

Where, T_f is the floor surface temperature ($^{\circ}\text{C}$), T_a is the indoor air temperature, IST is the inside surface temperature ($^{\circ}\text{C}$), IDT is the inside design temperature ($^{\circ}\text{C}$), ΔT_d is the design temperature difference ($^{\circ}\text{C}$), AUST is the average temperature of unheated surfaces in the greenhouse (walls and roof) ($^{\circ}\text{C}$), A is the surface area of the glazing material (m^2). The pipe length can be calculated as follows (El-Fiky, 2009):

$$L_s = \frac{q \times \ln \ln \left[\left(8 \left(\frac{H}{d} \right)^2 - 1 \right) + 4 \left(\frac{H}{d} \right) \times \sqrt{4 \left(\frac{H}{d} \right)^2 - 1} \right]}{4\pi t_m \lambda_m}$$

$$t_m = \frac{(T_{wt} - T_{wo})}{\ln \frac{(T_{wt} - T_p)}{(T_{wo} - T_p)}}$$

To provide an even distribution of temperature throughout the greenhouse, the pipes are placed parallel to the structure's length. The number of pipes (n) is determined by (El-Fiky, 2009):

$$n = \frac{L_s}{L_{s,h}}$$

Where L_s denotes the pipe length (m), H indicates the pipe burial depth (floor surface to pipe) (mm), d denotes the pipe outside diameter (mm), λ_j represents the earth heat conductivity ($\text{W/m } ^{\circ}\text{C}$), t_m symbolizes the log mean temperature difference ($^{\circ}\text{C}$), T_{wi}

connotes the water inlet temperature ($^{\circ}\text{C}$), T_{wo} signifies the water outlet temperature ($^{\circ}\text{C}$), T_p indicates the floor surface temperature ($^{\circ}\text{C}$), and $L_{g,h}$ is the greenhouse length.

Wind Turbine

Ducted Wind Turbine is also a significant part of our study since wind energy is a largely untapped field. An hourly data set for numerous locations is missing from the current study. Consequently, we have developed a numerical model of a wind turbine and evaluated its generating capabilities. The wind turbines accommodated on the agricultural field can produce electricity even with wind having low velocity [1].

$$P_{Turbine} = \frac{1}{2} \rho C_p A V^3$$

where, ρ is the wind density (kg/m^3), C_p is the coefficient of performance, A is the swept area of blades (m^2), V is the wind speed and $P_{Turbine}$ is the wind turbine power. The table 1 depicts the average wind speed in different locations in Bangladesh, referring to the general wind velocity found in cities does not produce enough energy to pay for wind turbine installation.

Ducted wind turbine guides the incoming wind to the blades and makes a uniform and more powerful flow. Bontempo and Manna (2014) conducted a computational study and found that ducted turbines can overcome the theoretical Betz limit of 0.53 and have power coefficient of 0.6 or a little more than that. This will directly increase wind turbine output. Figure 2 depicts computed power coefficient versus rotor thrust coefficient for open and ducted turbines.

Current study followed Dhakshinamurthy et al. (2018) foot mark to assume wind turbine specification suggested that NACA series 63415 turbine blades as it gives better performance than most other alternatives. Authors simulated energy generation results in MATLAB and conducted an economic analysis

Table 1: Average wind speed in different locations of Bangladesh

Sta tions	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann -ual
Dhaka	1.23	1.6	2.59	4.21	3.8	3.7	3.64	3.21	2.24	1.28	0.93	0.92	2.45
Chitta- gong	2.54	3.27	5.03	7.54	7.44	8.77	8.87	7.92	5.56	3.06	2.14	2.11	5.37
Comilla	1.16	1.58	2.81	4.3	4.36	4.64	4.73	4.1	2.69	1.44	0.89	0.88	2.82
Cox's Bazar	3.6	3.85	4.3	4.84	5.36	6.15	6.41	5.75	4.2	3.15	2.93	3.13	4.48
Rajshahi	1.64	1.77	2.26	3.4	3.73	3.55	3.24	2.9	2.45	1.53	1.45	1.66	2.46
Ishurdi	1.57	1.75	2.64	4.62	4.92	4.73	4.23	3.85	2.89	1.58	1.34	1.53	2.98
Sayeed pur	2.67	3.14	4.6	4.76	4	3.73	3.56	3.05	2.74	2.12	2.04	2.24	3.22
Mongla	1.86	2.05	2.71	3.96	4.17	3.98	3.7	3.46	2.71	2.87	1.45	1.5	2.78
Jessore	1.38	1.85	3.42	6	6.25	5.41	4.84	4.29	3.37	1.71	1.19	1.11	3.42

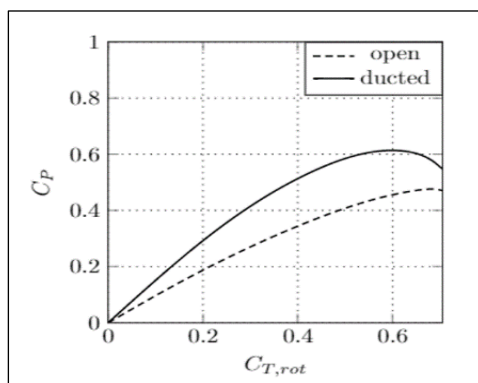


Figure 2: Computed power coefficient versus rotor thrust coefficient for open and ducted turbine

Cost of Small Wind Turbines:

A regular initial cost of £1500 in the United Kingdom for roof mounted small wind turbines (<1kW) without technical specifications or scalability options (Checktrade, 2020). In general, the cost in Bangladesh will be significantly less. Also roof mounted wind turbine guidelines and standards haven't been provided by Bangladesh to facilitate us to study. But we have analyzed wind turbine performance for different locations to determine suitable wind turbine installation sites. Emission analysis is not required as wind turbines do not produce any waste or exhaust.

Solar PV:

We plan to cover the main electricity demand of farming, irrigation pump, by solar energy. First, to fix our scenario, we took rice field as our study site. T. Aman and Boro rice is one of the most water-hungry crops cultivated in Bangladesh and the staple food of the country. It needs 1212 mm irrigation throughout its 180-day-long cultivation period starting from mid-October to mid-April (Hossain et. al.,2017). Farm area is chosen 0.5 hectare in a sense that average farmland a farmer owns in Bangladesh is less than 0.6 hectares (The Financial Express, 2022). As a standard irrigation pump available in Bangladesh, we chose WALTON WPHF-5A-1.5 centrifugal pump having rated power of 1.5 HP that equals to 1.1kW. It operates at 180-240 V and is able to discharge 150-450 liter/min (waltonbd.com). We assumed 400 liter/min discharge rate. With all the data, we calculated the average electricity demand to be 1615.82 Wh/day that needs to be met with solar energy.

During the cultivation period October-April, critical solar insolation was 4.21 hours in the month of December (Mondal and Islam, 2009). Solar energy harnessing system was simulated using HOMERPro. Solar PV array sizing was done using appropriate calculations. According to the optimal design recommended by HOMERPro, our used components were:

Solar PV: LONGi Green Energy Technology Co. Ltd. 375LR6-72PH-375M

Battery: BAE SECURA SOLAR 12V 1 PVS 70

Inverter: Beyond Building Group SR1500TLI (240V)

The chosen components are taken from HOMERPro library. PV array sizing is done using the following method:

Array Sizing: Average daily DC energy consumption for critical design month is calculated 1616 Wh/day as mentioned before. The DC system voltage is taken = 24 VDC. Average solar insolation in Bangladesh is 4.21 hour/day. Battery charging efficiency is assumed 90%. So the required array maximum power current is:

$$I_{array} = \frac{E_{crit}}{\eta_{batt} V_{SDC} t_{PSH}}$$

Soiling de-rating factor is assumed 0.95, as per high rainfall frequency in Bangladesh. Therefore, rated array maximum power current is calculated as:

$$I_{rated} = \frac{I_{array}}{C_s}$$

According to the model of PV module taken for simulation, temperature co-efficient is -0.379°C and maximum module temperature is 45.8°C . Rated array maximum power voltage is calculated by

$$V_{rated} = 1.2 * \{V_{SDC} * [V_{SDC} C_{\%V} * (T_{max} - T_{ref})]\}$$

From the values calculated, the required array size is obtained which is 6 X 2, totaling 12 modules, providing 4440 W power in total.

Table 2: PV array sizing

Description	Symbol	Values	Unit
Average daily DC energy consumption for critical design month	E_{crit}	1616	Wh/day
DC System Voltage	V_{SDC}	24	VDC
Critical design month insolation	t_{PSH}	4.21	Hr/day
Battery Charging efficiency	η_{batt}	90	%
Required array maximum power current	I_{array}	17.77	A
Soiling de-rating factor	C_s	0.95	
Rated array maximum power current	I_{rated}	18.2	A

Temperature coefficient for voltage	$C_{\%V}$	-0.379	/°C
Maximum expected module temperature		45.8	°C
Rating reference temperature		25	°C
Rated array maximum power voltage		255.84	VDC
Module rated maximum power current		9.90	A
Module rated maximum power voltage		48.50	VDC
Module rated maximum power		370	W
Number of modules in series		6	
Number of module strings in parallel		2	
Total number of modules		12	
Actual array rated power		4440	W

RESULTS AND DISCUSSIONS

Greenhouse Heating using Geothermal Energy:

Generally during winter, temperature is around 20-22 degrees Celsius in Bangladesh. But there is low temperature in the northern part of the country where temperature may get as low as 10 degrees Celsius. So we numerically evaluated greenhouse heating system operation feasibility by geothermal heating. The main cost components here are hole-boring, pipe arrangement and initial system setup. Pipe cost is taken from a regular website (indiamart.com, 2022).

The authors analyzed pipe length requirements for proper soil heating following the validated method of Fahmy et al. The results found are shown in Table 3:

Table 3: Geothermal Energy in Greenhouse Heating

Crop	Location	Month	Location Temperature	Soil Temp at 1km	Heat Loss (W)	Geothermal water in	Geothermal Water Out	Pipe Length (m)	Estimated Cost (Taka)
Maize		Dec.	17	42.6	24571	40.6	32.6	429	12878
		Jan.	14.9	40.5	30715	38.5	30.5	670	20091

Optim m Temp-eratur : 25°C	Cox's Bazar	Feb.		43.4					
			17.8		22182	41.4	33.4	360	10809
		Dec.						268	
	Sylhet		15.3	35.2	29689	33.2	25.2	3	80480
		Jan.	12	31.9	39927	29.9	21.9	764	22926
		Feb.							
	Dinaj-pur		15.5	35.4	29520	33.4	25.4	1	65416
		Dec.	12.1	60.8	39587	58.8	50.8	260	7789
		Jan.	9.2	57.9	48459	55.9	47.9	353	10578
		Feb.	13.8	62.5	34401	60.5	52.5	213	6399
		Mar.	17.8	66.5	22114	64.5	56.5	122	3646
Wheat/ Potato/ Cabbage : 20 Degree Celsius	Cox's Bazar	Dec	42.6	17	9214	40.6	32.6	55	1662
		Jan	40.5	14.9	15357	38.5	30.5	107	3213
		Feb	43.4	17.8	6825	41.4	33.4	39	1169
	Sylhet	Dec	35.2	15.3	14333	33.2	25.2	166	4978
		Jan	31.9	12	24571	29.9	21.9	540	16206
		Feb	35.4	15.5	14162	33.4	25.4	160	4801
	Dinaj-pur	Dec	60.8	12.1	24230	58.8	50.8	69	2058
		Jan	57.9	9.2	33103	55.9	47.9	103	3085
		Feb	62.5	13.8	19043	60.5	52.5	51	1537
	Bogra	Mar	66.5	17.8	6757	64.5	56.5	16	489
		Dec	42.8	13.3	20476	40.8	32.8	123	3683
		Jan	39.6	10.1	30372.82	37.6	29.6	232	6934
		Feb	44.2	14.7	16210.21	42.2	34.2	89	2671

Installing a vertical loop geothermal system cost around \$20000- \$25000 (Rafferty, 2013) converts to Tk. 200,000 approximately including pipe and accessories cost. Payback period of this system varies on numbers of parameters including crop yield in off-season, price of crops etc, so, payback period hasn't been determined for simplicity. But geothermal heating will enable the farmers to cultivate various crops even in unfavorable weather. This will surely increase crop yield and pay them back to recover from the initial high cost of geothermal system installation.

Wind Turbine

Figure 3 depicts the Simple Payback Period (SPP) for main cities in Bangladesh. Wind energy is a major source of renewable energy where turbine blades are powered by wind speed. Due to their size, wind turbines are typically limited to specific sites. Venters et al. (2018) shown, however, that ducted wind turbines (DWT) are suitable for installation in large buildings and perform well enough to contribute significantly to energy supply, as will be discussed in greater detail in the following sections of the paper. We demonstrated how a wind turbine can be included into a building's electricity system.

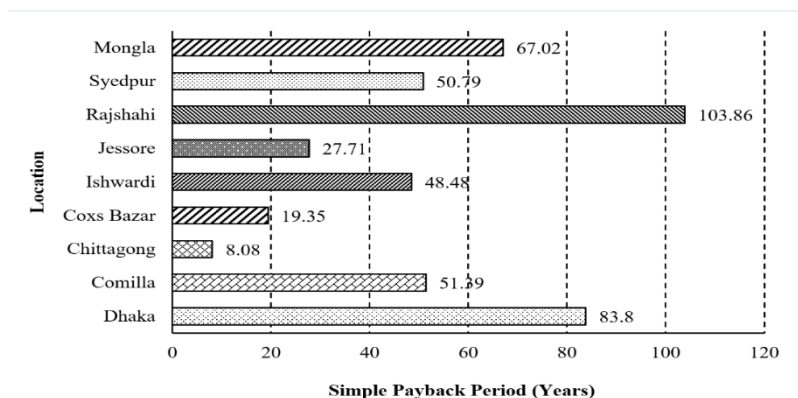


Figure 3: Simple Payback Period of Wind Turbines in Different Locations

Although wind speeds in the bulk of Bangladesh are below the ideal range, sufficient wind speeds exist in the south and along the coast to operate a wind turbine efficiently. Using a Ducted Wind Turbine (DWT) as a remedy may result in increased wind speed and orderly flow, hence facilitating the turbine's rotation and consequent energy production. We took some locations' wind speed (Table 4a) and conducted a numerical analysis with MATLAB. Total energy generation data is also shown in Table 4b.

It can be observed that Chattogram and Cox's Bazar show economically beneficial results with only 8 years and 19 years of payback period respectively. Generally, wind turbines last 20-25 years with proper maintenance (Twi-global.com. 2020). So, the other locations of the country show little promise. But from an environmental point of view, wind energy is one of the best options for us. There is no emission, and the end-of-life wastes can be recycled upto 85% (Gignac, 2020). The southern part of the country can use wind energy to power the farms and adopt clean energy while depending less on grid energy.

\Table 4a: Economic analysis of using DWT

Location	Total Energy Generated (kWh)	Annual Savings (Tk.)	Simple Payback Period (Years)
Chattogram	3292	18567	8.08
Dhaka	317.44	1790	83.78
Comilla	517.5	2917	51.39
Cox's Bazar	1374.7	77533	19.35
Ishwardi	548.65	3094.4	48.48
Jessore	959.74	5413.0	27.71
Rajshahi	256.06	1444.2	103.86
Syedpur	523.66	2953.5	50.79
Mongla	396.83	2238.1	67.02

Solar PV

Our estimated Levelized cost of electricity (LCOE) is only 0.116\$, which is cheap and affordable. So solar energy can easily replace traditional grid electricity. The solar energy system generates 2259 kWh/year, quickly covering the half-yearly demand of 286 kWh. The excess electricity can be used for other applications such as powering a home, running other agricultural equipment, etc.

Table 4b: Net Present Costs

BAE SECURA SOLAR 12V 1 PVS 70	\$360.00	\$0.00	\$132.56	-\$49.1	\$0.00	\$443. 43
Beyond Building Group SR1500TLI (240V)	\$112.87	\$0.00	\$47.89	-\$9.01	\$0.00	\$151. 75
LONGi Green Energy Technology Co., Ltd. 375LR6-72PH- 375M	\$292.21	\$0.00	\$0.00	\$0.00	\$0.00	\$292. 21
System	\$765.08	\$0.00	\$180.45	-\$58.15	\$0.00	\$887. 38

Solar PV module daily generation can be realized from the following contour map. The module produces around 0.8-1.0 kW on average throughout the year. We see some blue dominance in the months of July to September due to the monsoon that depicts that solar power generation is less, and close to 1.3 kW of power is produced in the months of February and March when the summer is about to start. Figure 4 depicts LONGi green energy output and Figure 5 represents state of charge of Secura solar battery bank.

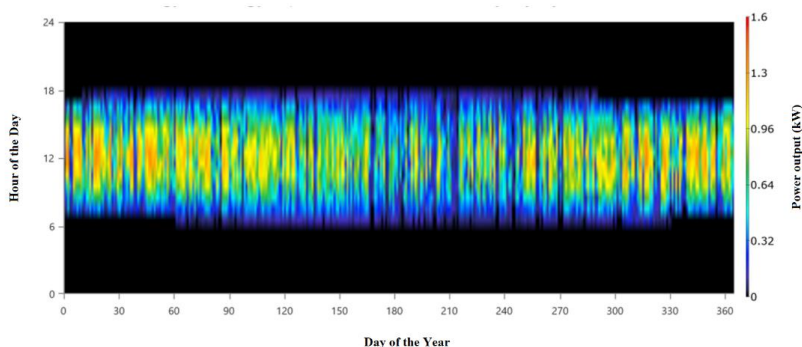


Figure 4: LONGi Green Energy Output

Battery Bank Performance

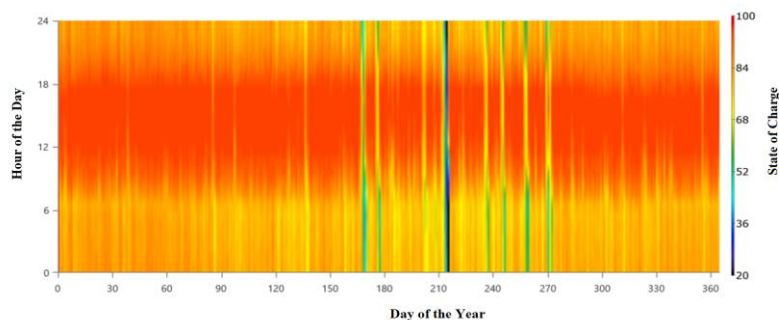


Figure 5: State of change of Secura Solar Battery Bank

6 units of battery is used in parallel to match the voltage and Ah ratings of our desired system. The state of charge map shows us that the bank is charged a great deal during daytime. Again, in monsoon, we see a huge drop of the charging state of the battery due to lack of sunlight that ends up using more energy harnessed from battery.

Table 5: BAE Secura Solar 12 V 1 PVS 70 Statistics

Quantity	Value	Units
Autonomy	57.2	Hr
Storage Wear Cost	0.7	\$/kwh
Nominal Capacity	4.82	kWh
Usable Nominal Capacity	3.86	kWh
Lifetime Throughput	5616	kWh
Expected Life	17.5	year

Battery autonomy is 57.2 hours in a year and is expected to last 17.5 years using in this fashion. Overall, the LCOE is around Tk. 11 per kWh that is very affordable and sustainable. If disposed of properly, it will not adversely affect the environment and there is no direct CO₂ emission associated to its use.

CONCLUSION

Renewable energy potential for agricultural use was conceptualized in this paper in the context of Bangladesh. Bangladesh is bestowed with natural resources, and there is much potential to use solar energy, geothermal energy, and wind energy for agriculture. Relying on renewable energy will not only be beneficial to the environment but also help to reduce electricity demand and grid dependency. Remote areas of the country where the grid connection is scarce can adopt these modern technologies to become self-reliant. Geothermal heating utilization is an untapped field. Few works have been done to use geothermal energy in Bangladesh. The authors researched the feasibility of using a vertical loop geothermal heating system to heat greenhouses and cultivated crops in adverse weather conditions. Soil heating technology has been adopted, and the authors observe

realistic cost estimation to install the system and get benefitted from it. Crop yield can be diversified by following the technique and the estimated cost is below 100,000 Tk.

Wind energy is another big part of the study. The ducted wind turbine has been used in agricultural fields as wind velocity in major parts of the country is insufficient to produce energy by a traditional open wind turbine. Ducted wind turbines provide the increased value of C_p , hence increasing energy generation. A numerical study was done using MATLAB, and a simple economic study was done to check for feasibility.

The solar photovoltaic module has initiated a revolution in Bangladesh as solar insolation is high in this geographical area. It can be utilized to meet the electricity demands of farming. We carried out a simulation project to determine the optimum solar PV system according to the loading size. The system consists of a PV array module, inverter, and battery bank. The initial cost of installing the system is about 90000 Tk, and the Levelized Cost of electricity is 12 Tk. Per kWh looks very promising and affordable. In the future, this will get cheaper as the technology develops and yields more energy. Combining all these renewable energy systems will make our agricultural sector more resilient to any energy scarcity occurrence. Also, it will facilitate mechanization and modernization of agriculture which has no alternative in the coming days of global development.

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RENEWABLE ENERGY IN BUILDINGS OF BANGLADESH: A NANO-GRID APPROACH

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Abstract

Bangladesh's current 53.65 billion kWh electric demand is met by 146 gas, coal, and diesel-based power plants with 68% requirement for buildings. Bangladesh is vulnerable to climate change and hence requires renewable energy use in buildings with national grid contribution. Increasing reliance on renewables in buildings can lead to achieve the government of Bangladesh's goal to obtain 30% of total energy from renewables by 2030 under its Mujib Climate Prosperity Plan (MCCP) (CRI, 2021). Bangladesh can adopt grid integration from renewables like numerous developed and developing countries (Norway- 99%, Sweden- 67%, Italy- 41.4%, Argentina-24.5%, USA- 20.5%, India- 20.4% etc.) to combat climate change and achieve sustainable development (Enerdata, 2022). Typically, buildings in Bangladesh require electrical power and cooling. In this climate, heating is only required during the three-month winter season. Integration of renewable energy sources like solar, wind, biomass etc, to meet such electric demands with grid contribution can help Bangladesh to achieve its 2030 energy goal. In this study, a typical medium sized three-storied office building has been used as reference with simulated hourly electrical, heating and

cooling consumption for a year. We discussed the use of combined cooling, heating, and power (CCHP) system with a single prime mover in a nano-grid system (a number of homes together that make an energy consumption and generation unit), introduced the concept of green roofs to promote water-energy-food-climate nexus and presented an approach for optimizing the system to enable the usage of renewables in buildings. Our analysis shows that optimization of CCHP system reduces emissions greatly from buildings and can be economical having payback period ranging 1-6 years only. The addition of roof mounted wind turbine resulted highest energy savings of about 11000kWh and cost savings of Tk. 61,890 annually. Roof mounted solar PV module integration had also been analyzed and it was found that more than 1.33 MWh solar energy can be harnessed. Adding green roof reduces cooling demand in a great deal and further helps with CO₂ emission reduction. Thus, wide adoption of renewable energy can meet the objectives of COP26: attaining a net-zero economy and phase-out of coal power.

INTRODUCTION, MOTIVATION AND BACKGROUND

Introduction

Buildings are the largest energy consumer and also the largest source of energy inefficiency in the world. So, they may be the most feasible target for accomplishing the common objective of sustainable development. However, excessive building energy use has detrimental effects on the environment, including air pollution, the greenhouse effect, and the urban heat island effect, all of which can have a severe impact on human health and societal economic progress (Pan Y, 2020). The primary source of environmental pollution is fossil-fuel-based energy which account for 84.7% of world energy use. On the other hand, renewable and nuclear energy sources contribute 5% and 4%, respectively, of total primary energy consumption (BP Statistical Review of World Energy, 2019).

Energy is used for a multitude of reasons during the lifecycle of a building. Among them Heating, Ventilation and Air Conditioning (HVAC) systems is used to maintain comfortable temperatures throughout the year which consume about 94. percent of the total

energy in building energy usage (Scheuer, 2003). From Bangladesh's perspective, majority of this energy is coming from fossil fuels. Being a country with low fossil fuel reserves and to reduce the government expenditure on fossil fuel imports we need to adapt passive technologies and renewable energy sources like solar, wind, geothermal, biofuel, etc to serve buildings' energy demand.

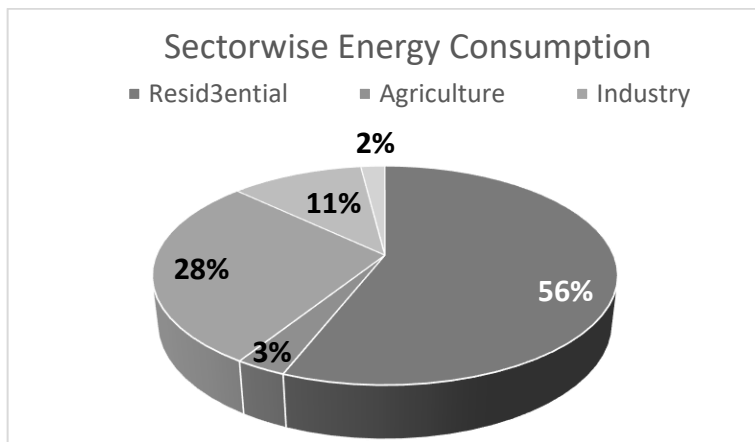


Figure 1: Sector Wise Electricity Consumption in Bangladesh (Annual report, Bangladesh Power Development Board, 2020-21)

Bangladesh's focus on sustainable development and industrialization is critical as the country enters the fourth industrial revolution. From Fig.1, it is evident that residential and commercial energy consumption accounted for almost 70% of total electricity consumption in fiscal year 2020-21. Integrating cutting-edge renewable energy technology with CHP/CCHP systems will go a long way toward promoting more energy-efficient systems in buildings. We seek to pave the road for the adoption of current technologies that maximize the use of renewable energy in building systems while minimizing grid electricity usage and fossil fuel exploitation. Natural gas is the most often used fuel in households.

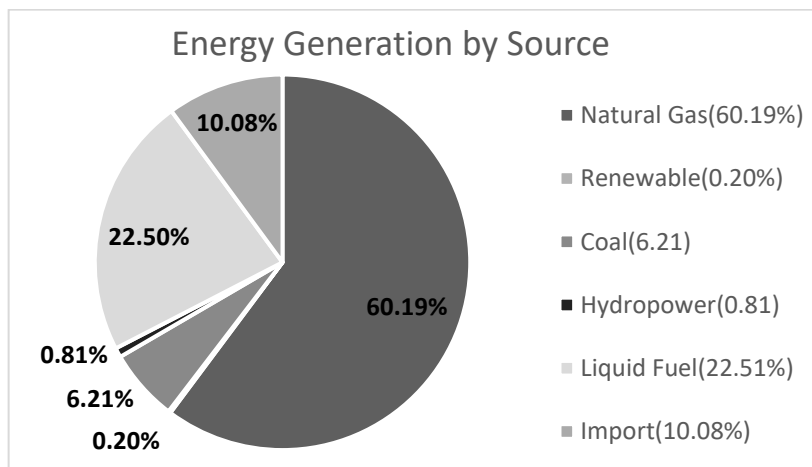


Figure 2: Energy Generation Source in Bangladesh (Annual report, Bangladesh Power Development Board, 2020-21)

According to 2021 data, 60.19% of power is generated using gas/LNG as a fuel as we can see from Fig. 2. Together, liquid oil and coal account for little less than 30%. Thus, our power generation industry remains significantly reliant on fossil fuels, even though the most successful off-grid solar energy project in the world is located here (OKR,2021). To maximize the use of renewable energy, Bangladesh should prioritize social awareness, government incentives, the availability of technical equipment and support etc.

Literature Review

Observing the importance of building energy in global energy consumption, lots of research has been done regarding this topic all over the world and lately renewable energy is being implemented into the energy supply system to reduce the burden on fossil fuel. The works provide various important discoveries and observations regarding CCHP and renewable energy system implementation in buildings. Hasan et al. (2018) conducted optimization simulation on a two-storied building and succeeded in reducing electricity consumption and CO₂ emission. Rezaie et al. (2010) concluded that

solar energy is one of the most economical renewable energy sources available. Abohela and Hamza (2013) introduced Building Augmented Wind Turbine to accelerate wind speed and increase wind turbine energy yield. Tabassum and Baten (2020) observed indoor temperature drop by using green roof and thus leading to less energy consumption for cooling.

Current Status of Renewable Energy in Bangladesh

Since 2008, the Bangladesh government issued its Renewable Energy Policy. This policy has not been updated in the interim. The policy included a number of aims and goals, of whom, some major objectives relevant to our issue are the following:

- a) Harness the potential of renewable energy resources and spread renewable energy technology in rural, peri-urban, and urban areas.
- b) Develop sustainable energy sources to replace non-renewable energy sources indigenous to the region.
- c) Increase the contribution of renewable energy to electricity and heat production.
- d) Train and promote the use of renewable energy at all levels of energy use.
- e) Promote indigenous technology development in the field of renewable energy.
- f) Attain the targets for developing renewable energy resources to meet 5% of total electricity consumption by 2015 and 10% by 2020.

We have the world's largest solar energy project, which illuminates rural areas and lowers rural communities' reliance on grid electricity and fossil fuels. Infrastructure Development Company (IDCOL) is a public-private partnership (PPP) company that runs numerous renewable energy projects including Solar Home System (SHS) Program, solar mini-grid project, biogas and bio fertilizers etc. They have installed over 4.13 million SHS, 26 solar mini-grids throughout the country. Also more than 13 thousand biogas plants have been installed in the Dhaka division alone (IDCOL, 2022). However, the target renewable energy contribution to electricity generation by 2022 remains unachieved.

Table 1: Previous works on renewable energy in buildings

Serial No.	Topic	Focus	Location of Research	Overview	Methodology	Discussion Outcome and	Comments	Authors (Year)
1	Energy in Bangladesh	Current status and future energy mix	Bangladesh	Discussed current energy breakdown and proposed future sustainable mix	Calculated unit rate by varying coal, natural gas and renewable energy (RE) percentage for optimization	Presented the current energy scenario of Bangladesh and proposed future energy mix for economic energy generation and supply	They concluded that 25% coal, 25% gas and 35% RE fights best against emission	Das et al. (2020)
2	Building Energy	Potential of renewable energy (RE) in building energy	Global	Different RE sourced active and passive systems have been discussed	Discussed methods are: Light tube, solar PV, building integrated wind turbine, geothermal heat pump etc.	Possible use of renewable energy in buildings through active and passive solar, wind, geothermal, biomass and hydrogen energy systems	Active and passive systems ensure maximum utilization of RE	Yuksek and Karadag (2020)
3		Method of Building energy system for less CO ₂ emission	Ontario, Canada	Compared optimized energy performance	Drew analysis among 4 buildings considering budget, emission and reliability	Determined that the most effective method for reducing carbon Dioxide emissions is mixed systems, where both active and passive systems are used together	Hybrid systems are found to be most environmentally friendly, but solar power is the most economical one	Rezaie et al. (2010)

Table 1: Contd.....

Serial No.	Topic	Focus	Location of Research	Overview	Methodology	Discussion and Outcome	Comments	Authors (PYear)
4		Energy analysis in a commercial building	Khulna, Bangladesh	Conducted energy analysis on a building to inspect energy use pattern	Used 3D model in BIM and ran analysis on the reduction of energy consumption after optimization	Performed energy analysis in a two-storied commercial building and simulated optimized energy system using solar PV, green roof and changed window-wall ratio. They observed a reduction of electricity consumption and net CO ₂ emission, concluding a good model of energy efficient building	9% electricity consumption and 3 tons of CO ₂ emission reduction has been achieved	Hasan et al. (2018)
5		Optimization of Hybrid energy system	Feni, Bangladesh	Proposed hybrid energy system for minimized cost	Hybrid energy system was simulated with HOMER and results are analyzed	Designed hybrid diesel-solar-wind based energy for cost reduction and emission reduction in coastal areas of Bangladesh	Solar-wind-diesel hybrid system gives lower cost than existing system	Zubair et al. (2013)
6		Sustainability analysis of building through exergy	Bangladesh	Investigated sustainability and exergy potential in residential sector	Various parameters were calculated to connect energy, exergy and sustainability parameters	Exergy-based case study to determine sustainability of residential sector of Bangladesh and resolved that LNG cooking stoves and oil lighting are most responsible for irreversibility. They suggested using electrical alternatives instead.	Suggested that electrical appliances cause the least exergy, hence recommended mostly	Chowdhury et al. (2020)

Table 1: (Contd.)

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Serial No.	Topic	Focus	Location of Research	Overview	Methodology	Discussion and Outcome	Comments	Authors (Year)
7	Solar energy	Design of asymmetrical solar collector	Athens, Greece	Attempted design for efficient solar collector	Solar space heaters, cookers etc. were designed using CAD separately	Proposed different designs of asymmetrical solar collectors and evaluated the parameters that dictate the feasibility of solar energy implementation in a building.	Different types of asymmetrical solar collectors and heaters show best performance	Tzivani and Bellos (2018)
8	Wind Energy	Ducted Wind Turbine	USA	Optimized Ducted wind turbine	Numerical evaluation using data from UIUC airfoil database	Ducted Wind Turbine (DWT) optimization for buildings	DWT achieves greater C_p than Betz Limit and gives more power output	Venters et al. (2017)
9		Change in roof shape to facilitate air flow	Bangladesh	Suggested to change roof shape to accelerate wind	Computational Fluid Dynamics (CFD) analysis was done using ANSYS Fluent	Proposed changing roof shape for accelerating wind to facilitate roof mounted wind turbine operation in the context of Bangladesh. Promoted the concept of Building Augmented Wind Turbine (BAWT).	Wind velocity can almost be doubled passing it through half circular wall	Abohela and Hamza (2013)
10	Green Roof	Thermal performance of green roof	Bangladesh	Green roof thermal performance analysis	Conducted real-life study on 8 buildings and analyzed thermal performance by using green roofs.	Roof top gardening may contribute to as much as 2.5-degree Celsius temperature drop indoors in contrast to only 0.6-degree temperature drop when rooftop plants are not planted.	Using green roof significantly reduces cooling demand	Tabassum and Baten (2020)

The Renewable Energy policy established the Sustainable and Renewable Energy Development Authority (SREDA). They are aiming to expand renewable energy (most notably solar energy) around the country and are regularly issuing statistical reports to track progress.

The anticipated 10% proportion of renewable energy in electricity generation is significantly more than what we achieve. We generate less than 0.20% of our electricity from renewable sources (Fig. 2). Bangladesh is one of the most vulnerable countries to global warming, so we must accelerate our efforts toward and beyond our objective.

Table 2: Renewable Energy Mix in Bangladesh (SREDA, 2022)

Technology	Off-grid (MW)	On-grid (MW)	Total (MW)
Solar	347.4	196.0	543.4
Wind	2	0.9	2.9
Hydro	0	230	230
Biogas to Electricity	0.7	0	0.7
Biomass to Electricity	0.4	0	0.4
Total	350.5	426.9	777.4

To encourage the expansion of electricity generation from renewable energy, the 2018 Net Metering Guideline was established. Until recently, over 50 nations, including our neighbors India and Sri Lanka, have successfully implemented net metering schemes. Net energy metering (NEM) enables excess electricity generated from renewable sources after self-consumption to be supplied to the distribution grid, in exchange for which the prosumer (consumer who also produces electricity) can either import equal amounts of electricity from the grid or receive

the price of the net amount of exported electricity at the end of the settlement period as specified in this guideline. Thus, the consumer gains control over the amount of electricity consumed from the grid and any excess electricity generated by rooftop solar systems or other renewable energy sources after self-consumption. A schematic diagram of the Net Metering System is shown in Fig. 3.

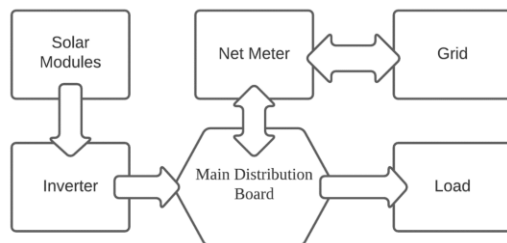


Figure 3: Net Metering System Schematic Diagram
(Conceptualized from Chowdhury and Khan (2020))

Wind energy is a big aspect of promoting renewable energy in Bangladesh. BAWT has made it possible to install small-scale wind turbines in large structures, rendering outdated the notion that wind turbines must be extremely tall and located in open fields. Geothermal energy, biomass energy also have potential to meet our national energy demand in a great deal.

Current policies of developing countries compared to Bangladesh:

Renewable Energy Policy of India:

India is pursuing renewable energy utilization in power generation aggressively. They have already developed the infrastructure necessary to generate 37 percent of power from renewable sources, which equated to 142 GW in 2022 (The Indian Express, 2022). They aim to achieve 175 GW of renewable energy generation capacity. India has established countrywide competitive auctions for wind and solar photovoltaic (PV) energy.

The Indian government offers financial and technical assistance for rooftop photovoltaic systems. Solar and biomass energy dominate India's renewable energy sector. Wind power, while still a minor component of the national supply, has grown rapidly over the previous decade, averaging 14% annual growth and accounting for 3.3% of total energy output in 2017.

The Indian government has implemented several policies such as Renewable Purchase Obligation (RPO), Hydro Purchase Obligation (HPO), and Renewable Energy Certificates (REC) to promote renewable energy generation among businesses and to ensure economic feasibility. The State Electricity Regulatory Commission (SERC) supervises and monitors RPOs, HPOs, and RECs. Such policies and regulations have aided renewable energy in gaining a foothold in power generation, hence reducing reliance on fossil fuels (IEA, 2021).

Renewable Energy Policy in Nigeria:

The Renewable Energy Master Plan (REMP) 2006 of Nigeria aims to boost the percentage of renewable energy in Nigeria's power output from 13% in 2015 - primarily from hydropower - to 23% in 2025 and 36% by 2030. A significant factor driving this rise is the diversification of the country's electrical mix. Hydro, solar photovoltaic, wind, biomass, and solar thermal technologies all have installed capacity targets. Installed capacity for small hydro should reach 2,000 MW by 2025, 500 MW for solar PV, and rapidly increase from 50 MW in 2015 to 400 MW by 2025 for biomass. Wind energy capacity should reach 40 MW by 2025. Simultaneously with this growth in produced electricity, the REMP aims to boost electricity availability in both urban and rural regions, from 42% in 2005 to 60% in 2015 and 75% in 2025. Concerning the institutional framework for renewable energy (RE) deployment, the REMP emphasizes the importance of establishing a specialized fund and agency, the Nigeria Rural Electrification Agency (NREA). Additionally, the REMP establishes a series of fiscal and commercial incentives to encourage RE deployment. In the medium term, the strategy calls for an import duty moratorium on renewable energy technology. In the long term, the plan envisions

the elimination of customs duties on imported renewable energy equipment, as well as the adoption of tax credits, capital incentives, and preferential financing options (IEA, 2013).

Renewable Energy Policy in the Philippines:

The 2008 Renewable Energy Act establishes the legislative and administrative framework for coordinating policies relating to the development of renewable energy technology. The Act intends to accelerate the Philippines' transition to 60 percent energy self-sufficiency by 2010 by developing and utilizing renewable energy sources such as solar, wind, hydropower, ocean, and biomass. The new law offers the renewable energy sector the following incentives:

1. A seven-year tax holiday on income and tax exemptions for carbon credits earned by renewable energy sources.
2. Once the income tax holiday expires, a 10% corporate income tax is also granted, rather than the standard 30%.
3. A 1.5 percent cap on real estate taxes on the initial cost of renewable energy equipment and installations.

Additionally, the law prioritizes the purchase, grid connection, and transmission of electricity generated by companies using renewable energy sources, and renewable energy produced will be tax deductible.

In comparison to other countries, Renewable Energy policy in Bangladesh was more aggressive but unfortunately, we are far behind our expected goals. The Scaling Up Renewable Energy Program for Bangladesh (SREP Bangladesh) was launched in late 2015 to highlight the country's renewable energy development and investment opportunities (IEA, 2017).

If implemented, the SREP Investment Plan would revolutionize Bangladesh, kicking off an aggressive push toward grid-connected renewable energy generation and continuous expansion of the country's off-grid electrification programs.

RESEARCH QUESTIONS AND HYPOTHESIS:

Following the National Renewable Energy Policy (2008) and Renewable Energy Act (2015), it is very important to initiate

extensive use of renewable energy to meet building energy demand. As domestic and commercial buildings take up almost 70% of the total energy demand, it is evident that influencing building energy consumption will be reflected directly in the national energy scenario. This raises several questions that need to be answered through research and scientific study:

- Is it possible to use hourly data to optimize and control energy consumption behavior instead of flat demand trend?
- Is there any mechanism, where individually generated excess electricity may add to the national grid? Consequently, can NEM be optimized to perform the best by using an intelligent CCHP control system?
- What type of renewable energy is the most suitable for implementation in building systems?
- How can we improve the energy policy to reach our goal with more pace and sustainable growth?

To shine a light on these questions, we are presenting a conceptual paper to show the promises and possibilities that renewable energy offers if associated with an intelligent CCHP system. Our hypothesis is:

- CCHP systems will be used by forming nano-grids throughout the community.
- Biomass/Biogas will power the prime mover that is the heart of the CCHP system.
- Roof mounted Solar PV and wind turbines will also be integrated into the building energy supply ecosystem.
- A hybrid energy generation system fueled by renewable sources will be in operation that will substantially reduce grid electricity consumption and improve building energy performance.
- Green roofs will be used in buildings to reduce energy consumption and supply vegetation attempting a water-energy-food-climate nexus framework.

GOALS AND OBJECTIVES:

Renewable energy utilization in buildings is beneficial in a variety of ways, including electricity generation, reduced pollution, and the load reduction in HVAC systems. Thus, the research objective is to investigate every feasible application of renewable energy in Bangladesh. We have the following objectives to accomplish the goals:

- a) to conduct research on various sources of renewable energy
- b) to incorporate the concept of CCHP systems to reduce reliance on grid energy supply
- c) to address the benefits of green roofs in urban farming and heat island effect reduction

Table 3: Steps proposed for employing renewable energy

N o.	Energy type	Steps to be taken	Expected Outcome
1	Solar	Install intelligent solar panels on rooftop	-Electricity generation during the day -Replacement of cooking gas
2	Wind	-Use the ducted wind turbine - Building Augmented Wind Turbine	-Electricity generation to reduce grid consumption
3	Biomass	Install bio waste collector system and biomass energy generator	-Generate electricity and reduce grid consumption -Alternative to cooking gas
4	Geothermal	Use geothermal energy to run HVAC systems in buildings near geothermal sites	Cooling (mostly) and heating demands will be met regardless of the supply of electricity.
5	Green Roof	Urban roof gardening	-Lower cooling demand and reduce air pollution -Production of vegetation and fruits
6	CCHP system	Build a CCHP system using prime movers fueled by renewable energy	-Efficient and minimal energy consumption -reduction of dependency on fossil fuel

The components of our proposed system and the expected outcomes after using those are tabulated in Table 3 for the convenience of study:

If properly integrated and synchronized in a building, these systems should greatly increase the energy performance, depending on its geographical location and technological availability. Thus, Bangladesh's energy scenario should significantly improve by expanding its reliance on renewable energy.

ACTIVITIES AND METHODOLOGIES:

Proposed Activities:

We aim to promote all kinds of renewable energy that are economically feasible to implement them into building energy supply systems and hence impact the national energy consumption in a positive manner. We will discuss 5 different aspects to improve building design and develop energy performance. They are: CCHP system, solar energy, wind energy, biomass energy, green roof. Our propositions and concepts on how to use them in buildings are demonstrated in the following section of the paper.

Implementation of CCHP System in Buildings The first step toward reducing building energy use is self-sufficiency. As part of the 'Net Zero' culture, commercial buildings and large residences should incorporate and standardize on-site combined cooling, heating and power (CCHP) systems. A CCHP system is one in which a prime mover generates electricity, and its exhaust heat is recovered and used to meet the heating and cooling demand. Heat recovered from the exhaust can be used to power either a heating coil or a chiller. In this instance, absorption chillers are typically utilized instead of classic compression chillers, as absorption chillers can generate cooling effect of using heat. K. Roman (2015) demonstrated that the Internal Combustion Engine (ICE) is the most efficient prime mover in a CCHP system. Typically, an ICE is powered by fossil fuel. However, we intend to power the prime

mover entirely using renewable energy namely biofuel. In the context of Bangladesh's weather, cooling requirements far outweigh heating requirements, yet it may be required to provide heating energy during specific seasons (during winter).

To date, there is no information accessible online concerning the CHP/CCHP system installation in Bangladesh. However, the prevalent idea in our country is to use grid electricity to power a variety of energy-consuming equipment along with a backup prime mover especially in commercial buildings (Fig. 4). In many buildings, a diesel generator may be installed to provide power only when the grid electricity is unavailable due to load shedding. Recovery of exhaust heat is an entirely new concept. However, if ICE is employed, an efficient and well-maintained CCHP system may cut energy use by 12.4% (K. Roman, 2015). While microturbines and phosphoric acid fuel cells are alternatives to ICE, they are not as commonly accessible in Bangladesh as ICE. We suggest the integration of CCHP systems into buildings, which will not only save energy but also significantly cut emissions and carbon footprint.

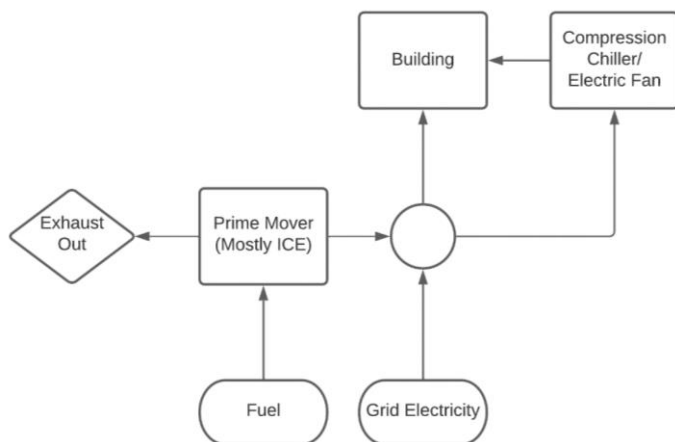


Figure 4: Current setup of energy in buildings

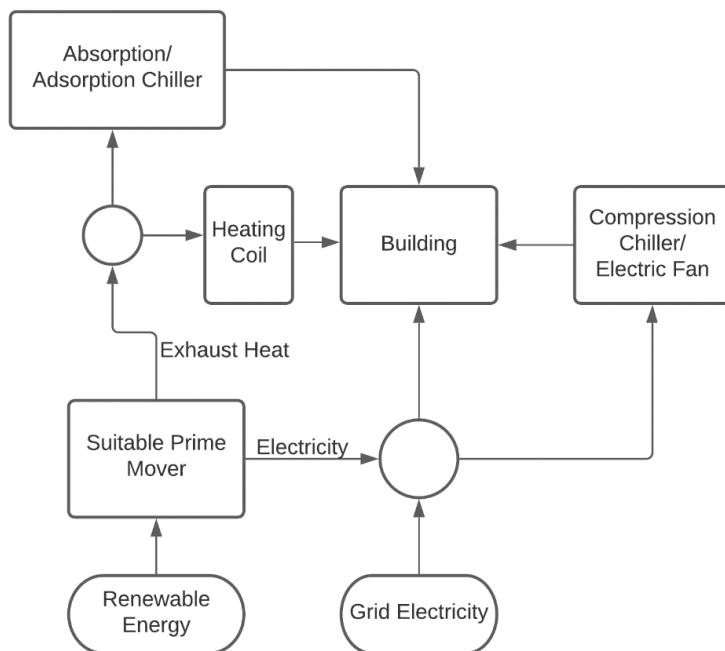


Figure 5: Proposed CCHP system with cooling and heating facilities

The suggested CCHP system (Fig. 5) will deliver the heating, cooling and electricity to the building, therefore minimizing the facility's reliance on grid electricity. The prime mover will be powered by renewable energy (solar, biomass, etc.) to reduce reliance on fossil fuels and emissions. The chiller will receive heat from the prime mover's exhaust. In the CCHP system we advocate employing an adsorption chiller rather than an absorption chiller since adsorption chillers may operate with environmentally benign refrigerants such as water, ethanol, and so on. If further cooling is required, a compressor chiller or an electric fan can be used.

Implementation of Solar Energy in Buildings:

Solar photovoltaic (PV) cells are prevalent in Bangladesh because of extensive promotion of solar energy in rural regions and

government control of solar panel installation in buildings. However, its contribution to the national energy supply is insignificant compared with total energy demand. We recommend that solar energy be used in a variety of ways to meet heating, cooling and electricity demand. A prototype diagram is provided in Fig. 6. We demonstrated two distinct ways to utilize solar energy: one is to directly contribute to the building's electrical supply via photovoltaic panels, and another is to use solar heat to power an absorption/adsorption chiller system that will meet a portion of the building's cooling requirement. The average solar radiation intensity is 4.24 kWh/m² (Mistry, 2009) in Dhaka, Bangladesh. Thus, maximizing the solar energy potential in Bangladesh is a significant step toward our objective of becoming a 'Net-zero' building.

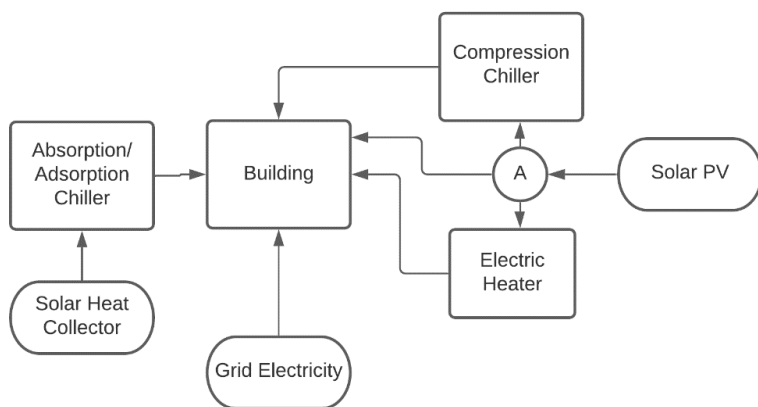


Figure 6: Implementation of Solar energy devices in buildings

Implementation of Wind Energy in Buildings:

In addition to the CCHP system and Solar PV, we have presented a customized wind turbine integrated system to power the building (Fig. 7).

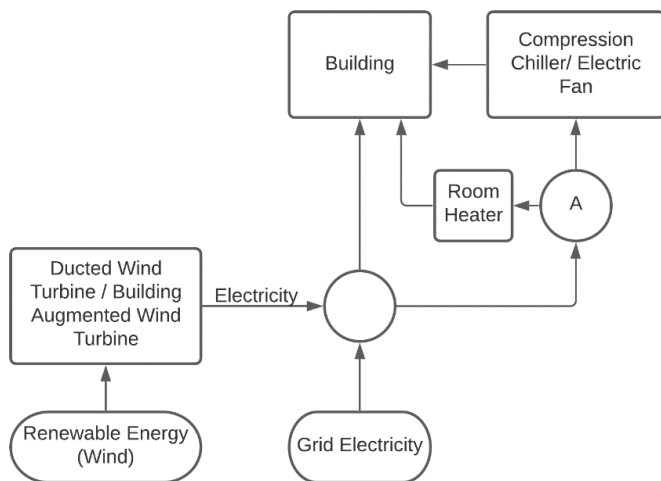


Figure 7: Proposed Wind Turbine Integration

Wind energy is a prominent type of renewable energy since it utilizes wind velocity to power turbine blades. Generally, wind turbines are limited to specific locations due to their vast size. However, Venters et al. (2018) demonstrated that ducted wind turbines (DWT) are appropriate for installation in big buildings and perform well enough to contribute considerably to energy supply, which will be described in further detail in the subsequent sections of the paper. We offered an illustration of how a wind turbine may be integrated into building energy system.

Although wind speeds are below the optimal range in the majority of Bangladesh (Fig. 9), the southern parts and coastline region have sufficient wind speeds to operate a wind turbine efficiently. As a solution, changing the roof shape of a building and constructing a Building-Augmented Wind Turbine (BAWT) may result in enhanced wind velocity with orderly flow, facilitating the turbine's rotation and subsequent energy generation.

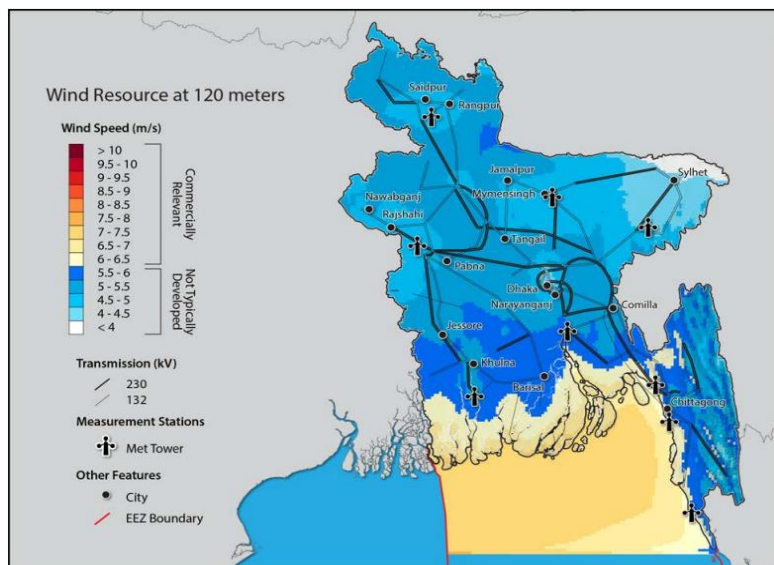


Figure 8: Wind Velocity Map of Bangladesh (USAID, NREL, 2018)

As seen in Fig. 8, coastal areas experience wind speeds of up to 7.5 m/s, whilst the majority of Bangladesh has wind speeds of approximately 4.5-6 m/s. BAWT can generate power at wind speeds as low as 2.24 m/s (Stankovic, 2009). According to Islam Abohela (2013), as the peak of the building climbs, the wind velocity increases and consequently the power output from a rooftop wind turbine. Islam (2013) conducted another study in which he investigated various roof shapes (Fig. 9) and discovered that installing wind turbines on barrel vaulted roofs might give 56% higher energy than a free-standing wind turbine in the same location.

We can observe that primary wind velocity of 4.4 m/s can go up to almost 9 m/s at its throat if passed through a half circular wall (Fig. 10). These data are very promising as it can open new dimensions in using personalized wind turbines in buildings to generate electricity leaving no carbon footprint.

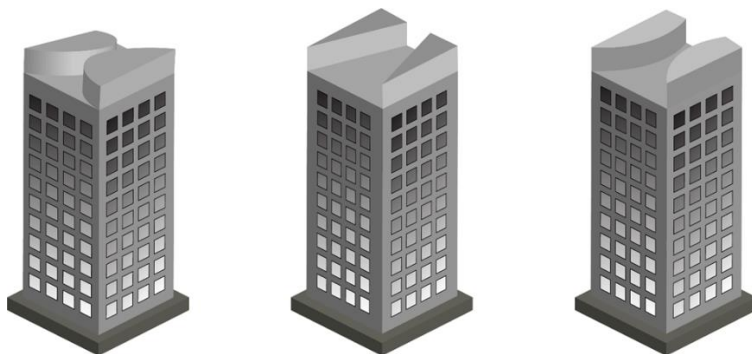


Figure 9: Differently Designed Rooftops tested to operate wind turbine (Abohela and Hamza (2013))

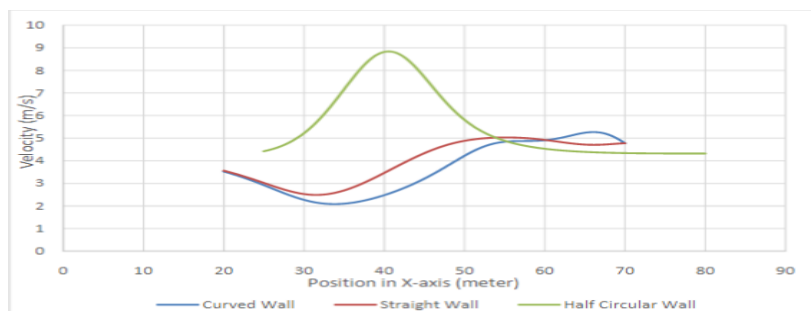


Figure 10: Acceleration of wind observed for different roof shapes (Adopted from Rahman et al. (2019))

Implementation of Biomass in Buildings:

Biomass has been a big fuel contributor in rural areas of Bangladesh where people don't get access to gas and electricity transmission systems. Energy can be generated using various types of biomasses. Some of them which are useful and stated below:

1. Agricultural Residue:

The agricultural residue could be used as biomass fuel in buildings. Table 4 shows the agricultural residue produced in Bangladesh in 2011. To understand the range of expected energy output, we can give an example that 3 kilograms of rice husk have the same amount of energy as 1 kg of fuel oil or 1.5 kg

of coal. The energy content of rice chaff is estimated to be around 16 MJ/kg (Das, 2014). The Higher Heating Value (HHV) of specific biomass reveals its energy content.

Table 4: Agricultural Residue Produced in Bangladesh in 2011 (Retrieved from Islam et al., 2021)

Crops	Production In 2011 (Million tons)	Fraction	Amount of Fraction	Crop residue (Million tons)
Rice	50.63	Straw	50.00	25.31
		Husk	20.00	10.13
Maize	1.02	Stalks	200.00	2.04
		Cobs	30.00	0.31
Wheat	0.97	Straw	65.00	0.63
Jute	1.52	Stalks	58.84	0.90
		Leaves	13.91	0.21
Sugarcane (Trimmed)	4.67	Bagasse	36.00	1.68
Mustard	0.23	Straw	75.00	0.17
		Husk	31.00	0.024
Coconut	0.08	Shell	24.00	0.019
Lentil	0.081	Straw	72.46	0.058
Total residue production is 41.66 (million tons) in 2011				

2. Municipal Solid Waste (MSW):

Table 5 showed the MSW Produced in Urban Areas of Bangladesh which could be used for biomass fuel as well. Municipal wastes empirically produce 0.076 cubic meters of gas per kg of waste. If we divide that with 0.71, we find the total possible energy that can be generated (in KW) (Nahian, 2016). In 2015, the theoretical electricity generation potential in Bangladesh was estimated almost 2700 MW.

Table 5: MSW Produced in Urban Areas of Bangladesh (Islam et al., 2021)

Year	Urban Populatio n	%Total populatio n	Waste Generatio n Rate	Total Waste Generatio n (tons/day)
1991	20,872,204	20.15	0.49	9873.5
2001	28,808,477	23.39	0.5	11695
2004	32,765,152	25.08	0.5	16382
2015	54,983,919	34.20	0.5	27492
2025	78,440,000	40.00	0.6	47,064

3. Forest Residue:

Table 6 shows another form of biomass fuel, forest products in Bangladesh. It is common for timber mills and some other industries to use saw dust as fuel.

Table 6: Forest products in Bangladesh produced in 2011 (Das and Haque,2014)

Forest Products	Production
Saw logs and veneer logs	174000 m ³
Plywood	1000 m ³
Sawn wood	388000 m ³
Wood Fuel	27286834 m ³
Industrial round wood	282000 m ³
Pulpwood round and splits	18000 m ³
Particleboard	2200 m ³
Hardboard	5100 m ³
Wood charcoal	326684 ton
Paper and paperboard	8000 ton
Writing and printing paper	30000 ton
Fiber pulp	18000 ton
Newsprint	20000 ton

4. Animal Manure

Livestock manure is also used a lot as biomass fuel shown in Table 7. Cows, goats, and sheep are the most common sources of animal dung in the country. Dry cow dung is one of the most common fuels in rural areas. Biomass energy production and power generating using animal dung may become viable energy and power demand solution in Bangladesh's rural areas.

Table 7: Livestock Population with varying year (Department of Livestock Services, 2021)

Name of Species	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Cattle	232	233.4	234.8	236.0	237.85	239.35	240.8	242.38	243.91	245.45
Buffalo	14.43	14.50	14.57	14.64	14.71	14.78	14.79	14.86	14.93	15.00
Sheep	30.82	31.43	32.06	32.70	33.35	34.01	34.68	35.37	36.07	36.79
Goat	252	252.7	254.4	256	257.66	259.31	261.0	262.67	264.35	266.04
Total Ruminant	528	532.1	535.9	540	543.5	547.5	551.3	555.3	559.3	563.3
Chicken	2428	2490	2553	2618	2684	2751.8	2821	2892.8	2966	3041
Duck	457	472.5	488.6	505.2	522.40	540.16	558.5	577.52	597.16	617.46
Total Poultry	2886	2963	3041	3123	3206.3	3292.0	3380	3470.3	3563.1	3658.5
Total Livestock	3414	3494	3577	3662	3750	3839	3931	4025	4122	4222

Currently in Bangladesh the common biomass use in rice mills and saw mill where we use rice husk and saw dust to produce energy. But for sustainable growth and development, a definite framework is required to use biomass to contribute significantly to the national grid. Biogas may also replace cooking natural gas which is also a critical issue in buildings.

Implementation of Green Roof in Buildings:

Green roofs are an effective way to reduce the demand for air conditioning during the summer, resulting in an increase in the rate of energy savings in buildings. It is defined as the structural integration of plantation and vegetation area on the roof's surface. Green roofs absorb rainfall in order to evaporate the gathered moisture, releasing latent heat and lowering sensible heat. which improves the heat insulation performance. Green roof temperatures can be 30–40 °F lower than those of conventional roofs, and they can reduce city-wide ambient temperatures by up to 5 °F. Furthermore, when compared to conventional roofs, green roofs can cut building energy use by 0.7 percent, lowering peak electricity demand, and resulting in an annual savings of \$0.23 per square foot of roof area (US EPA, 2021).

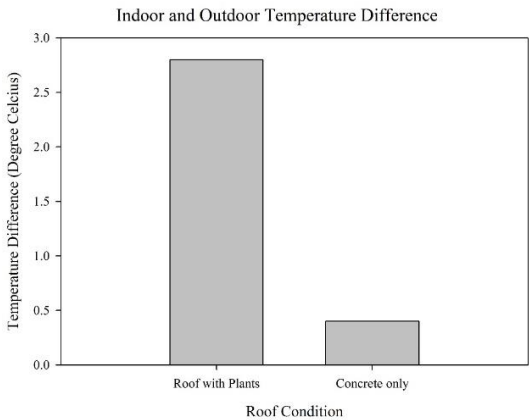


Figure 11: Temperature difference indoor and outdoor with/without green roofs (Tabassum, 2020)

Figure 11 shows that green roof building has a significant temperature difference of 2.5C between the indoor and outdoor compared with traditional concrete roofs. This helps reduce the cooling loads demand and subsequently less reliance on national grid. Also, roof gardening involves farming, cultivating, etc. which will contribute to public health.

Methodologies

Adopted methodologies for CCHP system applied in this current study were from the publication of K. Roman (2015) that analyzed hourly electric, cooling, and heating load for a commercial building in Chicago. We deployed similar strategies for a two-storied residential building following the paper of Hasan and Akter (2019). In that paper, monthly electric, heating, and cooling load were observed and analyzed using Building Information Modeling (BIM). The hourly demand data is needed to optimize the CCHP system however till date demand data are not available for Bangladesh. So, for analysis it was assumed that building energy should replicate the same trend as the national daily demand curve as our electricity is consumed more than 60% by buildings. The hourly data was obtained from Saiful et al. (2020) that consisted of conventional daily load curves for summer and winter. We took that data and scaled it for the heating load and cooling load.

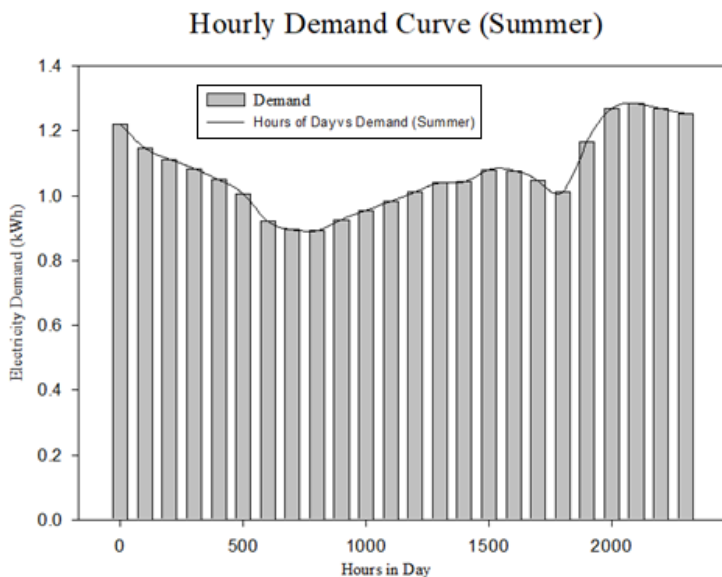


Figure 12: Hourly Electricity Consumption in kWh (Summer)

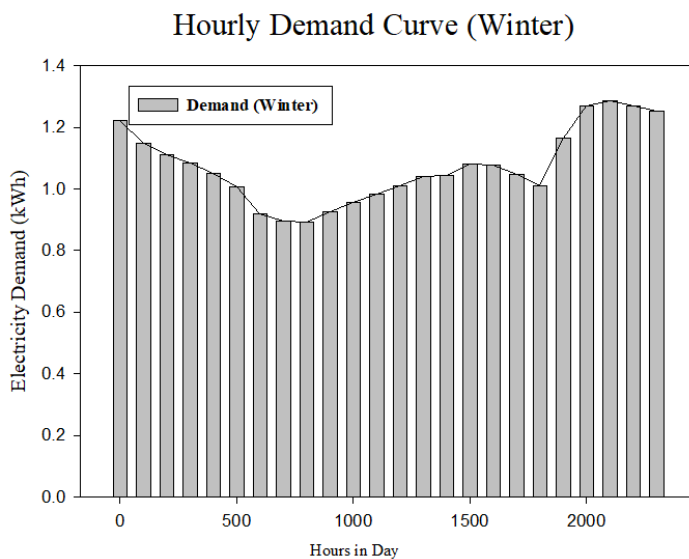


Figure 13: Hourly Electricity Consumption in kWh (Winter)

For electric load, we examined a typical household Electric bill by Dhaka Power Distribution Company (DPDC) and scaled it according to the daily curve we have access to (Fig 12 & 13). To distinguish between summer and winter, we referred to a typical household heating load demand pattern which is shown in Figure 14 (Hasan and Akter, 2019). As there was no heating load demand from April to October so this period of the year was considered as summer and the rest of the year as winter. The load data was fitted separately for summer and winter and ran a Matlab code was used to analyze the energy performance of the buildings.

To run the simulation, several assumptions were adopted in the algorithm:

- A) A single IC engine will power the entire CCHP system, and the exhaust heat will be recovered.
- B) There is no sellback and storage capacity of energy generated.
- C) Maximum prime mover capacity has been varied from 1 to 20 kW during simulation.

D) Partial loading and corresponding efficiency were adopted in the simulation (Fig. 15).

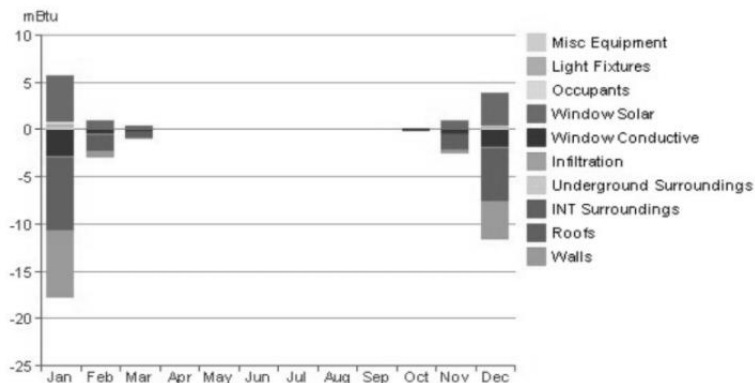


Figure 14: Monthly Heating Load diagram (Adopted from Hasan and Akter, 2019)

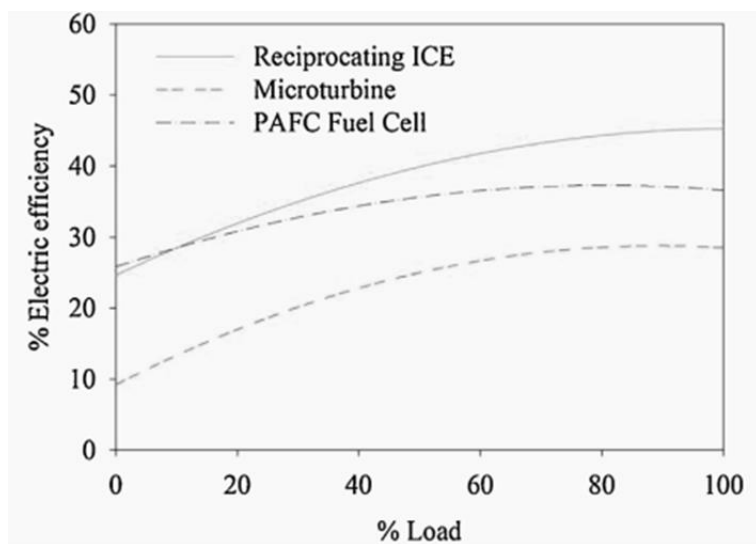


Figure 15: Efficiency fashion on varying degree of loading in energy generating units (Roman et al., 2015)

Hourly energy consumption is very low for a single building in Bangladesh as energy usage per capita in Bangladesh is one of the lowest in the world (326 kWh). So, we introduced the concept of nano-grid in the communities. Our proposition is to make a decentralized power plant consisting of several buildings to increase the load enough to operate the prime mover efficiently. Bangladesh Government has specified the definition of solar grid sizes and resolves that a grid must have at least 10 consumers (SREDA, 2018). We inspected the CCHP system performance for different size of nano-grids (more than 10 buildings).

We are planning to run analysis on roof mounted solar PV, but there isn't standard data for research purposes on solar PV installation based on the size of a building. So, we are working on it and in future will publish an analytical report on the solar PV integration with CCHP system. However, we have presented an analysis of estimated energy output, though the calculation is not detailed and rather gives an idea instead of in-depth analysis.

An analysis was conducted on roof mounted solar PV. However, solar PV installation guidelines and data is not available in Bangladesh. A thorough insight on annual energy yield and economic feasibility was added in this research paper.

Roof Mounted Wind Turbines are also a significant part of our study, as wind energy in urban housing is a relatively unexplored sector in Bangladesh. Average wind velocity statistics over several places were found, but hourly data for Bangladesh are unavailable. Consequently, a numerical model of a wind turbine was presented, and its generation performance was investigated. The standard installation and maintenance costs for wind turbines could vary wildly on the types of Wind Turbines and the location of installation. These data are not available for small-scale wind turbines in Bangladesh. However, the initial cost was assumed £1500 in this study based on the research conducted in the United Kingdom for roof-mounted small wind turbines (<1 kW) (Checktrade, 2020). In general, costs in Bangladesh will be substantially lower. However, it will be difficult to obtain resources

and high-quality components in Bangladesh. Wind turbines performance conducted for different locations to determine suitable wind turbine installation sites. The wind velocity found in different cities in Bangladesh is not enough to produce energy to payback installation costs. However, if the roof shape can be modified to accelerate the wind velocity, then the new shape of the roof could improve the economic viability of wind turbines in Buildings. Figure 11 shows different potential roof shapes to accelerate the wind velocities in BAWT (Adopted from Rahman et al., 2019).

It was observed that half circular wall in roof has the most notable wind speed acceleration. GetData Graph Digitizer software was used to obtain the equation of the half circular wall's accelerated wind speed at different locations (Fig. 21). Maximum wind speed was found at the throat on the circular wall in roof and was used for wind turbines energy analysis. A MATLAB code was used to explore the wind turbine power generation potential and furthermore economic viability of this new shape wind turbines in buildings.

RESULTS

CCHP System in Nano-grids

The Nano-grid CCHP system is simulated using MATLAB software and several parameters have been observed such as:

- a) Economic: Simple Payback Period (SPP)
- b) Energy: Primary Energy Consumption (PEC)
- c) Emission: CO₂, CH₄ and NO₂ emission

A key thing we observed during the simulation is that the output results vary depending on the size of the Nano-grid. So, we tried to portray a scenario explaining how economic, energy and emission results change with a varying number of households in a Nano-grid. We used reference values of emission and PEC for a traditional commercial building in Chicago, USA taken from Roman and Alvey (2015) as such data is scarce in Bangladesh.

Economic Analysis

Simple payback period (SPP) is the ratio of the installation cost of a system and the annual savings by using the system. So, it shows how much time a system takes to pay back its cost. After the simulation with input of various size of Nano-grid, changes in payback period are shown in table 8.

Table 8: Change in Payback Period with different size of Nano-grid

Size of Nano Grid (No. of Buildings)	10	20	40	50	60	80	100
Simple Payback Period (Years)	5.82	2.04	0.95	0.86	1.07	1.48	2.76

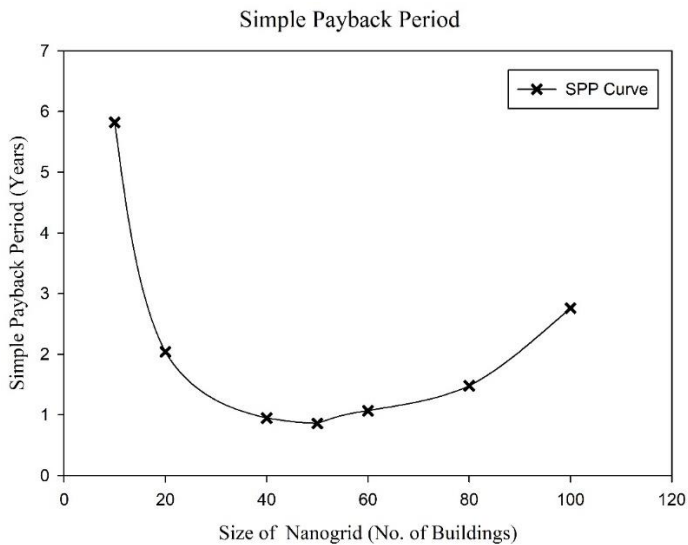


Figure 16: Trend of SPP with changing size of Nano Grid

Fig. 16 depicts the optimal nano-grid size. With 40 to 50 households in a nano-grid, the simple payback period is reduced to less than one year. However, as the grid size increases, its economic viability decreases. On the other side, 10-15 houses per unit is a poor choice because it makes the system fiscally burdensome.

Energy Savings

Primary Energy Consumption (PEC) is the total energy consumption of a building annually. It is measured in kWh/year. PEC values decrease as we use CCHP system. The results are shown in Table 9 and Fig. 17.

Table 9: PEC values of a CCHP Nano-grid system compared to traditional energy in buildings

Size of Nano-grid (No. of Buildings)	PEC (Reference) kWh/year	Output PEC kWh/year	% Reduction
10	336520	289000	14
20	673050	492670	26.8
40	1346100	868530	35.5
50	1682600	1117700	33.6
60	2019100	1520200	24.7
80	2692200	2269900	15.7
100	3365200	3157300	6.

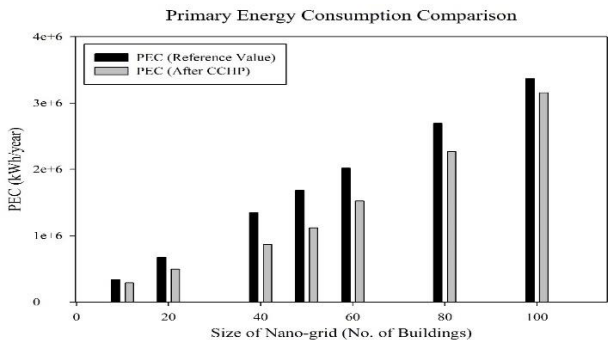


Figure 17: PEC comparison with reference values

Emission Analysis

Three types of emission were evaluated for the proposed CCHP system: CO₂ emission, NO₂ Emission and CH₄ emission. All the results found are very promising compared with the traditional reference system. Collected values are summarized in Table 10.

Table 10: CH₄, NO₂ and CO₂ emission comparison with reference values

Size of Nano grid	CH ₄ Emission (Ref.)	CH ₄ Emission	%Reduction	NO ₂ Emission (Ref.)	NO ₂ Emission	%Reduction	CO ₂ Emission (Ref.)	CO ₂ Emission	%Reduction
(No. of Buildings)	(Ton per year)	(Ton per year)		(Ton per year)	(Ton per year)		(Ton per year)	(Ton per year)	
10	0.0009	0.000215	75	0.0012	0.0005	61	78.14	56.97	27
20	0.0017	0.000006	99.65	0.0024	0.0004	82.3	156.28	90.18	42.3
40	0.0035	0.000010	99.70	0.0047	0.0008	84	312.56	158.98	49
50	0.0043	0.00063	85.5	0.0059	0.002	72.9	390.7	216.32	44.6
60	0.0052	0.0024	53.8	0.0071	0.0037	47.9	468.84	323.31	31
80	0.0069	0.0051	26.1	0.0094	0.0071	24.5	625.12	510.25	18.4
100	0.0087	0.0077	11.5	0.0118	0.0105	11	781.4	713.31	8.7

The following graphs (Fig. 18-20) visualize the table and give an idea of how much we have succeeded in reducing emissions. CO₂

emission has too large value to accommodate in the same graph. So, we generated a separate graph for CO₂.

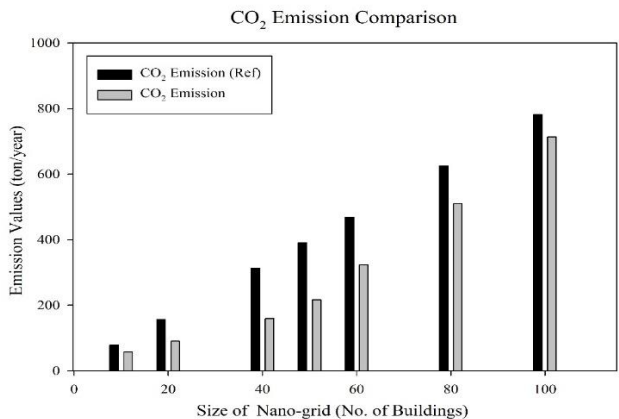


Figure 18: CO₂ emission comparison with reference value

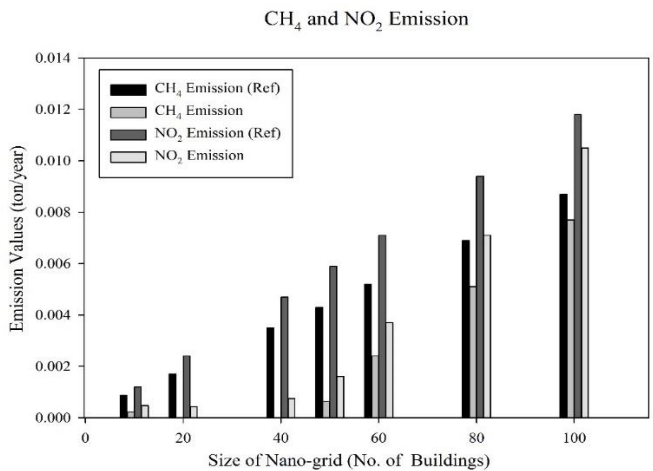


Figure 19: Methane and NO₂ emission comparison with reference values

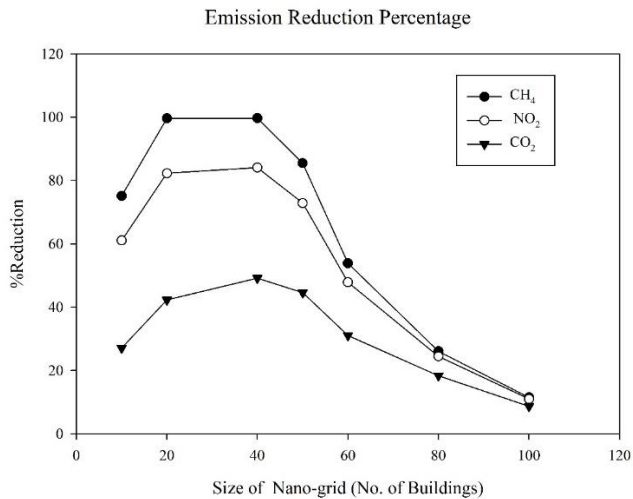


Figure 20: Methane and NO₂ emission reduction percentage

Building Augmented Wind Turbine (BAWT)

The wind acceleration pattern for the half circular wall on the roof is shown in Figure 21 which was used in the analysis.

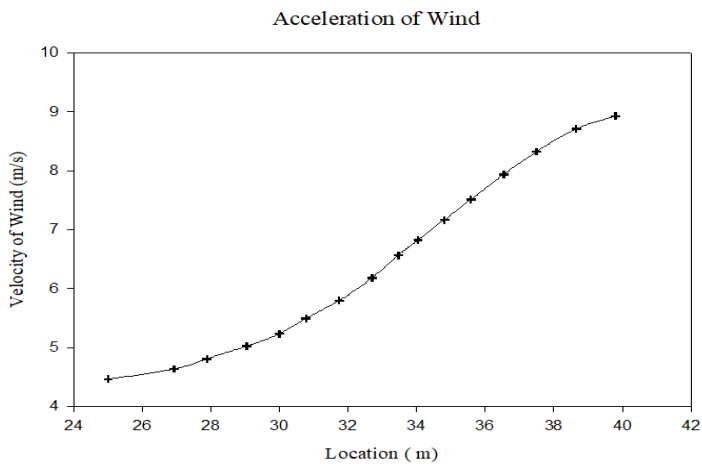


Figure 21: Wind acceleration pattern using half circular wall on the roof

We used this relation to get increased velocity, then analyze wind turbine performance. Average wind velocity is obtained from Bangladesh **Meteorological Department (2016) (Table 11)**.

Table 11: Average wind speed in different locations of Bangladesh

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dhaka	1.23	1.6	2.59	4.21	3.8	3.7	3.64	3.21	2.24	1.28	0.93	0.92	2.45
Chittagong	2.54	3.27	5.03	7.54	7.44	3.77	3.87	7.92	5.56	3.06	2.14	2.11	5.37
Comilla	1.16	1.58	2.81	4.3	4.36	4.64	4.73	4.1	2.69	1.44	0.89	0.88	2.82
Cox's Bazar	3.6	3.85	4.3	4.84	5.36	5.15	5.41	5.75	4.2	3.15	2.93	3.13	4.48
Rajshahi	1.64	1.77	2.26	3.4	3.73	3.55	3.24	2.9	2.45	1.53	1.45	1.66	2.46
Isurdi	1.57	1.75	2.64	4.62	4.92	4.73	4.23	3.85	2.89	1.58	1.34	1.53	2.98
Sayeedpur	2.67	3.14	4.6	4.76	4	3.73	3.56	3.05	2.74	2.12	2.04	2.24	3.22
Mongla	1.86	2.05	2.71	3.96	4.17	3.98	3.7	3.46	2.71	2.87	1.45	1.5	2.78
Jessore	1.38	1.85	3.42	5	5.25	5.41	4.84	4.29	3.37	1.71	1.19	1.11	3.42

To assume wind turbine specification, we took similar data from the study conducted by Dhakshinamurthy et al. (2018). They suggested using the NACA series 63415 turbine blades as it gives better performance than most other alternatives and blade length equals to 1.1m. Both the 63415 turbine blade and 1.1m blade length were adopted in this study. The energy generation, annual savings, and Simple Payback Period (SPP) for different major cities in Bangladesh are shown in Tabel 12 and Fig. 22.

Table 12: Economical Analysis of using BAWT

Location	Total Energy Generated (kWH)_	Annual Savings (Tk)	SPP (yr)
Chittagong	10973.00	61890.00	2.42
Dhaka	1058.10	5967.90	25.13
Comilla	1725.00	9728.70	15.42
Cox's Bazar	4582.30	25844.00	5.80
Ishwardi	1828.80	10315.00	14.54
Jessore	3199.10	18043.00	8.31
Rajshahi	853.54	4814.00	31.16
Syedpur	1745.50	9844.90	15.24
Mongla	1262.40	7119.90	21.07

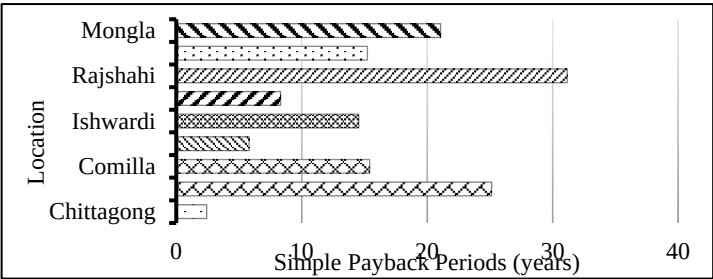


Figure 22: Payback Period of BAWT in different locations in Bangladesh

Roof Mounted Solar PV

Extensive research hasn't been done on roof mounted solar PV for its broader scope. But a preliminary study can be shown with the help of Global Solar Atlas (globalsolaratlas.info) as the site provides preliminary solar PV output data for different locations around the world. We generated a report for Dhaka (23°43'30", 90°24'23") with the help of the website and presented an

estimation of producing 1.33 MWh per year and more than 100 kWh every month (Fig. 23) which equivalents to 4 kWh per day. The map data (Table 13) and specification of the assumed PV system (Table 14) are shown below. However, production depends on a lot of parameters such as solar irradiation, facing angle, accumulation of dirt and dust etc.

Table 13: Solar Data for Dhaka, Bangladesh

Parameter	Acronym	Value	Unit
Direct normal irradiation	DNI	982.3	kWh/m ²
Global horizontal irradiation	GHI	1642.9	kWh/m ²
Diffuse horizontal irradiation	DIF	950.4	kWh/m ²
Global tilted irradiation at optimum angle	GTI_opta	1747.9	kWh/m ²
Air temperature	TEMP	25.7	°C
Optimum tilt of PV modules	OPTA	23	°
Terrain elevation	ELE	12	m

Table 14: Specification of the PV system assumed

PV System Configuration	
Title	Description/Value
Small Residential	Photovoltaic system mounted on a tilted roof of a residential building. Azimuth and tilt of the PV modules are homogeneous, and the modules do not shade each other. The modules are mounted on rails attached to a tilted roof, thus allowing back-side ventilation. This type of PV system is usually directly connected to a low-voltage grid through an inverter. No electricity storage is considered.
System Size	1kWp
Tilt of PV Panels	23 Degree
Azimuth of PV Panels	180 Degree

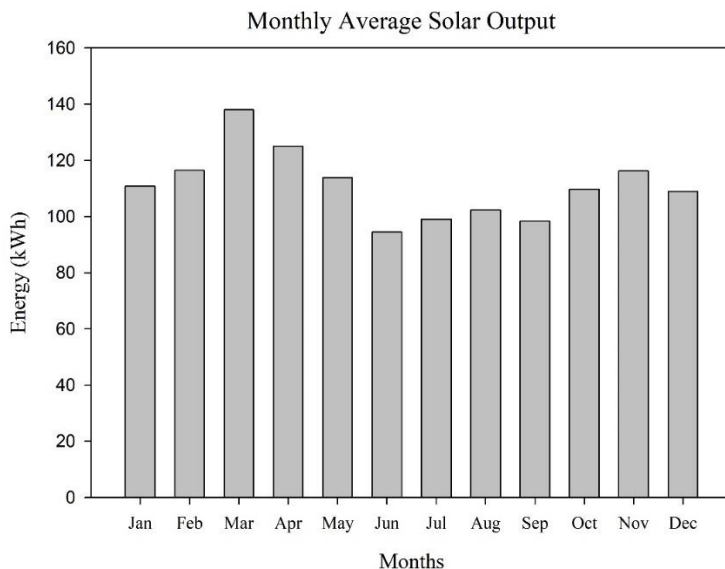


Figure 23: Monthly average energy output using a solar PV

Solar output per month averages above 100 kWh, which will play a vital role in energy and cost savings. The monthly electricity savings amount to more than Tk 450. In India, the installation of a 1kWp solar panel system cost approximately 22,000 Rs (The Economic Times, 2020), which is equivalent to about 30,000 taka in Bangladesh. A simple calculation suggests that the solar panel installation should pay for itself within six years, proving that it is an excellent and environmentally friendly investment.

DISCUSSION

In this study, when compared to conventional building energy systems, the nano-grid CCHP system achieves astoundingly positive outcomes. Primary Energy Consumption (PEC) and all three types of emissions are decreasing. When economic, energetic, and emission characteristics are analyzed closely, the most effective size of the nano-grid is 40-50. In this range, we obtain the lowest SPP, which is less than a year. This region achieves an 8-49%

percent reduction in CO₂ emissions. Methane emissions are reduced by 99.7%, which is extremely beneficial for the environment (Fig. 20). Thus, a CCHP system comprised of 40-50 buildings forming a nano-grid should provide optimal performance at the lowest possible cost. The fuel of the prime mover will be biomass gasification and biogas, which may require some retrofitting. This retrofitting is about taking care of 3 parameters (Siripornakarachai, 2009):

1. Spark ignition system must be added to the engine and the ignition timing adjusted to yield maximum efficiency.
2. Compression ratio must be reduced so biogas can be used as the fuel.
3. A biogas carburetor should be used for easy adjustment as well as lower pollution.

Siripornakarachai (2009) conducted an experimental study on retrofitting a large 13,000 cc diesel to run on biogas consisting of 60-80% CH₄. He did modifications that include:

- An addition of biogas carburetor for air- fuel mixing,
- Replacing the fuel injection system with spark ignition system,
- Reduction of compression ratio from the original 16:1 to 8:1 using a cylinder head spacer, and
- Modification of the turbocharger waste gate so the boost pressure can be adjusted.

In the context of a wind turbine with a specific roof shape, we identify feasible locations throughout the country where BAWT should be economically viable. In general, wind turbines are predicted to survive between 20 and 25 years (TWI, 2021). Thus, Chittagong, Jessore, Cox's Bazar, and Syedpur all offer considerable potential as wind energy extraction zones, however Dhaka, Rajshahi, and Mongla may not be the best choice.

Roof mounted domestic solar PV system proves satisfactory performance to predict primary results on energy generation. 4kWh daily will save more than 8500 Tk. yearly and is expected to pay back the solar PV system installation cost in a few years.

Although the implementation and effect of a green roof have not been modelled, the reduction in inside temperature will result in less cooling demand, resulting in decreased energy consumption. Additionally, the plants generated will provide fresh food for city people.

Kokogiannakis et al. (2011) constructed a database to quantify the influence of green roofs on heating and cooling loads in Chinese climates and found that indoor temperatures can be as much as 7 degrees lower than they would be without the green roof. As a result, the cooling load is reduced, resulting in lower reference PEC. However, because a decreased load will reduce prime mover efficiency, our SPP values have increased slightly. Green roofs are particularly effective in poorly insulated structures. Heating load decrease, on the other hand, is less significant than cooling load reduction. So, we did not investigate the effect of green roofs in the winter. For the months of April to September, we reduced our cooling load by 20% (linear variance with temperature) while maintaining the same heating load. One thing to keep in mind is that CO₂ emissions will reduce substantially as plants absorb it. This may not be shown in the calculations, but it will undoubtedly occur.

Grid integration of renewable energy sources is also critical for decentralizing power generation and avoiding catastrophic grid supply failure. Grid integration of renewable energy is the practice of power system planning, interconnection, and operation that allows for the efficient and cost-effective use of renewable energy while ensuring electricity supply stability and reliability. Certain policy adjustments should be undertaken while keeping four points in mind:

- A) New renewable energy generation
- B) New transmission
- C) Increased system flexibility
- D) Planning for a high renewable energy future

The most difficult aspect of establishing a stable energy network is the inconsistent behavior of wind and solar resources. This can be remedied by utilizing appropriate energy storage to

retain surplus energy generated and compensate during periods when the sources are unavailable. If a distributed PV system is connected to a low-voltage distribution line, it may cause issues such as reverse power flow and voltage violations. As a result, interconnecting diverse networks and employing a large network minimizes overall fluctuation and may neutralize each other's instability. The following are some policies that could be implemented to encourage customers to connect their home energy generation equipment to the grid:

- A) Financial and technical assistance for renewable energy source installation and operation
- B) 'Grid-aware' incentives to keep prosumers engaged
- B) Grid expansion and upgradation to access high-quality solar and wind resources
- D) Enabling operational flexibility sources (USAID, NREL, 2015)

The Bangladesh government's Net Energy Metering Guideline (2018) establishes net metering rules and regulations. The following are some of the most important rules to follow:

- A prosumer cannot supply more than 70% of his sanctioned load.
- Maximum AC output can be 3MW.
- Low-voltage interconnection can have a maximum of steady state voltage limit of 10%.
- Voltage fluctuation must not be greater than 6%.

Individuals will be influenced to create energy and contribute to the grid if proper guidelines and awareness initiatives are in place.

CONCLUSION:

We tried to show possible steps that can be taken to improve Bangladesh energy situation by developing building energy performance. Potential of using CCHP system by several households have been discussed and according to the study, 40-50 buildings is the optimal size of a Nano-grid in economic, energy consumption and emission perspective. Wind energy utilization and solar PV usage have also been discussed individually for buildings and we concluded that a great deal of energy can be

extracted using natural renewable resources which will decrease our grid dependency. Grid integration of such personal-level energy sources will also benefit the country and relieve the burden of generating electricity only on their own.

There are different directions of research that we have not connected BAWT with the CCHP system or examined the system. This would result in increased energy and pollution savings. Additionally, the rooftop solar photovoltaic (PV) potential has not been studied critically in conjunction with a combined heat and power (CCHP) or wind energy delivery system. Researchers will continue to examine further optimization of total renewable energy systems comprising of solar, wind, biomass and CCHP systems altogether. Exploring new renewable sources will enable the diversification of energy yield and the reduction of greenhouse gas emissions. Implementing hybrid renewable energy sources will undoubtedly contribute significantly to reducing dependency on fossil fuels and achieving sustainable development. Furthermore, the use of a hybrid energy generation system will undoubtedly minimize reliance grid electricity. Government should implement more technically sound legislation, standards, and regulations that, if adhered to, will also help us attain a greener Bangladesh.

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RENEWABLE ENERGY SECTOR (RES), A POTENTIAL AVENUE FOR SUSTAINABLE DEVELOPMENT OF BANGLADESH BY 2041.

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Abstract

This paper describes “A journey from climate vulnerability to resilience to climate prosperity.” The present status of different sources of renewable energy in Bangladesh, future potential and action for addressing climate change in the long run are discussed.

HOW WILL RENEWABLE ENERGY SECTOR CONTRIBUTE TO ADDRESS CLIMATE CHANGE?

“According to the Mujib Climate Prosperity Plan (MCP) of the Hon“ble Prime Minister of Bangladesh Renewable Energy Sector“s (RES) contribution will be 40% of total electricity power in the country”. It is generally accepted that the emission of greenhouse gases upset the thermal balance of the earth-atmosphere system and ultimately lead to global climate changes. The extent of the changes will depend on future emissions of greenhouse gases.

Bangladesh is one of the most vulnerable countries of Global Climate Changes in the coming decades. It has been estimated that by 2050, one in every seven people in Bangladesh will be displaced by climate change. Specifically, with a projected 19.6 inch (50 cm) will be risen in sea level. Bangladesh may lose approximately 11% of its land and up to 18 million people may have to migrate because of sea-level rise alone. The temperature will be increased and average rainfall

will be higher. Meanwhile we have been observing the changes in Bangladesh!

In this context, Renewable energy has been playing an important role in energy security and reducing greenhouse gases emission. Using renewable energy sources like, Solar System, Wind System, Hydro power System, Biogas & Biomass System, Geothermal System & Tidal System provide energy without the planet-warming effects of fossil fuels. The Renewable Energy sources are emission free of carbon and other greenhouse gases that contribute to global warming as well as help to reduce energy imports.

Conventional power generation involves burning of fossil fuels that releases Greenhouse gases (GHGs) emission resulting in global warming and climate changes. Growing concern about climate change, countries around the world are searching for the best alternative to fossil fuels. Renewable energy is the solution but current state of technology and cost factor makes it the least suitable option as an alternate choices. However, since the past one decade, the technology has evolved in such a way that we can see utility scale renewable energy power projects based on Solar, Wind and other renewable technologies coming up. For countries like India where coal is the dominant fossil fuel to generate electricity, the least GHG emission intensive option is the major requirement.

Especially, Solar System is one of the most effective sources in Renewable Energy Sector, because, Solar radiation is depend on the atmospheric image, daytime & season of a year. Bangladesh could apparently meet its unprecedented demand as well as increasing energy supply for energy security by acknowledging the potential of solar-energy resources. The country is situated between 24o0'0" N latitude and 90o0'0" E longitude, which is an ideal position in the earth for preserving & producing solar power.

POTENTIALS

We have strong potentials and prospects of Renewable Energy Sector to address the above situation as well as the commitment of the **Hon^{ble} Prime Minister Sheikh Hasina**. In this regard, the implementing agencies in RES are working hard with Infrastructure Development Company Limited (IDCOL).

PRESENT STATUS OF RENEWABLE ENERGY IN BANGLADESH

Before 2003, Bangladesh faced a severe energy crisis owing to sluggish growth in energy supplies. Initially, IDCOL entered into the Renewable Energy Sector through launching Solar Home System Program in 2003. The program kick-started with initial objective to avail electricity access to the remote and off-grid communities of the country and to materialize the GoB's vision to ensure universal access to electricity by 2021. Till December 2021, a total number of 6 Million SHSs have been installed across the country, which is remarkably about 50% of the installation in the world. Solar Irrigation Pumping System, Solar Rooftop System, and Solar Street Lighting System have been installing rapidly.

The government has a target to contribute 10% of the total energy from renewable energy sector by the end of 2021. However, such contribution 777.43MW up to December, 2021 which shares only **3%** of the total energy, of which Solar Energy share is 543.44MW (remarkably high), Wind System is 2.90MW, Hydro System is 230.00MW, and Biogas and Biomass System is 1.09MW.

Presently, Renewable Energy is one of the thrust sectors of the Honorable Prime Minister of the Government of the People's Republic of Bangladesh. The sector has been growing very fast with its competent, potential, experience, knowledgeable and committed personnel in its field of operation.

FUTURE ACTION FOR ADDRESSING CLIMATE CHANGE IN THE LONG RUN:

The government has setup “committed goal” for providing electricity for all of the inhabitants of the country by uninterrupted supply of green energy at a reasonable and affordable price. Since, sustainable social, environmental and economic development depends on the adequate power generation capacity of a country. In this aspect, there is no other way to accelerate the development of the country except increase in the power generation by fuel diversifications.

According to the visionary policy and planning of the Government of Bangladesh, followings are the measureable and applicable issues in the renewable energy sector for accelerating its tremendous growth towards the development of the country by 2041.

- 8th 5 year plan (2020-2025): It is planned that, total power generation capacity will be achieved up to 30,000MW of which 10% will be contributed by renewable energy sources. It indicates that renewable energy will contribute 3000MW by the year ended 2025. Out of which, 2014MW will be contributed from solar energy systems and the rest comes from other sources.
- SDG-30 (2016-2030): Targeted power generation capacity will be up to 40,000MW of which 4100MW will be contributed from Renewable Energy Sector and 20% reduction in primary energy consumption by 2030.
- Bangladesh Perspective Plan (2021-2041): Targeted power generation capacity will be 60,000MW aims to reduce production cost emphasizing on Renewable Energy sector through energy efficiency. The target is to reduce 20% of primary energy consumption by 2031 and 25% by 2041.
- National Solar Energy Action Plan (2021-2041): Targeted power generation capacity targeted up to 60,000MW aims to reduce 20% primary energy consumption by 2030 and 25% by 2041.

- The latest addition in the Renewable Energy related policy landscape is the approval of Bangladesh Delta Plan 2100. It is the first time ever that GoB has taken up such „a long- term strategy to prevent floods and soil erosion, manage rivers and wastes, and supply water throughout the country.“ The plan is important for the Renewable Energy landscape from multiple viewpoints. In it, a renewed target of generating 30% of the total energy from renewable sources by 2041.
- Mujib Climate Prosperity Plan (MCP) aims to reduce temperature up to 1.5 degree aligned with Paris Agreement 2015 and produce 30% energy by 2030, 40% by 2041 and 100% by 2050 from Renewable Energy sources. This target will be achieved within the framework of national planning process (NPP) and will further strengthen by the already foreseen actions of 8th 5 year plan, Bangladesh Delta Plan - 2100, Vision - 2041 and Nationally Determined Contributions.
- Our Honorable Prime Minister Sheikh Hasina expressed her views in the National Statement in 26th Session of the United Nations Framework Convention on Climate Change in Glasgow, Scotland on Monday November 1, 2021 that “Bangladesh has one of the world’s most extensive domestic solar energy programs. We hope to have 40% of our energy from renewable sources by 2041. We are going to implement the „Mujib Climate Prosperity Plan“- a journey from climate vulnerability to resilience to climate prosperity.”

Experienced Actors in the Renewable Energy Sector are committed and must be able to fulfill the commitment of the Hon’ble Prime Minister’s Vision-2041.

CONDENSATION AND ENERGY RECOVERY: SUSTAINABLE METHODS TO MITIGATE PLASTIC INCINERATED AIR POLLUTION

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Abstract

Plastic waste incineration in an open field is a major cause of air pollution. Plastic production and incineration might emit 2.8 gigatonnes of CO₂ per year by 2050. This is equivalent to 615,500-megawatt coal plants, and thus, directly contributes to climate change. This study employed a narrative literature review to examine the impact of incineration-induced air pollution in Bangladesh. The process yielded 26 relevant papers that were included in this study. We also consulted three experts to understand and resolve the problem in the context of Bangladesh. The paper investigated eco-friendly solutions such as recycling, Effluent Treatment Plant (ETP), and energy recovery processes to describe how plastic waste can be managed more sustainably. As part of the recycling process, sorting will be done manually involving slum women; this will create employability as well. This process is cost-

effective and suitable for a lower middle-income country like Bangladesh. Most municipal solid waste, which contains about 12% plastic, is incinerated. This paper proposes a plant that collects, separates, and recycles plastics through an environmentally friendly systematic chain process and recovers energy from plastic waste incineration.

INTRODUCTION

Since the discovery of numerous techniques for producing polymers from petrochemical sources, the plastic sector has grown significantly. Plastics have significant advantages over many other material types in terms of weight, durability, and cost (Andrady & Neal, 2009; Thompson et al., 2009). In 2015, global polymer output was predicted to be 380 million metric tonnes per year which is comprised of thermoplastics, thermoset plastics, adhesives, and coatings (Geyer et al., 2017). Plastic is so versatile but non-biodegradable, plastic pollution is an issue that affects everyone on the planet (Lau et al., 2020).

Nearly 700 marine species and over 50 freshwater species have been reported to have consumed or become entangled in plastics (Gall & Thompson, 2015; Rochman et al., 2016). A growing body of research suggests that plastic is also consumed by a variety of terrestrial creatures (Huerta Lwanga et al., 2017). Microplastics were found in the gastrointestinal tracts of 73.3% of Bangladeshi freshwater fish (Parvin et al., 2021). Plastic pollution has an impact on several elements of human wellbeing: having an impact on the attractiveness of beaches (Wyles et al., 2016), obstructing drainage and wastewater engineering systems (Fobil & Hogarh, 2009) as well as serving as a breeding place for disease vectors (Boelee et al., 2019; Wyles et al., 2016).

To prevent the accumulation of enormous amounts of plastic in the environment, recycling and incineration of plastics are commonly used methods (Lau et al., 2020; Yang et al., 2021). Only 18% of plastic garbage is recycled globally, while 24% is incinerated. The remainder 58% enters the landfills or oceans, where plastics can stay for a few hundred years, polluting the environment (Geyer et al., 2017). However, landfilling,

composting, and burning still cannot fully dispose of plastic garbage (Yang et al., 2021).

Incineration is not the end-all solution for plastic trash and by the end of the process, ash remains as a source of microplastics that can heavily pollute the environment (Yang et al., 2021). Open garbage incineration releases significant amounts of greenhouse gases such as carbon dioxide, methane, and particulate matter into the atmosphere through fumes (Kumari et al., 2019). This process also pollutes the air and endangers the health of individuals who are immediately exposed to the smoke (Babayemi & Dauda, 2010; Igoni et al., 2007). Dioxins, furans, arsenic, mercury, polychlorinated biphenyls (PCBs), lead, carbon monoxide, nitrogen dioxide, sulfur dioxide, and hydrochloric acid are among the pollutants found in the smoke of burning wastes, although some contaminants can also be found in the ash (Ebi et al., 2014). People with sensitive respiratory systems are particularly vulnerable to open burning, which can result in respiratory disorders and carcinogens (Cogut, 2016).

In recent years, Bangladesh High Court has banned single-use plastics in coastal areas, hotels, and restaurants (Paul, 2020). However, there are no specific laws regarding mitigating plastic-induced air pollution in Bangladesh. As such, open-air plastics burning, and recycling-plant based air pollution are still not effectively regulated in Bangladesh- allowing damaging impacts on the environment and human health (Marium, 2021).

This paper is aimed to resolve these issues in a multifaceted way. By establishing a solid waste- management plant that would collect, segregate and process, recycle and incinerate plastics through an eco-friendly systematic chain process with an energy recovery system.

METHODOLOGY

The study employed a narrative literature review. We searched these terms for the first two sections in Google Scholar, for 2015-2021: “reduction of air pollution generated by plastic incineration”, “plastic incineration induced air pollution”, “plastic waste management”, “plastic waste management using

incineration”, “condensation”, “open-air plastic burning”, “waste management”. For the energy recovery section, we searched “energy recovery”, “energy recovery from plastic waste incineration”, “energy recovery from MSW (municipal solid waste) combustion” these terms with no time limit in Google Scholar due to lack of paper. All authors independently searched for papers and consulted to include the final papers. ABK and SAR independently extracted key findings from the selected papers. All authors contributed to writing the draft and preparing the figures.

We also consulted experts, lecturer 1 from Jahangirnagar University, lecturer 2 from Bangabandhu Sheikh Mujibur Rahman Science and Technology University, and lecturer 3 from Stamford University Bangladesh, to understand and resolve the problem in the context of Bangladesh. They all have a background in the environmental sciences. Figure 1 below shows the data collection and analysis flow diagram.

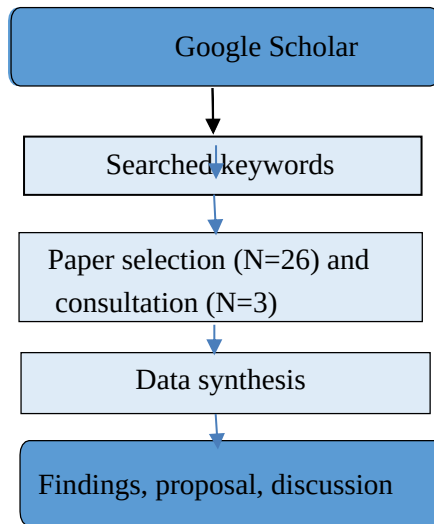


Figure 1: Research methodology flowchart

RESULTS

The process yielded 26 relevant papers that were included in this study. This paper investigated major waste management systems in Bangladesh including plastic waste incineration and proposed ways to mitigate the related air pollution sustainably. Table 1 below describes the key findings of these papers.

Three experts said that open-air incineration is now a major problem in Bangladesh. As a developing country, people use a lot of plastics, but these plastics are collected and incinerated in a manner that contributes to further environmental pollution. Our policymakers have not taken any effective actions regarding this. There are also not so many researchers who have researched this topic. Consequently, the impacts of open-air incineration of plastics or the polluted elements on this air could not be found for analysis.

Table 1: Key findings of the papers

Authors et al. (Year), Country	Title	Methods and sample size	Key Findings
Borrelle et al. (2020), Global	Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution	Systematic review and Meta-synthes is; 173 Countries	Given the ambitious promises the government is currently making, annual emissions could reach up to 53 million metric tonnes per year by 2030. Reducing emissions far below these projections will require special efforts to transform the global plastics economy.

Proshad et al. (2017), Bangladesh	Toxic effects of plastic on human health and environment: A consequences of health risk assessment in Bangladesh	Review paper	Plastics are found in serious environmental pollution such as soil, water, and air pollution. The application of appropriate rules and regulations for the production and use of plastics can lead to toxic effects of plastics on human health and the environment.
Forrest et al. (2019), Global	Eliminating Plastic Pollution: How a Voluntary Contribution from Industry Will Drive the Circular Plastics Economy	Perspective paper	We evaluate the worldwide expenses of plastic pollutants and explain why fixing that is vital for humanity's well-being. We display that FFP (Filtering Face Piece) pollutants are a long way past a marine environmental issue: it now invades our bodies, inflicting ailment and dysfunction, even as hundreds of thousands of adults and youngsters' paintings in situations comparable to slavery, choosing via our waste. We argue that an included monetary and technical solution, catalyzed via a voluntary industry-led contribution from new FFP production is valuable. to arresting plastic waste flows viaway of means of making used plastic a cashable commodity, incentivizing healing and accelerating the industrialization of polymer-to-polymer technologies. Without much-wished systematic transformation, pushed via way of means of a contribution from FFP production, humanity and the oceans face a troubling future.

Silva et al. (2019), Europe	Rethinking and optimizing plastic waste management under COVID-19 pandemic: Policy solutions based on redesign and reduction of single-use plastics and personal protective equipment	Qualitative paper	The rapid increase in plastic waste and its composition due to the COVID-19 pandemic creates an urgent need to strengthen (and urgently shift) plastic reduction policies, expand innovation for sustainable green plastic solutions, and immediately develop dynamic and responsive waste managementsystems. Emphasize the need. Policy recommendations and future research directions are discussed.
Verma et al. (2016) India	Toxic Pollutants from Plastic Waste- A Review	Review Paper	This review presents the potential for developing strategies for developing alternative procedures for incineration, open-air combustion of plastics and the risks of plastic exposure in water, and for the treatment of plastic waste.
Nagy & Kuti (2016) Hungary	The Environmental Impact of Plastic Waste Incineration	Perspective Paper	This article takes a closer look at the impact and harm of plastic burning on the environment and health. We wrote this study to draw people's attention to the importance of reducing plastic waste, its environmental impact, and the risks to humans and the environment of incineration.
Gradus et al. (2017) Netherlands	A Cost-effectiveness Analysis for Incineration or Recycling of Dutch Household Plastic Waste	Perspective Paper	We compare the economic efficiencies of two options for recycling plastic waste. This paper uses data from the Netherlands to evaluate the recycling of plastic waste through more traditional plastic waste incineration.

Bujak(2015), Globals	Thermal utilization (treatment)of plastic waste	Perspec- tive Paper	This paper presents the results of a pilot study of a thermal recycling plant for the incineration of plastic waste. This study was conducted on an industrial scale in a plant that produces plastic tapes (used for warning, packaging, and masking purposes). The system was considered from three aspects: energy, environment and economy.
Bujak(2015), Globals	Thermal utilization (treatment) of plastic waste	Perspec- tive Paper	This paper presents the results of a pilot study of a thermal recycling plant for the incineration of plastic waste. This study was conducted on an industrial scale in a plant that produces plastic tapes (used for warning, packaging, and masking purposes). The system was considered from three aspects: energy, environment and economy.
Lazarevic et al. (2010), Europe	Plastic waste management in the context of a European recycling society: Comparing results and uncertainties in a life cycle perspective	Perspec- tive Paper	Due to the uncertainty surrounding some assumptions in the studies, it cannot be said with confidence that the waste hierarchy should be applied to plastic waste management as a general rule.
Tomsej et al. (2018), Czech Republic	The impact of co-combustion of polyethylene plastics and wood in a small residential boiler on emissions of gaseous pollutants, particulate matter, PAHs and 1,3,5-triphenyl benzene	Case study	This study aimed to simulate a banned but common wood-plastic co-firing operation in small residential boilers and to quantify its impact on the emissions of gaseous, particulate, and particulate pollutants. Particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs), and 1,3,5-triphenylbenzene (135TPB), a novel marker of polyethylene resin combustion.

Nabavi-Pelesaraei et al. (2017), Iran	Modeling of energy consumption and environmental life cycle assessment for incineration and landfill systems of municipal solid waste management-A case study in Tehran Metropolis of Iran	Case Study	In this study, back-propagation prediction models based on the Levenberg Marquardt training algorithm are developed to predict electrical and environmental factors related to energy consumption for municipal solid waste management.
Patrício Silva et al. (2020) Brazil	Incineration of Municipal Solid Waste in Brazil: An Analysis of the economically viable energy potential	Perspective paper	The need for government intervention to make this technology economically viable will reduce improper waste disposal nationwide.
Brunner & Recheberger (2015), Global	Waste to energy – a key element for sustainable waste management	Perspective paper	WTE (Waste to Energy) plants help make decisions about waste management and the environment. Information on the chemical composition of waste and the proportions of bio and fossil carbon in MSW and waste gases can be provided on a regular and cost-effective basis.
Margallo et al. (2015), Global	Environmental sustainability assessment of the management of municipal solid waste incineration residues: a review of the current situation,	Perspective paper	This paper aimed to study the properties of solid MSW residues, the handling, and reuse of these wastes, as well as environmental assessment from a life cycle perspective.

Zhang et al.(2019), Global	Measurement of Dioxin Emissions from a Small-Scale Waste Incinerator in the Absence of Air Pollution Controls	Qualitative	With the help of SRW, it is very realistic to significantly reduce PCDD/F emissions by retrofitting major MSWs that will have a positive impact on the future development of SRW (rural solid waste) treatment.
Fruergard et al. (2010), Global	Life-cycle assessment of selected management options for air pollution control residues from waste incineration	Review paper	The LCA (Life cycle assessment) modeling showed that thermal processes were associated with the highest loads in the non-toxicity categories (energy consumption), while differences between the remaining alternatives were small and generally considered insignificant. In the toxicity categories, all treatment/utilization options were significantly better than direct landfilling without treatment (lower leaching), although the thermal processes had somewhat higher impacts than the other options (air emissions). Transportation distances did not affect the overall ranking of the management alternatives.
Quina (2008), Global	Treatment and use of air pollution control residues from MSW incineration: An overview	Review Paper	This work reviews strategies for the management of MSWI (municipal solid waste incineration) residues, particularly solid particles collected from flue gases.
Beylot et al. (2018), France	Municipal Solid Waste Incineration in France	Qualitative	This study aims to provide complete and up-to-date information on MSW incineration in France in terms of technical, environmental, and energy properties, in a context where these properties are important for reliable life cycle assessment (LCA).

Ashiku zzama n, M., & Howlad er, M.H. (2020), Bangla- desh	Sustainable Solid Waste Management in Bangladesh: Issues and Challenges	Case Study	It has been found that law enforcement agencies are unable to implement their strategies on the 3Rs method for waste management. This chapter provides examples of case studies of community approaches, the recycling sector, and management of medical waste. Finally, the authors discuss issues and challenges related to sustainable solid waste management practices and suggest ways Bangladesh can achieve sustainable solid waste management.
Idumah & Nwuzor (2019), Global	Novel trends in plastic waste management	Review Paper	Currently, there is a global problem with the effective management of municipal solid waste. Various degrees of Environmental issues, including regular greenhouse gas emissions and lack of waste space. The build-up of these wastes increased and they were discarded because waste management was inadequate. These issues aroused public concern, and political legislation was adopted to minimize them. The amount of waste released into the environment. These actions aim to provide improved solutions. Sustainable waste management by promoting the recycling of MSW and the efficient conversion of waste to energy; and other valuable chemicals. This conversion procedure can be achieved using one of the biological processes such as thermochemical processes such as anaerobic digestion or pyrolysis. Therefore, this review is new pathways used efficiently to convert MSW into energy and other valuable chemicals.
Prata et al.(2019) , Global	Solutions and Integrated	Review Paper	Here are 10 recommendations for stakeholders to reduce plastic pollution:

	Strategies for the Control and Mitigation of Plastic and Microplastic Pollution		(1) production and consumption regulation; (2) eco-design; (3) increasing demand for recycled plastics; (4) reducing the use of plastics; (5) use of renewable energy for recycling; (6) expanded producer responsibility for waste; (7) improvement of waste collection systems; (8) recycling priority; (9) the use of biodegradable and biodegradable plastics; (10) Improving waste recycling capacity.
Alam & Boie (2001), Bangladesh	Energy recovery from municipal solid waste in Dhaka city	Literature review, Incineration plant visit, Secondary data collection	The study provides an opportunity to analyze the quality assessment of the waste and introduce a system that will enable the generation of energy. It also describes the mitigation of environmental hazards that are affiliated with waste and its traditional management system.
Marzia & Sakib (2019), Bangladesh	Ranking of Technologies for Energy Recovery from Municipal Solid Waste in Bangladesh Using the Analytic Hierarchical Process (AHP): A Case Study	Literature review	This study, along with other similar developing countries, will guide waste to energy decision-makers in Bangladesh.
Abdel-Shafy & Mansour (2018), Global	Solid waste issue: Sources, composition, disposal, recycling, and valorization	Review Paper	The formation of OSW (organic solid waste); increases sharply every year. Most OSW consists of agricultural waste, household food waste, and human and animal waste. It is usually treated as animal feed or is incinerated or landfilled. OSW is a protein, mineral, and sugar-rich

			material that can be used as a substrate or raw material in other processes.
Makarichi et al. (2018), Global	The evolution of waste-to-energy incineration: A review	Review Paper	The review found that incineration of waste energy has played an important role in reducing the global waste problem, and much more can be achieved today by maximizing its potential.
Dong et al. (2018), Finland France, and China	Comparison of Waste-to-Energy technologies of gasification and incineration using life cycle assessment: case studies in Finland, France, and China	Case studies	Recycling of metals and materials is widely used for incineration in France. This presented study contributes to the development of specific WTE technologies and local waste management plans for decision-makers.

After synthesizing the 26 papers and collating experts' opinions, we assessed the impact of three broad plastic waste management strategies in the context of Bangladesh, (a) plastic waste collection and management, (b) Effluent Treatment Plant (ETP): an eco-friendly method of plastic incineration and, (c) Energy recovery from plastic incineration, at different levels of effort to estimate plastic emissions to 2030 for 173 countries (Proshad et al., 2018). Findings have suggested that there are about 20 types of prime plastics used worldwide (Proshad et al., 2018).

Plastic waste collection and management

Since 1950, there was a rise in plastic usage (Nagy & Kuti, 2016). Plastic manufacturing was 359 million metric tonnes (Mt) in 2018, with 6.9 Mt of waste generated (3.2 Mt for short-life items) (Patrício Silva et al., 2020). We found that 19 to 23 million metric tonnes, or 11% of plastic waste generated globally in 2016 have entered aquatic ecosystems (Borrelle et al., 2020).

Plastic waste incineration in an open field is a major cause of air pollution (Verma et al., 2016). Incineration can cause human health problems. Most municipal solid waste, which contains around 12% plastics, is burned, releasing harmful substances such as dioxins, furans, mercury, and polychlorinated biphenyls into the atmosphere. Additionally, burning Poly Vinyl Chloride (PVC) releases harmful halogens and pollutes the air, resulting in climate change (Verma et al., 2016). The poisonous compounds discharged, as a result, pose a threat to the ecosystem, as well as to plant, human and animal health (Nagy & Kuti, 2016). The central nervous system is harmed by polystyrene. Burning plastic poses serious health hazards, including heart disease, exacerbates respiratory conditions like asthma and emphysema, and causes rashes, nausea, and headaches, as well as harm to the nervous system, kidneys, liver, and reproductive and development systems.

Dioxins accumulate on crops and in our waterways, eventually finding their way into our food and our bodies. Black carbon (soot) is released when plastic is burned, contributing to climate change and air pollution. Plastic is a petroleum-based polymer that, when burned, emits the same pollution as any other fossil fuel (Verma et al., 2016). Marine plastic pollution is a symptom of an inherently wasteful linear plastic economy, costing us more than US\$ 2.2 trillion per year (Forrest et al., 2019).

In most circumstances in Bangladesh, the city authority is responsible for collecting and disposing of waste at final disposal points or sites. At the generating stations, residents reuse and recycle a large part of non-hazardous inorganic trash. Non-governmental organizations (NGOs) and community-based organizations (CBOs) who provide door-to-door collecting services also sort the waste and reuse it without processing it. Residents gather their daily garbage in a plastic or metal bin within their homes or on their property and deliver it to the waste collectors. During collection, the collectors keep all the waste in an open vehicle (Ashikuzzaman & Howlader, 2020).

Now globally, approximately 22% of plastic waste was burnt, 25% was recycled, and 42% was inefficiently processed (Patrício Silva et al., 2020). Of 6.3 billion tonnes of fossil fuel-derived plastic (FFP) waste produced to date, only 9% has been recycled, the rest being incinerated (12%) or dumped into the environment (79%). FFPs take centuries to degrade, meaning five billion tonnes of increasingly fragmented and dangerous plastics have accumulated in our oceans, soil, and air. Rates of FFP production and waste are growing rapidly, driven by increased demand and shifting strategies of oil and gas companies responding to slowing profit growth (Forrest et al., 2019). Most of the recycling is done by incineration (Makarichi et al., 2018).

On the other hand, the incineration of plastic waste generates revenues from an energy perspective. Plastic waste produces more than three times more energy when compared to other materials. A decrease in the plastic content of municipal waste lowers the energy output per unit of input and thus increases overall incineration costs (by reducing effectiveness and energy return). The difference in costs and benefits between the two different waste treatment options for plastic packaging in the

Netherlands provides an interesting analysis of relative costs and benefits from an economic and environmental perspective (Gradus et al., 2017).

Effluent Treatment Plant (ETP): an eco-friendly method of plastic incineration

To offset the negative impact, we can employ technology. For example, we can use a method to collect plastic from individuals at the ***collection point*** using a machine that will immediately refund them with cash. This technique will maximize our plastic collection because it is financially motivated. The collected plastics will go to the ***segregation and processing point*** to next be separated into ***recyclable and non-recyclable*** categories. Because contamination and non-recyclable components might make a batch of materials unsuitable for recycling, this is critical. Sorting will be done manually with the help of slum-women, which will increase employability. Recyclable plastics will then be processed by a machine to create new things in the next step. Finally, non-recyclable objects will be burnt in a ***furnace***, with the resulting air pollution being minimized by ***condensation***, a process that converts gas or vapor to liquid. If the dew point of the plastic pollutant is higher than the carrier gas, condensation can be employed to remove it from the gas stream. The overall gas stream can be cooled below the pollutant's dew point, allowing the pollutant to be separated from the remaining gas stream as a liquid. Following that, the water is treated at the ***Effluent Treatment Plant (ETP)***. This technique is low-cost, making it appropriate for a low-income country like Bangladesh (Figure 2).

Another method for converting garbage to energy is gasification, which involves melting polymers at extremely high temperatures in the absence of oxygen (which prevents the formation of pollutants like dioxins and furans). The

procedure produces synthetic gas, which is used to power turbines. Gasification facilities, on the other hand, are not cost-effective because natural gas is so cheap. Pyrolysis, in which plastics are shredded and melted at lower temperatures and with even less oxygen than gasification, is a more appealing technology right now. Plastic polymers are broken down into smaller hydrocarbons by heat, which can be processed into diesel fuel and other petrochemical products, such as new plastics (Carlson, 2016).

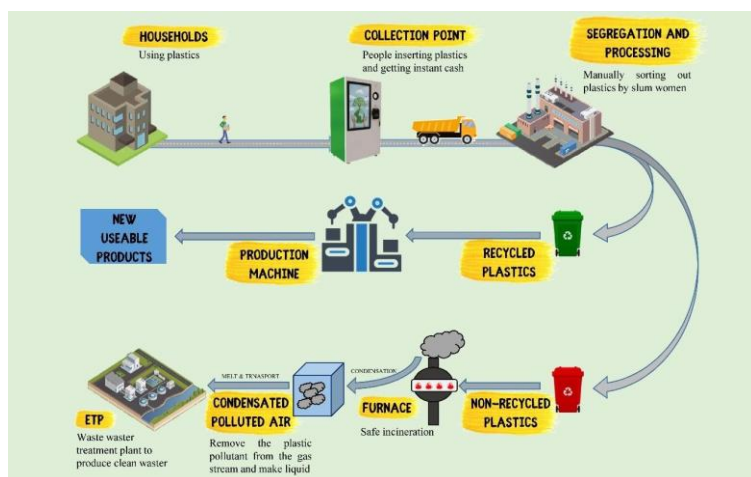


Figure 2: Proposed methodology for plastic recycling

Energy recovery from plastic incineration

Energy recovery from waste is a process to convert non-recyclable waste materials into usable heat, electricity, or fuel. This waste to energy can be obtained through various processes including combustion, gasification, pyrolyzation, anaerobic digestion, and landfill gas recovery (US EPA, 2021).

With the quick advancement in urbanization coupled with the change in consumption patterns, thousands of tonnes of waste including plastics are generated every day (Marzia &

Sakib, 2019). The volume of waste generated in 1970 was 11,00,000 tonnes which in 2015 amplified to 52,00,000 tonnes (Shams et al., 2017). In two separate studies, it was found that in 2013, the total amount of municipal solid waste (MSW) generated in urban areas of Bangladesh was 52,00,919 tonnes/year whereas in 2015 the total amount of urban waste was 5,11,000 tonnes/year (Islam, 2017; Shams et al., 2017). The amount is expected to increase by 57,718 tonnes/day by 2025 (Ashikuzzaman & Howlader, 2020).

This extensive amount of waste is managed by dumping in landfill sites. But mostly are illegally dumped in low land beside streets, riversides, and households. Management of solid waste, particularly non-biodegradable plastic waste has become a major concern for Bangladesh. It represents a social, environmental, and technical challenge (Marzia & Sakib, 2019). This uncontrolled disposal of solid waste in public places causes serious environmental hazards and health risks. Uncontrolled and open dumping also clogs the urban drainage system, causes water to stagnant, and threatens the contamination of the water supply (Alam & Boie, 2001). Energy recovery by proper management of solid waste can be the solution to sustainable waste management as well as providing energy security in Bangladesh (Marzia & Sakib, 2019). However, the choice of appropriate waste to energy technology is a complex and challenging issue.

Energy can be recovered from waste in the proposed incineration-condensation method. This generates a renewable energy source and reduces carbon emissions by balancing the need for energy from fossil sources. Additionally, it reduces methane generation from landfills (US EPA, 2021). The heat released from burning wastes in the incinerator converts water to steam, which is then sent to a turbine generator to produce electricity. Simultaneously, the ash produced from the plant can also be used as an inert

aggregate in the construction industry, including raw material in brick-kiln, or in cement production and using flue gas, the gas that comes out of combustion plants and contains the reaction products of the fuel and combustion air, as well as residual substances such particulate matter (dust), sulfur oxides, nitrogen oxides, and carbon monoxide, purification clean flue gas is produced (Alam & Boie, 2001; Speight, 2019). This would also avoid the need for disposal of the ash to landfills. Please see below Figure 3 for details.

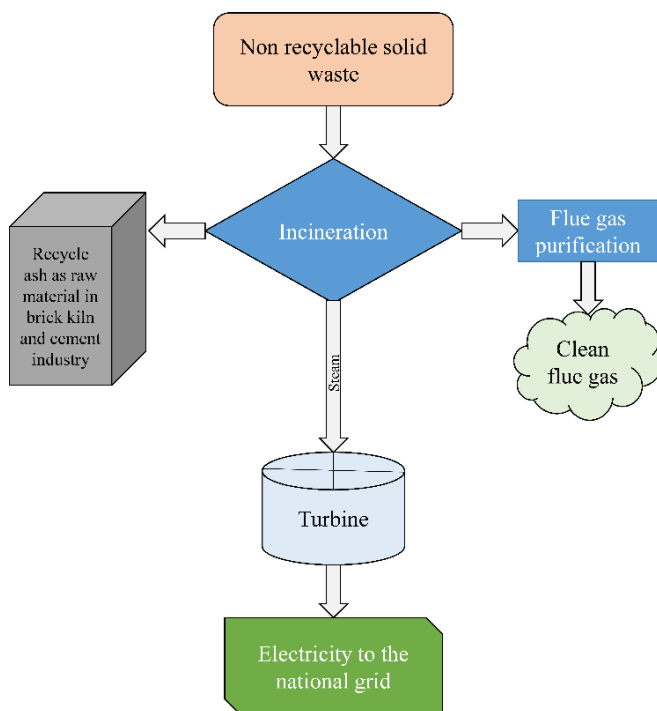


Figure 3: Energy recovery from waste incineration

Study limitations

Due to the limited research, we have no primary data and in the context of Bangladesh, we have no secondary data either. Due to the lack of empirical studies found through the literature review process, we have not appraised the quality of the selected papers.

CONCLUSION

Outdoor incineration of plastic waste is a major cause of air pollution. Most municipal solid waste, which contains about 12% plastic, is incinerated, releasing hazardous substances such as dioxins, furans, mercury, and PCBs into the atmosphere.

This paper proposes a plant that collects, separates, recycles, recycles, and incinerates plastics in an environmentally friendly systematic chain process. In the proposed method, the plastic is collected from the people at the collection point using an immediate machine. With financial incentives, this process will increase plastic collection. The collected plastics are separated into recyclable and non-recyclable items.

In the next step, the recyclable plastic is machined to produce new products. Finally, non-recyclable items are incinerated in Furness. If the dew point of the contaminant is higher than the dew point of the carrier gas, condensation can be used to remove plastic contaminants from the gas stream.

Few policies are needed to be able to tackle plastic-induced air pollution effectively. Firstly, lobbying with the government to impose strict laws on 'open air' plastic burn. Initiating and increasing 'service tax' on plastics would be another effective way to resolve this issue. Finally, further community awareness against overall plastic pollution will ensure everyone complies with the enforced laws and policies and most importantly, reduce their overall plastic consumption towards a greener, eco-friendly Bangladesh.

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GHG EMISSION FROM FUEL ENERGY, CLIMATE CHANGE AND MITIGATION INITIATIVES WITH BANGLADESH PERSPECTIVE

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Abstract

Global air pollution and climate change are among the most challenging issues for the countries with developing economies. There are direct effects of and interactions between, environmental pollution and climate change on ecosystem health. Further, adverse impacts of domestic & trans-boundary air pollution have been causing deaths, certainly children and aged people apart from causing low air quality and global warming.

Shipping & Marine transportation is discharging pollutants to air and sea. Global emissions from shipping have been expected to be triple between 2020 and 2050. Around 2.4% of global CO₂ emissions come from Aviation Industry as well. Jet Liners are contributing to climate change by emitting CO₂, Emissions from flights stay in the atmosphere, keep warming it for several centuries and having a potent climate impact that heat the planet.

On the other hand Vehicular Transport has the largest contribution to emission from fuel combustion and thus causing air pollution. Old fleet, maintenance, adulterated fuel etc., have driven to such negative contribution. Hence, impact of Emission and discharged pollutants on health & socio-economy apart from climatic conditions including regulation initiatives has been consideration in this presentation.

In that context, Bangladesh perspective stood worthy of inclusion herein so far as its energy related environmental pollution and climate change impacts are concerned, including Government's responding to the cry of enacting the 'Clean Air Act' as soon as possible. All of these, along with a review of global and national

legislative approaches and policy initiatives to reduce emissions of obnoxious gases and particulate matters have been included too. Further legislation will be needed to counterbalance the lack of supranational ambition on pollutants, GHG Emission and climate change mitigation.

INTRODUCTION

World-wide air pollution is released from many sources including industry, electrical power generation, home heating and all modes of transportation. Combined, aviation and marine transportation are among the fastest growing modes in the transportation sector. While Vehicular Transport has the largest contribution to emission from fuel combustion and thus causing air pollution, mostly Carbon Dioxide (CO₂) and the best understood GHG. Much of this pollution appears to be unregulated, poor air quality is linked to health issues such as asthma, respiratory and cardiovascular disease, and thus untimely death.

According to the World Health Organization, air pollution is the greatest environmental health risk to people as it triggers a range of health problems. In 2012, approximately 3.7 million deaths worldwide resulted from ambient air pollution. In Canada, approximately 14,400 untimely deaths each year can be linked to air pollution. As of 2016, worldwide ambient air pollution accounts for:

- 43% of lung disease deaths
- 29% of lung cancer deaths
- 25% of heart disease deaths
- 24% of stroke deaths

There are several examples of traffic jam, miss-management of traffic system, in appropriate tariff fixation for fly-over traffic, multiple traffic modes including the members of public allowed to use the same road. Such Jam and mostly by diesel operated trucks & buses causes obnoxious gases and thus enhanced GHG emissions polluting the city environment with toxic air. Further, this pollution

caused from fuel energy has obvious potential negative impact on health & economy of the city dwellers.

ENERGY RELATED POLLUTION AND CLIMATE CHANGE

Graphical Review of Energy Related Regional Emission Levels

Studies conducted on Emission Levels of East Asia and Pacific, Europe and Central Asia, United States, South Asia, Middle East and North Africa, Latin America and Caribbean, Canada and during 1990-2018. The increases in GHG related to energy consumption in million metric tons CO₂ equivalent are presented in the Figure 1. A comparison of GHG emission from different sources is during 1990 to 2015 is shown in Figure 2. It may be observed that energy consumption is the main source of GHG emission.

In many ways, climate change and modern transportation go hand in hand. The life-changing technological advances from the Industrial Revolution that ushered in new modes of travel are the same technologies that have contributed to the wide-scale pollution of the planet. As machinery began to replace manual labor in the latter half of the eighteenth century, the use of fossil fuels, such as coal and oil, for power increased.

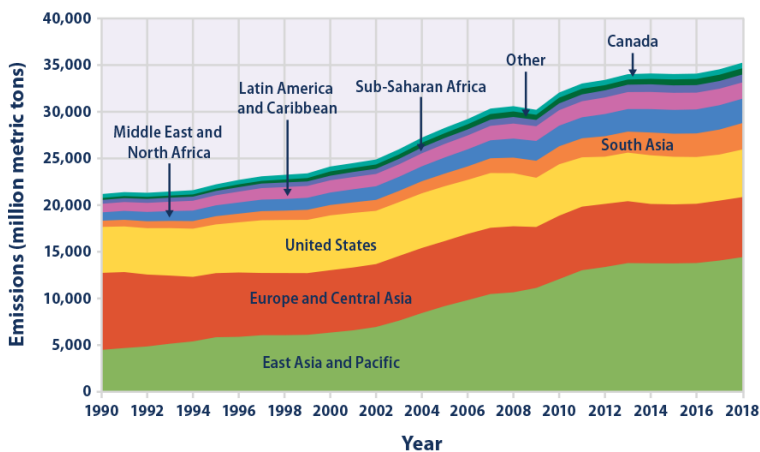


Figure 1 : Emission of GHG (CO₂ Equivalent) from different regions
Data sources: WRI, 2021;² FAO, 2020³ (Web update: April 2021)

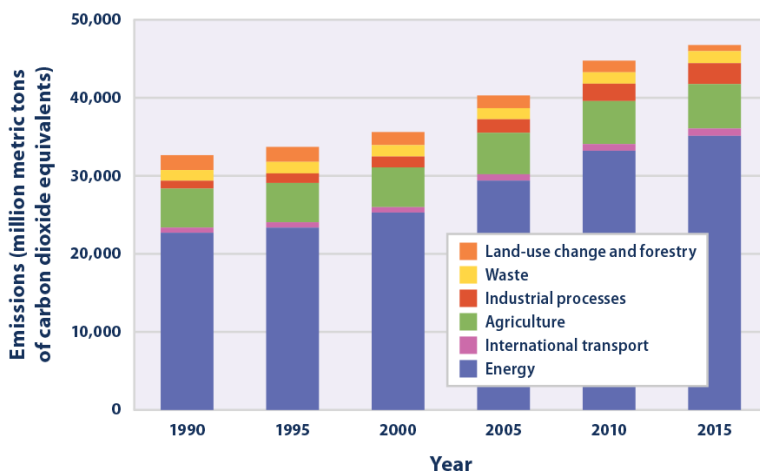


Figure 2 : Comparison of GHG emission from different sources from 1990-2015.

Exciting new transportation vehicles, like cars and steam-powered trains and boats, were also powered by fossil fuels, which release large quantities of carbon dioxide into the air when burned. These growing levels of carbon dioxide have generated a significant greenhouse effect, which has caused the planet to warm at a much more rapid pace—and to higher temperatures—than pre-Industrial Revolution rates, thus leading to the changes in climate seen in the twenty-first century.

Climate Change & Green House Gas

Climate change impacts both the natural environment and human health through a wide variety of environmental mechanisms. Climate change is caused by greenhouse gas absorption of infrared radiation. The greenhouse gases differ in their warming effects on the global climate system due to their different radiative properties and life spans in the atmosphere. Due to the impact of Climate Change natural environment is affected and in turn, leads to the loss of species due to temperature increases, by the changes in oceans and seas and by the impacts of extreme weather. Human health, for example, is affected directly

by heat waves and indirectly by infectious diseases and malnutrition.

Air Emissions from Shipping & Environmental Criteria

The air emissions from shipping have received a great deal of attention in recent years, and the focus has been on SO_x, NO_x, PM and greenhouse gas emissions. It is required that the fuel alternatives fulfill the present environmental regulations (emissions of NO_x and SO_x). It is also likely that the environmental regulations will become Stricter in the future, and the fuel alternatives therefore need to be able to meet tougher future environmental requirements to avoid there being yet another fuel change in the near future. It is also important that the environmental life cycle performance of the fuel alternatives is acceptable

Impact of Air Pollutants from Marine Shipping in Canada generate Ocean Acidification (CO₂), Ground-level Ozone (NO_x) Acid Rain (SO_x), Smog (Particulate Matter) and Black Carbon (Particulate Matter) CO₂, NO_x also harm marine and aquatic life by contributing an over-abundance of nutrients to coastal waters and inland lakes that causes toxic algal blooms and decreases water oxygen levels

Different Modes of Transportation and Air Pollution

Congestion, poor traffic management system, inefficient road use, mixed traffic & population are the basic reasons for maximum air pollution from different modes of vehicular Transportation, It has been revealed from Vehicle Emission Inventory for Dhaka: >85% of PM₁₀ is generated from Diesel Vehicles. The figure 3 depicts the quantum distribution of the Traffic Air pollution in Dhaka City

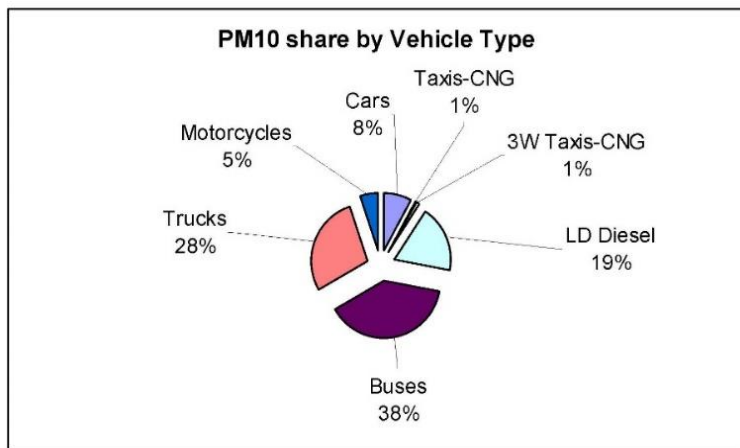


Figure 3: PM10 contributed by vehicles type

Ships move approximately 80% of the world's goods. When compared to other forms of transportation, marine shipping is the most energy-efficient way to move large volumes of cargo. Like all other forms of transportation that burn hydrocarbon fuels for energy, ships create air pollution that degrades air quality, adversely affects human health and contributes to the wide-reaching effects of climate change. These emissions can harm human health and our environment.

GHG Emissions from Shipping Industry

The commercial marine shipping industry is in general, Essential to the world's economy and well-being. But it's on record that, while responsible for the release of less greenhouse gas (GHG) per ton-kilometer of cargo transported than other forms of transportation, ships contributed 2.2% of the world's total CO₂ emissions in 2012. In coming years, global shipping traffic is expected to grow in response to increased trade. Unless additional measures to limit emissions from ships are adopted, GHG emissions from shipping could increase by as much as 20% to 120% by 2050, depending on economic conditions. On a global scale, the marine shipping industry's share of total emissions from human sources is: NO_x 15% per year SO_x 13% per year as well. For context, Canada's

annual contribution from all sources to global CO₂ emissions is 1.6%.

Air Transportation and the Environment

The integrated aviation modeling teams at the Massachusetts Institute of Technology and the University of Cambridge carried out studies on air transportation and the environment. The analyses directly or indirectly relate to the challenges of measuring and/or responding to the environmental impact of air transportation in terms of noise, air pollution, and climate change and identified several promising mitigation opportunities. However, in light of an anticipated continued growth in global aviation demand in the order of 5–6% per year, the identified opportunities are likely to only mitigate the growth in environmental impacts, at least over the next 20–30 years.

Highlights of their findings are:

1. Global aviation-related annual damages are likely greater than \$ 1 billion for noise and up to 10 times as large for climate change.
2. There is no single solution that effectively addresses noise, air quality, and climate change impacts.
3. The anticipated growth in air transportation demand will almost certainly exceed fuel burn reductions, at least over the next 20 years.
4. Assessing the complex socio-technical air transportation system requires integrated models that take feedback loops into account

Affect of SO_x , Acid Rain and Acidification Damages

The harm caused by SO_x is widespread as pollutants can travel hundreds of kilometers inland; the provinces located on the Precambrian Shield – Ontario, Quebec, New Brunswick and Nova Scotia – are most affected by acid rain. In Canadian coastal waters, acidification damages the shells of clams and mussels, affecting the productivity of a \$5.2 billion aquaculture

industry, and weakens coral structures, affecting their function as important habitat for other species.

Economic Impacts from Air Pollution

Emissions from flights stay in the atmosphere and will warm it for several centuries and having a potent climate impact, would trigger chemical reactions and atmospheric effects that heat the planet. The economic impacts from all sources of air pollution, including lost productivity; increased healthcare costs; decreased quality of life; stunted crops, plants, and trees and discolored and damaged outdoor structures and materials – all of which costs economy in billions of dollars per year.

The health and environmental impacts of air pollution from marine shipping are also felt, for example in Canada, where marine shipping produced 4 million tons of GHG emissions in 2015 or about 0.6% of total Canadian GHG emissions.

Impact of Air Pollutants from Marine Shipping in Canada generates Ocean Acidification (CO₂), Ground-level Ozone (NO_x) Acid Rain (SO_x), Smog (Particulate Matter) and Black Carbon (Particulate Matter) CO₂. NO_x also harm marine and aquatic life by contributing an over-abundance of nutrients to coastal waters and inland lakes that causes toxic algal blooms and decreases water oxygen levels.

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Air pollution from marine shipping both within and outside the Arctic impacts climate change and the health of people and ecosystems in the Arctic, and the number of ships transiting the Arctic, although currently low, is projected to increase. The regulations for the Prevention of Air Pollution from Ships (Annex

VI) seek to control airborne emissions from ships (SO_x, NO_x, ozone depleting substances, and VOCs) and their contribution to local and global air pollution, human health issues and environmental problems. The health and environmental impacts of air pollution from marine shipping are also felt, for example in Canada, where marine shipping produced 4 million tons of GHG emissions in 2015 or about 0.6% of total Canadian GHG emissions.

POLLUTION PREVENTION INITIATIVES

Regulations and Practical Initiatives

It is a reality that all major contributor to global air pollution and without action, these transportation industry emissions are expected to increase. New regulations and practical initiatives are planned or in force to reduce the amount of air pollution produced by ships. Thus it is essential to share objective information about the impacts of air pollution from the marine shipping industry – including the types of air pollution ships emit, how these emissions are harmful, what's being done to reduce them – and to encourage informed conversations about these issues.

The existing regulations for the Prevention of Air Pollution from Ships seek to control airborne emissions from ships (SO_x, NO_x, ozone depleting substances, and VOCs) and their contribution to local and global air pollution, human health issues and environmental problems. New regulations and practical initiatives are planned or in force to reduce the amount of air pollution produced by ships.

Ships move approximately 80% of the world's goods. When compared to other forms of transportation, marine shipping is the most energy-efficient way to move large volumes of cargo. Like all other forms of transportation that burn hydrocarbon fuels for energy, ships create air pollution that degrades air quality, adversely affects human health and contributes to the wide-reaching effects of climate change. In April 2018, the IMO adopted an initial strategy to reduce ship-source GHG, intended to reduce total annual emissions by at least 50% (compared to 2008 levels) by 2050.

The IMO has implemented a tiered approach to reducing NO_x emissions for new-built ships. The three tiers specify NO_x restrictions for ships built after certain dates, with more stringent restrictions for newer ships. Tier III requires up to an 80% reduction in NO_x emissions for all ships constructed after January 1, 2016, compared to Tier I. Regulations have positively impacted air quality in Canada with the majority of air pollutants decreasing significantly since 1990.

ECAs are established by the IMO to limit emissions from ships in coastal areas. In North America's ECA, ships must burn fuel or scrub exhaust to emit a maximum of 0.1% sulphur content since January 2015. Canadian ships in the Great Lakes and St. Lawrence Seaway currently operate under Canada's fleet averaging regime, which bases compliance on the average sulphur content of all the fuel used by a firm's fleet. As of December 31, 2020, all Canadian vessels will have to comply with ECA standards.

Paris Agreement and Global Response to Climate Change

In force since November 2016, the Paris Agreement aims to strengthen the global response to climate change by limiting global temperature increases this century to less than 2°C above pre-industrial levels. To achieve this, global GHG emissions must be reduced by 40% to 70% below 2010 levels by 2050 and reduced to near zero in the long term.

If all other sources of GHG are limited according to the Paris Agreement but shipping CO₂ emissions are not, the industry could contribute up to 17% of the world's total air pollution by 2050. If Paris Agreement limits are exceeded, the average global temperature is projected to rise with potentially devastating effects on people and the environment, particularly in the Arctic.

Potential of Bio-Energy for Climate Change Mitigation

The increasing prices and environmental impacts of fossil fuels have made the production of bio-fuels to reach unprecedented volumes over the last 15 years. Given the increasing land requirement for bio-fuel production, the assessment of the impacts that extensive bio-fuel production may cause to food supply and to

the environment has considerable importance. The potential of bio-energy for climate change mitigation remains unclear due to large uncertainties about future agricultural yield improvements and land availability for biomass plantations. While essential to the world's economy and well-being, the commercial marine shipping industry is a major contributor to global air pollution and without action; the industry's emissions are expected to increase.-

Air Pollution Prevention Regulations of Arctic Emissions

Air pollution from marine shipping both within and outside the Arctic impacts climate change and the health of people and ecosystems in the Arctic, and the number of ships transiting the Arctic, although currently low, is projected to increase. The regulations for the Prevention of Air Pollution from Ships seek to control airborne emissions from ships (SO_x, NO_x, ozone depleting substances, and VOCs) and their contribution to local and global air pollution, human health issues and environmental problems.

Health Impacts from Air Pollution

World-wide air pollution is released from many sources including industry, electrical power generation, home heating and all modes of transportation. Poor air quality is linked to health issues such as asthma, respiratory and cardiovascular disease, and untimely death. According to the World Health Organization, air pollution is the greatest environmental health risk to people as it triggers a range of health problems. In 2012, approximately 3.7 million deaths worldwide resulted from ambient air pollution. In Canada, approximately 14,400 untimely deaths each year can be linked to air pollution.

The 2008 Amendments to Annex VI to the International Convention for the Prevention of Pollution from Ships introduced progressive reductions for global emissions of SO_x, NO_x and particulate matter and also specific emission control areas (ECAs) in the Baltic Sea, the North Sea and coastal North America. The revisions are expected to have a beneficial impact on human health and the atmospheric environment, particularly in coastal areas.

Regulations for Prevention of Shipping Air Pollution

The existing regulations for the Prevention of Air Pollution from Ships seek to control airborne emissions from ships (SO_x, NO_x, ozone depleting substances, and VOCs) and their contribution to local and global air pollution, human health issues and environmental problems. New regulations and practical initiatives are planned or in force to reduce the amount of air pollution produced by ships.

The air emissions from shipping have received a great deal of attention in recent years, and the focus has been on SO_x, NO_x, PM and greenhouse gas emissions. It is required that the fuel alternatives fulfill the present environmental regulations (emissions of NO_x and SO_x). It is also likely that the environmental regulations will become stricter in the future, and the fuel alternatives therefore need to be able to meet tougher future environmental requirements to avoid there being yet another fuel change in the near future. It is also important that the environmental life cycle performance of the fuel alternatives is acceptable. Here, two aspects are considered the most important: the total extracted energy and the GWP.²⁹

Strategy to Reduce Ship-Source GHG

Ships move approximately 80% of the world's goods. When compared to other forms of transportation, marine shipping is the most energy-efficient way to move large volumes of cargo. Like all other forms of transportation that burn hydrocarbon fuels for energy, ships create air pollution that degrades air quality, adversely affects human health and contributes to the wide-reaching effects of climate change. In April 2018, the IMO adopted an initial strategy to reduce ship-source GHG, intended to reduce total annual emissions by at least 50% (compared to 2008 levels) by 2050.

Limiting Emissions from Ships in Coastal Areas

The IMO has implemented a tiered approach to reducing NO_x emissions for new-built ships. The three tiers specify NO_x restrictions for ships built after certain dates, with more

stringent restrictions for newer ships. Tier III requires up to an 80% reduction in NO_x emissions for all ships constructed after January 1, 2016, compared to Tier I. Regulations have positively impacted air quality in Canada with the majority of air pollutants decreasing significantly since 1990. ECAs are established by the IMO to limit emissions from ships in coastal areas. In North America's ECA, ships must burn fuel or scrub exhaust to emit a maximum of 0.1% sulphur content since January 2015. Canadian ships in the Great Lakes and St. Lawrence Seaway currently operate under Canada's fleet averaging regime, which bases compliance on the average sulphur content of all the fuel used by a firm's fleet. As of December 31, 2020, all Canadian vessels will have to comply with ECA standards.

Emission Reduction Potentials for Transport

The 2007 Intergovernmental Panel on Climate Change (IPCC) Report on Mitigation projected a rise of 80 % in CO₂ emissions by 2030 in the absence of specific reduction policies. The report estimated that emission reduction policies would only lower the total in 2030 from 11.34 Gt to at best 8.8 Gt.

The IPCC report also showed that to limit global temperature rise since the industrial revolution to 2 °C, thought to represent a prudent limit for avoiding dangerous climatic change, CO₂ emissions may have to be cut by the year 2050 to as little as 15 % of the year 2000 values.

The major options for emission reduction potentials for the various transport modes, both passenger and freight that could be achieved by the year 2030 would include increases in vehicle fuel efficiency and loading, and even shifts to non-carbon fuels.

These options, even combined, cannot deliver anywhere near reductions needed. Instead, it would not only need massive shifts to more energy- and greenhouse-efficient transport modes, especially for passenger transport, but also particularly in the high-income countries, travel reductions as well.

Regulations for Vehicles & Engine Emissions

In addressing Climate Change and Reduction of Emission of GHG, the National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA) conducted a workshop on November 16, 2016 on the Heavy-duty Greenhouse Gas Trailers. The final phase of the program promoted a new generation of cleaner, more fuel efficient trucks by encouraging the development and deployment of new and advanced cost-effective technologies.

The product of four years of extensive testing and research, the vehicle and engine performance standards would cover model years 2018-2027 for certain trailers and model years 2021-2027 for semi-trucks, large pickup trucks, vans, and all types and sizes of buses and work trucks. The final standards are expected to:

- Lower CO₂ emissions by approximately 1.1 billion metric tons;
- Save vehicle owners fuel costs of about \$170 billion; and
- Reduce oil consumption by up to two billion barrels over the lifetime of the vehicles sold under the program.

BANGLADESH PERSPECTIVE

Air Pollutants and Greenhouse Gas Emissions

The main air pollutants in two major cities of Bangladesh, Dhaka and Chittagong, are sulfur dioxide (SO₂), nitrogen oxides (NO_x), particulate matter (PM, usually expressed as PM with diameter of 10 microns or smaller, PM₁₀, or 2.5 microns or smaller, PM_{2.5}), carbon monoxide (CO), ozone, volatile organic compounds (VOCs), and lead. According to an emission inventory by World Bank it is predominantly the diesel-run

Vehicles and brick kilns. NO_x and SO₂ remained below Bangladesh national ambient air quality standards and World Health Organization (WHO) guideline values, but that PM₁₀ and PM_{2.5} levels continue to exceed both Bangladesh national ambient air quality standard and WHO guideline values.

For Bangladesh, monitoring of ambient air is a recent phenomenon. The journey to ambient air monitoring on a continuous basis just started from year 2002 with the installation of a continuous air monitoring station at the heart of the capital Dhaka.

Dhaka, the capital of Bangladesh, and one of the fastest growing megacities of the world, has been well known for being over-populated, traffic congested and the most emission polluted city in the world. In order to improve the severe situation, the authorities took some decisions e.g. banning two stroke engines, introducing CNG driven vehicles etc.

Trans-boundary Air Pollution,

It has been stated above that the deaths rates among children have seen a significant rise due to air pollution. Besides, airborne disease, including asthma, breathing problems, has seen a steady rise in Bangladesh, especially among low-income group people. Experts attributed this situation to trans-boundary air pollution, unplanned development and construction works, an absence of a central management system, a lack of coordination among government agencies, and lax monitoring.

Recently the South Asian country ranked the most polluted country globally while its capital Dhaka became the 2nd worst polluted city, said World Air Quality Index (AQI) Report published recently.

The two major causes of pollution are domestic and trans-boundary air pollution. Referring to a recent field study, it is said that Trans-boundary movement of air contributes much of the airborne pollutants that travel a long distance and cause unwanted air quality degradation.

The government is said to be working cordially to reduce carbon emission and taking measures to come out from the environmental pollution. It's further said after properly controlling home pollution, the Government would be looking into the trans-boundary pollution and coordination will be there among neighboring countries.

Steps Taken by Government to Improve Air Quality in Bangladesh

- Adoption of National Land Transport Program (NLTP).
- Formulation and approval of STP
- Introduction of unleaded gasoline from 1st July,1999
- Ban on import of two-stroke engine
- 2- stroke baby taxis banned from Dhaka city in Jan' 2003
- Ban on vehicles older than 20 years
- Bangladesh-1 and 2 framed per Euro emission norms
- Vehicles Emission Control Roadmap: Sept'04 or before
- Increase the use of Compressed Natural Gas
- Plying restriction of trucks in Dhaka from 8:00 am to 8 pm
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- Bangladesh-1 and 2 framed per Euro emission norms
- Vehicles Emission Control Roadmap: Sept'04 or before
- Increase the use of Compressed Natural Gas
- Plying restriction of trucks in Dhaka from 8:00 am to 8 pm
- Improvement of mass-transport system within urban areas
- Regular monitoring of the ambient air quality
- Increasing public awareness
- Introduction of 4-stroke 3 Wheeler CNG Auto Rickshaw
- Brick kiln chimney made to 120ft to check smoke impact.

Emission reduction potentials for transport

The 2007 Intergovernmental Panel on Climate Change (IPCC) Report on Mitigation projected a rise of 80 % in CO₂ emissions by 2030 in the absence of specific reduction policies. The report estimated that emission reduction policies would only lower the total in 2030 from 11.34 Gt to at best 8.8 Gt.

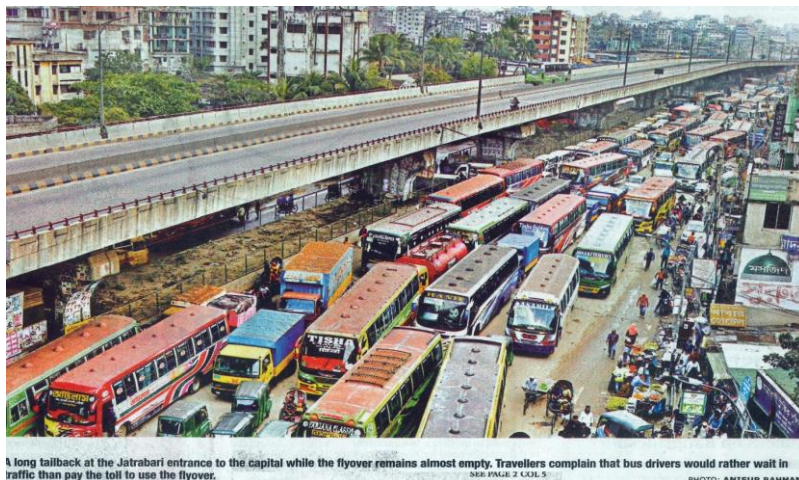


Figure 4: The source of the picture with caption is the Daily Star of Feb. 6, 2022.

The IPCC report also showed that to limit global temperature rise since the industrial revolution to 2 °C, thought to represent a prudent limit for avoiding dangerous climatic change, CO₂ emissions may have to be cut by the year 2050 to as little as 15 % of the year 2000 values.

The major options for emission reduction potentials for the various transport modes, both passenger and freight that could be achieved by the year 2030 would include increases in vehicle fuel efficiency and loading, and even shifts to non-carbon fuels.

These options, even combined, cannot deliver anywhere near reductions needed. Instead, it would not only need massive shifts to more energy- and greenhouse-efficient transport modes, especially for passenger transport, but also particularly in the high-income countries, travel reductions as well.

On the contrary, even though studies reveal that since 2015, citizens of Bangladesh have not experienced fresh air for even a week of a year. In responding to the situation the Clean Air Act has been drafted by BELA (Bangladesh Environment Lawyer's Association) & BUET

(Bangladesh University of Engineering & Technology) . This has been approved by the DOE (Department of Environment) as well. It's now urged upon the GOB to legislate the Clean Air Act without delay incorporating provisions for air pollution prevention & control and also to ensure implementation of existing laws and High Court directives including due monitoring for bringing the polluters to book .

CONCLUSION

Transport plays a crucial role in development and constitutes a significant share of world energy consumption. Transportation primarily relies on petroleum which supplies nearly 95 per cent of the total energy used by the world transport. The transport sector is still being largely responsible for the pollution and greenhouse gas (GHG) emissions which pervade all across the globe.

Further, the transport sector, road transport consumes the largest share of over 75% of the petroleum products followed respectively by shipping, international aviation, domestic aviation, domestic navigation, rail and others. Eventually, road transport has the largest contribution to emissions from fuel combustion in the transport sector comprising of the passenger cars and light & heavy duty vehicles.

The Intergovernmental Panel on Climate change (IPCC) advises in its fourth assessment report (AR4) that in order to avoid worst impact of climate change, global CO₂ emissions must be cut by at least 50 per cent and the onus would fall primarily on road transport. Higher trajectory of economic growth over the last two decades has been primarily associated with urbanization and rapid motorization both as a cause and as an effect. The key challenge in decoupling the economic and social development from the inherent growth would be in energy consumption and CO₂ emissions,

The air emissions from shipping have received a great deal of attention in recent years, and the focus has been on SOX, NOX, PM and greenhouse gas emissions. It is required that the fuel alternatives fulfill the present environmental regulations about emissions of NOX and SOX. It is also likely that environmental regulations will become stricter in the future, and the fuel

alternatives therefore need to be able to meet tougher future environmental requirements to avoid there being yet another fuel change in the near future.

Studies on air transportation and the environment directly or indirectly relate to the challenges of measuring and/or responding to the Environmental impact of air transportation in terms of noise, air pollution, and climate change and identified several promising mitigation opportunities to counter the potential negative impacts against the anticipated continued growth in global aviation demand in the order of 5–6% per year.

Finally, it's recognized that the two major causes of pollution are domestic and trans-boundary air pollution. Referring to a recent field study, it is said that Trans-boundary movement of air contributes much of the airborne pollutants that travel a long distance and cause unwanted air quality degradation. The government is said to be working cordially to reduce carbon emission and taking measures to come out from the environmental pollution. Thus the Government would be looking into the trans-boundary pollution and coordination will be there among neighboring countries.

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MATARBARI COAL POWER PROJECTS IN BANGLADESH: A CASE STUDY ON FINANCIAL, REPUTATIONAL AND CLIMATE RISKS

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Abstract

The Matarbari coal-fired power plan (Phase 1) is a 1,200 Megawatt (MW) under-construction project in Cox's Bazar, the south-eastern coast of Bangladesh. This project is financed as Japan's Official Development Assistance (ODA) loan through Japan International Cooperation Agency's (JICA), and Engineering Procurement and Construction (EPC) contractors companies are also based in Japan. Another additional project, the 1,200 MW Matarbari coal-fired power plant (Phase 2) is also proposed to be built. This briefing paper details the human rights, environmental and climate impacts of the Matarbari (Phase 1) project, and identifies financial, reputation and climate-relates risks for companies involved in the project.

Keywords: Matarbari, coal, energy, climate change, risks

BACKGROUND

Matarbari coal-fired power plant (Phase 1) is an under-construction 1,200 MW coal-fired power plant on Matarbari Island in Cox's Bazar, the south-eastern coast of Bangladesh. The project's sponsor is the Coal Power Generation Company Bangladesh (CPGCBL), and Sumitomo Corporation (Sumitomo), Toshiba

Corporation and IHI Corporation of Japan are the Engineering Procurement and Construction (EPC) contractors.¹ Matarbari (Phase 1) is financed as Japan's Official Development Assistance (ODA) loan through Japan International Cooperation Agency's (JICA), insured by Nippon Export and Investment Insurance (NEXI),² with Sumitomo Mitsui Banking Corporation (SMBC) serving as financial advisor.³

Sumitomo Corporation is also expected to be involved in the proposed Matarbari coal-fired power plant (Phase 2), which will add 1,200 MW capacity.⁴ The Bangladesh government has requested JICA finance the second phase of the project.⁵ JICA appointed Tokyo Electric Power Services (TEPSCO), a subsidiary of Tokyo Electric Power Company Holdings (TEPCO) to conduct a feasibility study on Matarbari (Phase 2).⁶ This briefing paper details the human rights, environmental and climate impacts of the Matarbari (Phase 1) project, and questions regarding financial, reputation and climate-relates risk for companies involved in the project.

¹ Sumitomo Corporation news release, '[Orders Awarded for Construction of Thermal Power Plant and Port in Bangladesh](#)' (23 August 2017).

² NEXI, '[バングラデシュ人民共和国／マタバリ超々臨界圧石炭火力発電所・港湾建設案件への支援](#)' (18 October 2017).

³ IJGlobal, '[Asset Data: Matarbari Coal Fired Power Plant \(1200MW\)](#)' (Accessed 17 January 2022, subscription source).

⁴ Sumitomo Corporation, '[Revision to "Policies on Climate Change Issues"](#)' (7 May 2021).

⁵ Energy Bangla, '[Plan to construct 2nd power plant to reduce cost of Matarbari project](#)' (31 May 2019).

Coal Power Generation Company Bangladesh (CPGCB), '[Annual Report 2019](#)' (2020).

⁶ Japan International Cooperation Agency (JICA), '[評価結果：バングラデシュ国マタバリ超々臨界圧石炭火力発電建設事業フェーズ2準備調査（QCBS）](#)' (August 2020).

SOCIAL, ENVIRONMENTAL AND CLIMATE RISKS

Human Rights Impacts Faced by Project-affected Communities

The construction work for Matarbari plant (Phase 1) blocked natural drainage systems and water gates, which were used for draining flood water during monsoon rains and cyclone-induced storms. The blockage of these drainage systems “result[ed] in waterlogging after heavy rainfall, causing immense suffering for locals”.⁷ In 2018, local communities reported five incidents of children drowning.⁸

As of June 2021, according to testimonials of local community members, salt farmers and fishermen who have lost their jobs due to the construction of Matarbari coal power project are yet to receive compensation.

Destruction of Livelihoods and Local Environment

Since the development of the Matarbari coal project began in 2015, Matarbari’s Kohelia river has been narrowed by the project proponent’s construction work and the resulting filling of the river.^{9,10} A road used to transport construction materials has been built running along Kohelia river,¹¹ and acts as an embankment to protect the power plant from flooding.¹²

As a result of the construction, more than 2,000 fishermen who used to rely on the river lost their livelihoods, and trade from the region has been disrupted as boats cannot navigate the river any

⁷ Khobor Torongo, ‘মহেশখালী মাতারবাড়ীতে বৃষ্টির পানিতে জলাবদ্ধতা সৃষ্টি হওয়ায় সীমাহীন দুর্ভোগে পড়েছে হাজার হাজার মানুষ’ (14 July, 2019).

⁸ Relief Web, ‘Cox’s Bazar: Maheshkhali - Water Logging’ (9 July 2018).

⁹ Daily Star, ‘[Stop sand-filling, road building along Kohelia](#)’ (24 Jan 2021).

¹⁰ Daily Star, ‘[The killing of Kohelia](#)’ (25 Jan 2021).

¹¹ JICA, ‘[Information Disclosure: Matarbari Ultra Super Critical Coal-Fired Power Project](#)’ (Accessed 4 Feb 2021).

¹² JICA, ‘[Environmental Impact Assessment \(EIA\) Study of Proposed 7.35 km long Embankment cum Road under Matarbari 1200 MW USC Coal Fired Power Plant Project](#)’ (Accessed 4 Feb 2021).

longer.¹³ Mangrove forests along the river bank have also been destroyed.¹⁴ Locals report pollution from the project's development work damaged adjacent shrimp farms, and the river water has become turbid after mixing with silt from the project work.¹⁵

The Environmental Impact Assessment (EIA) of Matarbari (Phase 1) coal plant has received heavy criticism from environmental and conservation experts.¹⁶ Calling the EIA approval process a "total sham", experts have warned that the EIA fails to properly assess the construction damage, the risk to human health and environment, and downplays threats to critically endangered species in the area.^{17,18,19} The Deputy Director of the Department of Environment (DoE), which approved the EIA in 2014, noted that the encroachment of Kohelia river was not mentioned by project proponents, and that "DoE would not have issued any clearance" if it was.²⁰

Risks from Air Pollution Caused by the Matarbari Plant

In Bangladesh, where the air quality has been ranked among the worst in the world,²¹ pollution from Matarbari (Phases 1 and 2) has been estimated to cause 6,700 premature deaths during the plants' operational years.²²

¹³ Daily Star, '[The killing of Kohelia](#)' (25 Jan 2021).

¹⁴ Ibid.

¹⁵ Eastern News Agency, '[Development impacts on river, "Where has the river legal status gone in Bangladesh?"](#)' (29 Jan 2021).

¹⁶ Daily Star, '[Coast or Construction?](#)' (8 Jun 2018).

¹⁷ Ibid.

¹⁸ Daily Star, '[Matarbari Coal-Fired Plants: Nature sacrificed for power | The Daily Star](#)' (17 November 2021).

¹⁹ Waterkeepers Bangladesh, '[The tourist capital of Bangladesh endangered by plans to build the largest coal power hub in the world](#)' (November 2019).

²⁰ Daily Star, '[The killing of Kohelia](#)' (25 Jan 2021).

²¹ IQAir, '[2020 World Air Quality Report](#)' (March 2021).

²² CREA, '[Air quality, health and toxics impacts of the proposed coal power cluster in Chattogram, Bangladesh](#)' (22 September 2020).

If built, the Matarbari coal plants would emit millions of tonnes of carbon dioxide throughout their operating lifetime.²³ These carbon emissions make all of Bangladesh's proposed coal and other fossil fuel projects,²⁴ including the Matarbari plants, inconsistent with the Paris Agreement's climate goals.²⁵

Climate Change Posing Physical and Transitional Risks

The Matarbari coal power projects and their associated infrastructure are highly vulnerable to physical risks, given extreme weather events exacerbated by climate change. Coastal areas of Bangladesh are highly prone to floods, cyclones and storm surges,²⁶ as can be seen from the devastating effects of Cyclone Yaas, which affected more than one million people and damaged around 26,000 houses.²⁷ Even in a scenario roughly in line with the 2015 Paris Agreement,^{28,29} the entirety of Matarbari island is projected to be inundated at least once a year by 2050.³⁰

In addition to physical climate risk, there are transitional risks associated with concerted efforts towards global decarbonisation, with investments shifting away from coal and other fossil fuels

²³ Lifetime CO₂ estimates are based on the Global Energy Monitor's (GEM) Global Coal Plant Tracker (GCPT) July 2021 dataset (not publicly available).

²⁴ IEEFA, '[Emerging Asia's unrealistic LNG-to-power project pipeline threatens macroeconomic and financial stability](#)' (15 December 2021).

²⁵ Dan Tong et al, '[Committed emissions from existing energy infrastructure jeopardize 1.5 °C climate target](#)'. Nature volume 572, page s373–377 (2019).

²⁶ Climate Analytics, '[Decarbonising South & South East Asia: Country Profile - Bangladesh](#)' (May 2019).

²⁷ Relief Web, '[Bangladesh: Cyclone YAAS - Operation Update Report](#)' (25 June 2021).

²⁸ Climate Central, '[Flooded Future: Global vulnerability to sea level rise worse than previously understood](#)' (29 October 2019).

²⁹ Benjamin H Strauss et al, '[Unprecedented threats to cities from multi-century sea level rise](#)' 2021 Environ. Res. Lett. 16 114015 (2021).

³⁰ Climate Central, '[Coastal Risk Screening Tool](#)' (Accessed 10 April 2020).

towards clean, renewable sources of power³¹ may lead to the Matarbari coal projects becoming stranded assets.³²

PRESENT STATUS

Construction Continues During Covid-19 Lockdown

While the entire world is fighting the coronavirus pandemic and taking strict measures for public health, the 3,000 labourers at the Matarbari construction site were forced to work despite strict government orders to stop.³³ In April 2020, the workers went on strike demanding their right to health.³⁴ In January 2022, at least 31 cases of positive COVID cases were identified at the Matarbari coal power project site.³⁵

Shareholders of Sumitomo Push for Climate Action

In June 2021, one-fifth of Sumitomo Corporation's shareholders voted to support a climate resolution lodged by Market Forces.³⁶ The resolution is a first of its kind targeting a Japanese trading house, calling on Sumitomo to adopt and disclose a plan outlining its business strategy to align its business with the Paris Agreement's goal of limiting global temperature increases to 1.5 degrees Celsius.³⁷ Despite the overwhelming pressure from its

³¹ Oil Price, '[Are Investors Ignoring The Largest Financial Risk Ever?](#)' (3 June 2020).

³² Alexander Pfeiffer et al, '[Committed emissions from existing and planned power plants and asset stranding required to meet the Paris Agreement](#)' 2018 Environ. Res. Lett. 13 054019 (2018).

³³ Prothom Alo, '[মাতারবাড়ী বিদ্যুৎকেন্দ্র লকডাউনের দাবি, কর্তৃপক্ষ বলছে কাজ চলবে](#)' (10 April 2020).

³⁴ Ibid.

³⁵ Daily Bangladesh, '[31 tests COVID positive in Matarbari Coal Power Plant](#)' (8 January 2022).

³⁶ Tokoheizai, '[住友商事、気候変動の株主提案「賛成2割」の重圧](#)' (24 June 2021).

³⁷ Market Forces, '[Sumitomo faces major rebuke from shareholders on climate inaction](#)' (21 Jun 2021).

shareholders, Sumitomo remains open to developing new coal power like the Matarbari (Phase 2) project.³⁸

Japan and Bangladesh Governments Shifting Away from Coal

Following the G7 Summit in June 2021, Japan has committed to stop funding new unabated coal power by the end of 2021.³⁹ In June 2021, the government of Bangladesh announced the cancellation of ten coal-based power projects stating two reasons behind the cancellations being environmental damage and the lack of progress on the projects.⁴⁰ António Guterres, the United Nations Chief has called on countries like Japan to “cancel all global coal projects in the pipeline and end the deadly addiction to coal.”⁴¹

Contradictions to Climate Commitments

JICA has committed to the Sendai Framework For Disaster Risk Reduction 2015 – 2030, which aims to make communities safer and more resilient to disasters.⁴² Any involvement to support the development of coal power in a climate vulnerable country like Bangladesh goes against the spirit of the Sendai Framework, which works hand in hand with the Paris Agreement.

Further, according to the agency’s Climate Change Cooperation Strategy, “JICA will strongly support the transformation to a low-carbon and climate-resilient society and economy in developing countries” with the aim of “attaining the objectives and goals of the

³⁸ Sumitomo Corporation, ‘[Revision to “Policies on Climate Change Issues”](#)’ (7 May 2021).

³⁹ ABC News, ‘[G7 agrees to stop financing coal projects by the end of 2021](#)’ (22 May 2021).

⁴⁰ BD News 24, ‘[Bangladesh scraps 10 coal-based power plants over environmental worries](#)’ (27 June 2021).

⁴¹ RenewEconomy, ‘[UN chief demands Australia ends “deadly addiction” to coal by 2030](#)’ (3 March 2021).

⁴² United Nations Office for Disaster Risk Reduction (UNDRR), ‘Sendai Framework For Disaster Risk Reduction 2015 - 2030’ (18 March 2015).

Paris Agreement.”⁴³ JICA’s involvement in the Matarbari coal plants conflicts with this strategy.

RECOMMENDATIONS

Companies and institutions involved with the Matarbari coal power projects (Phase 1 and 2) face significant financial, reputational and material transitional climate risks. JICA, Sumitomo, TEPCO, Toshiba, IHI Corp, NEXI and SMBC should suspend their plans to build new coal-fired power and utilise the capital to deploy clean, renewable energy projects in Bangladesh. According to Bangladesh’s Sustainable and Renewable Energy Development Authority (SREDA), the country has potential for 30 Gigawatts of solar energy by 2041.⁴⁴ Companies should support renewable alternatives for Bangladesh’s future energy needs.

⁴³ JICA, ‘JICA Climate Change Cooperation Strategy’ (September 2016).

⁴⁴ SREDA, ‘Draft National Solar Energy Roadmap 2021-2041’ (23 December 2020).

কয়লা ও আনবিক বিদ্যুৎ কেন্দ্র কেন বর্জন করবো!

বি.ডি. রহমতউল্লা

সারকথা

তথ্য,উপাত্ত ও বৈজ্ঞানিক বিশ্লেষণের ভিত্তিতে এটা প্রমানিত যে কয়লা ও পারমানবিক বিদ্যুৎ কেন্দ্র থেকে উৎসারিত বর্জ্য প্রকৃতির সাথে মারাত্মক ক্রিয়া-প্রতিক্রিয়া করে বায়ু দূষণসহ প্রাণ-প্রকৃতি-পরিবেশ ও জীববৈচিত্র্যকে বিপর্যস্ত করে এ সুন্দর ব্রহ্মাণ্ডকে বসবাসের অযোগ্য করে তুলেছে । বিশ্বব্যাপী বিদ্যুৎ উৎপাদনে এদের হিস্যা অনেক বড়, প্রায় শতকরা ৬০% । আমরা এও জানি দেশ ও জনজীবনের জীবনমানকে উন্নত করতে হলে বিদ্যুৎ অন্যতম প্রধান উপাদান । কাজেই জনজীবনের কথা ভাবতে গেলে বিদ্যুৎ বাদ দেয়া যাবে না । তাহলে বিদ্যুৎ উৎপাদনে আর কি কোন জ্বালানী আছে যা দিয়ে এধরনের জীববৈচিত্র্যবিনাশী জ্বালানী সম্পৃক্ত বিদ্যুতব্যবস্থা রহিত করে পরিবেশবান্ধব, প্রাণ-প্রকৃতি-বান্ধব বিদ্যুৎ ব্যবস্থা প্রবর্তন করতে পারি !! হ্যা অবশ্যই আছে । এসব জ্বালানী দিয়ে উৎপাদিত বিদ্যুৎ শুধু পরিবেশ বান্ধবই নয়, এগুলো অনেক সাশ্রয়ী, নির্ভরযোগ্য, সহজপ্রাপ্য ও জীববৈচিত্র্য রক্ষাকারী ।

তথ্য,উপাত্ত ও বৈজ্ঞানিক বিশ্লেষণের ভিত্তিতে এটা প্রমানিত যে কয়লা হচ্ছে প্রাণ-প্রকৃতি-পরিবেশ বিনাশী,জীববৈচিত্র্য বিধ্বংসী,মানব বিনাশী একটি অপাংক্তেয়, বর্জ্যনীয় ও নোংরা জ্বালানী । খনি থেকে উত্তোলনের ক্ষন থেকেই কয়লা বিশ্ব-ব্রহ্মাণ্ডের বিনাশ প্রক্রিয়ায় রত হয় । উত্তোলনের পর পরই কয়লা পরিষ্কার করন,ব্যবহারকালীন সময়ে কয়লা থেকে উদগীরিত ও ব্যবহার পরবর্তী সময়ে উচ্ছিষ্ট পরিত্যক্ত বিষাক্ত সব বর্জ্য দীর্ঘকালব্যাপী এ বিশ্ব-ব্রহ্মাণ্ডকে ভুগিয়েই যাচ্ছে ।

অনদিকে আনবিক বিদ্যুৎ কেন্দ্র থেকে নিত্য যে সর্বনাশা রেডিও এ্যাকটিভ(তেজস্ক্রিয়) বর্জ্য বের হয় তা খুবই ভয়ানক যা মানুষের বিভিন্ন অনিরাময়যোগ্য রোগ ব্যাধি পানি ও বায়ু দূষণ সহ সৃষ্টি সহ জমির উর্বরতা, জীববৈচিত্র্য অচিরেই ধ্বংস করে । এক্ষেত্রে বাংলাদেশের জমি ও ভূ-গঠনের

বিশেষ বৈচিত্র্যের বিষয়ে অবহিত হওয়া অত্যন্ত প্রয়োজন। বাংলাদেশের জমিই যে প্রধান সম্পদ ও কৃষি-সমস্যাই যে প্রধান সংকট তা কিন্তু ফুলবাড়ী আন্দোলনে স্পষ্টতঃই প্রমাণিত। ফুলবাড়ীতে কয়লা খনি হলে ঐ এলাকার জমি ও চাষের জল বিনাশ হয়ে যাবে বিধায় হাজার হাজার কৃষক কাঁপিয়ে পড়ে যে এক আকাশ-কাঁপানো গণ-অভ্যুত্থান সৃষ্টি করে এদেশের বিপ্লবী আন্দোলনে ইতিহাস সৃষ্টি করলো, রামপাল ও রূপপুরে কেন তা হচ্ছে না? অথচ পরিবেশ বিধ্বংসী, জীব-বৈচিত্র্য বিনাশী প্রতিক্রিয়ার কথা বিশ্লেষণ করলে দেখা যায় রামপাল ও রূপপুরে তা হবে আরো ভয়ানক। এখানে কথিত প্রকল্প বাস্তবায়িত হলে কৃষকরাই তাঁদের জমি হারাবে, ঐ এলাকার জমির উর্বরতা শক্তি ধ্বংস হবে, জল ভয়ানক দূষিত হয়ে যাবে, বায়ু দূষণ সহ জীববৈচিত্র্য অচিরেই ধ্বংস হয়ে যাবে। ফুলবাড়ীতে যারা কৃষকদের এ তথ্যটি দিতে পারলো তাঁরা রামপালে, রূপপুরে, মাতারবাড়ীতে, সাতক্ষীরায়, রাউজানে, সেন্ট মার্টিনে কিংবা যে সব স্থানে মানব বিনাশী কয়লা ভিত্তিক ও আনবিক বিদ্যুৎ কেন্দ্র হলে প্রতিটি কেন্দ্রের ১০/১২ কিলোমিটার ব্যাপী বসবাসরত কৃষক পরিবারসমূহকে বসবাসের অযোগ্য হয়ে যাবে বিধায় বসতভিটা ছেড়ে চিরতরে বাস্তহারা হতে হবে। আর বাংলাদেশ হারাবে অনেক মূল্যবান জমি, নদী-খাল-বিল সহ ভূ-গর্ভস্থ পানি, জলজ ও বনজ প্রাণী! তো আর রইলো কি!! বিদ্যুৎ জলবে অথচ কোন জন-মানুষ নেই, কোন প্রাণীও নেই!! কয়লা ও পারমাণবিক বিদ্যুৎ কেন্দ্র বসানোর এই হলো শেষ পরিনতি।

৫টি মূল শব্দ : জীবাশ্ম জ্বালানী ; গ্রীন হাউস গ্যাস ; এসিড রেইন ; পারমাণবিক বর্জ্য ; নবায়নযোগ্য জ্বালানী ;

ভূমিকা

আজ থেকে প্রায় ৩০০০ বছর আগ থেকে জ্বালানী হিসেবে কয়লার ব্যবহার শুরু হয়। তবে তখন তা শুধু আগুন জ্বালানোর জন্যে। এটা তাপ ও বিদ্যুৎ উৎপাদনে জ্বালানী হিসেবে ব্যবহার হতে থাকে মাত্র ১৫০/১৬০ বছর আগ থেকে। শিল্প বিপ্লবের পর পরই ব্যাপক শিল্পায়নের চাহিদার কারণে ক্রমবর্ধমান বিদ্যুৎ উৎপাদনের চাহিদা মেটাতে কয়লা গুরুত্বপূর্ণ ও মূল্যবান জ্বালানীর ভূমিকায় সামনে চলে আসে। জাহাজ এবং রেলের ইঞ্জিনে স্টীম উৎপাদনে

কয়লার ব্যবহার এ জ্বালানীকে মুনাফা লুটকারীদের কাছে আরো ঘনিষ্ঠ, আরো "উন্নয়ন বান্ধব" করে তোলে । অষ্টাদশ শতাব্দীতে কয়লা দিয়ে চালিত রেলের লোকোমোটিভ ইঞ্জিন রেল যোগাযোগকে সাশ্রয়ী ও আরামদায়ক করে তোলেচাহিদা বৃদ্ধির সাথে সাথে কয়লার বাণিজ্যিক ব্যবহারও বেড়ে যেতে থাকে । পুঁজিবাদের উত্থান ও সাম্রাজ্যবাদী শক্তিতে রূপান্তরে কয়লা অত্যন্ত গুরুত্বপূর্ণ ভূমিকা পালন করে । উন্নত পুঁজিবাদী রাষ্ট্র ও সাম্রাজ্যবাদী শক্তিসমূহের অর্থনীতির গতিপ্রবাহ যদি আমরা গভীরভাবে পর্যবেক্ষণ করি তাহলে কি দেখি ! গনতন্ত্র উদ্ধারের নামে সামন্তবাদকে বিতাড়িত করে কারিগরি উৎকর্ষতা, শিল্প-সাহিত্য সংস্কৃতি, অর্থনীতির ব্যাপক প্রসার ঘটিয়ে নিজ দেশের জনগনের শিক্ষা, আবাস-স্থান, স্বাস্থ্য সেবার সুযোগ বাড়িয়ে সম্ভ্রষ্ট রেখে পুঁজিবাদ এক দানবীয় রূপ ধারণ করে অচিরেই পর রাজ্য দখল, লুণ্ঠন ও অবর্ণনীয় শোষণ বিশ্বব্যাপী এক অসহনীয় অরাজকতা সৃষ্টি করে । উপনিবেশিক রাষ্ট্রের শ্রমিক কৃষকসহ প্রায় সবধরনের মেহনতী জনগনের উপর নির্মম অর্থনৈতিক শোষণ, মুনাফা লুণ্ঠন ও এদের "দাস" বানাবার কৌশল বিশ্ব সভ্যতার এক কালিমালিঙ্গ অধ্যায় !

ইতিহাস ঘাটলে আমরা দেখবো যে বিশ্বের আধুনিক রাষ্ট্রসমূহের অর্থনৈতিক উন্নয়নে শিল্পোৎপাদনের ব্যাপক প্রসারে কয়লা ছিলো এক গুরুত্বপূর্ণ জ্বালানী । তেমনি সাম্রাজ্যবাদী উত্থানে নিজদেশের মেহনতী জনগনসহ ঔপনিবেশিক ও ভিন্ন দেশসমূহে জনগনকে শোষণ ও লুণ্ঠনের জন্য অন্যতম সহায়ক মাধ্যম হিসেবে এরা বেছে নিলো কয়লাকে । কয়লা স্থানান্তরযোগ্য, সাশ্রয়ী ও ব্যবহারপদ্ধতি সহজ বিধায় চাহিদা যেমন বেড়েছে তেমনি সাম্রাজ্যবাদী রাষ্ট্রসমূহের কাছে এ যেন সোনার হরিন হয়ে উঠলো । কয়লা খনির সন্ধান, কয়লা প্রাপ্তির সম্ভাব্যতা যাচাই, খনি খনন, কয়লা যল উত্তোলন, কয়লা দিয়ে বিদ্যুৎ উৎপাদন এ সব কিছুই প্রকৌশলগত উৎকর্ষতা নিজেদের দখলে রেখে ধনী দেশগুলো বিরাট এক কয়লা সাম্রাজ্য গড়ে তুললো । এ ভাবে কয়লা হয়ে উঠলো ধনীদেশ ও সাম্রাজ্যবাদী রাষ্ট্রসমূহের "বুকের ধন" !! পুঁজিবাদীরা যেমন নিপীড়নমূলক সামন্তবাদকে হটিয়ে গনতন্ত্রের বাতায়নে সাম্রাজ্যবাদে রূপান্তরিত হয়ে বিশ্ববাসীর জন্য আজ "গোঁদ ফোঁড়া" হিসেবে আবির্ভূত হয়েছে, কয়লা তাদেরই "পোষ্য" হয়ে পৃথিবীতে এক শক্তিশালী

ভয়ঙ্কর জ্বালানী হিসেবে সামনে এসে দাঁড়িয়েছে । ৩০০ থেকে ৪০০ বছরের মাথায় এটা যেমন স্পষ্ট হয়ে উঠলো যে পুঁজিবাদ কোটি কোটি মানুষের জীবন লাঞ্ছনার সৃষ্টি করেছে , তেমনি মর্ত্যে কয়লার উপস্থিতি ও ব্যবহার এ নির্মল পৃথিবীর জলবায়ু, জীববৈচিত্র্য,প্রাণ-প্রকৃতি-পরিবেশ,নদ-নদী-জলাশয়-খালবিল, ভূমি-জমি-গাছপালা, জলজ প্রাণী ও মনুষ্যজীবনের জন্য ভয়ানক এক হুমকি হিসেবে দেখা দিয়েছে ।

কয়লার গঠন ও বাংলাদেশের কয়লা

তথ্য,উপাত্ত ও বৈজ্ঞানিক বিশ্লেষণের ভিত্তিতে ভূবিজ্ঞানীরা স্পষ্ট করেছেন যে অসংখ্য যানবাহন, কল-কারখানা,উদারভাবে বৃক্ষনিধন, নদ-নদী-খাল-বিল দখল করার ফলে পানি শুকিয়ে যাওয়া ইত্যাদি অনেক কারণ থাকলেও আজ বিশ্বে অধিক পরিমাণে CO₂ নির্গত হয়ে যে প্রচণ্ড উষ্ণতা বৃদ্ধি পাচ্ছে তার জন্য শতকরা ৭০% দায়ী কয়লা কিংবা কয়লা সম্পৃক্ত কল কারখানা, কয়লা ভিত্তিক বিদ্যুৎ উৎপাদন ইত্যাদি কার্যাবলী । ভূবিজ্ঞানী, পরিবেশবিদ ও সচেতন নাগরিকেরা কয়লাকে কেন এতো বিষাক্ত বলছে সে বিষয়ে একটি বিজ্ঞান ভিত্তিক বিশ্লেষণ করা দরকার ।

কয়লা একটি জৈব জ্বালানী । হাজার বছর গাছ-পালা ইত্যাদি জীবাশ্ম উপাদান ভূ-তলে চাপা পড়ে থেকে কয়লাতে রূপান্তরিত হয় । এ ধরনের কয়লা যেগুলোকে খনন করে উত্তোলন করতে হয় ঐগুলোকে খনিজ কয়লা বলা হয় । আর কাঠ পুড়িয়ে যে কয়লা পাওয়া যায় সেগুলোকে বলে কাঠ কয়লা । এর পরিমাণ একেবারেই নগন্য । এ দুটির চারিত্রিক বৈশিষ্ট্য এতো পার্থক্য যে একটির সাথে অন্যটির তুলনা করা একটি মুর্খতা বৈ আর কিছুই নয় !! আমরা খনিজ কয়লাতেই আলোচনাটি সীমাবদ্ধ রাখবো । ভূপৃষ্ঠের বৈশিষ্ট্য ও ভূ-তলে চাপা পড়ে থাকার সময়কাল ও জীবাশ্ম উপাদানের উপর নির্ভর করে কয়লার গুণাগুণ নির্ধারিত হয় । বায়বীয় উপাদান [H, O ও H₂O ইত্যাদি] ও তাপ রূপান্তর ক্ষমতার [Caloric Value /KG] উপর নির্ভর করে কয়লাকে নিম্নোক্ত কয়েকটি ভাগে বিভাজন করা হয়েছে : (১)পীট (২) লিগনাইট (৩)

সাব-বিটুমিনাস (৪) বিটুমিনাস (৫) স্টীম কয়লা (৬) এনথ্রেসাইট (৭) গ্রাফাইট ইত্যাদি ।

বিদ্যুৎ উৎপাদনে মূলতঃ বিটুমিনাস ও সাব-বিটুমিনাস কয়লা ব্যবহৃত হয় । এ দুটির বায়বীয় উপাদান অন্যান্য ধরনের কয়লা থেকে অনেক কম আবার তাপ রূপান্তর ক্ষমতাও বেশী যা বিদ্যুৎ উৎপাদনে অনেক সহায়ক । উল্লেখ্য যে বাংলাদেশে সম্ভাব্য সবগুলো খনিতেই বিটুমিনাস ও সাব-বিটুমিনাস কয়লা মণ্ডল আছে বলে পর্যবেক্ষণে প্রমাণিত হয়েছে । সিসমিক সার্ভে থেকে এটাও প্রতিফলিত যে বাংলাদেশের এ কয়লা প্রায় ২৫ থেকে ২৮ কোটি বছরের সঞ্চিত কার্বন থেকে সৃষ্ট ॥ ফলে এগুলো খুব উচ্চমানের, পরিমাণও বেশী । স্বরন রাখতে হবে যে ” উচ্চমান ” ও ” পরিমাণ ” অত্যন্ত সন্তোষজনক এই প্রত্যয়ন পত্রটিই হচ্ছে বাংলাদেশের জন্য এক অশনি সংকেত । কারণ এ উচ্চমানের ও সমৃদ্ধ পরিমানে কয়লাসম্পদের সম্ভাব্য প্রাপ্তিতে সাম্রাজ্যবাদী ও বহুজাতিক কোম্পানীসমূহ বাংলাদেশের উপর ঝাঁপিয়ে পড়তে আগ্রাসী হয়ে উঠেছে । সে কারণেই আমরা দেখছি ফুলবাড়ী, দিনাজপুরে এশিয়া এনার্জি নামক একবহুজাতিক ফটকা কোম্পানীর নগ্ন আগ্রাসনের হুমকি আর এদিকে রামপালে ভারতীয় আধিপত্যবাদী শক্তি পৃথিবীর সর্ববৃহৎ বাদাবন [Mangrove Forest] সুন্দরবন যা ”বিশ্ব ঐতিহ্য” হিসেবে UNESCO কর্তৃক স্বীকৃত এদেশের জীববৈচিত্র্য, প্রাণ-প্রকৃতি-পরিবেশ, নদ-নদী-জলাশয়-খালবিল, ভূমি-জমি-গাছপালা, জলজ প্রাণী ও মনুষ্যজীবন ধ্বংস করতে বিরাট এক ঢাউস আকৃতির ১৩২০ মেগাওয়াট ক্ষমতার কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র বসাতে এক নির্মম নিষ্ঠুর হোলি খেলায় মেতে উঠেছে । উল্লেখ্য যে এর পাশে এদেশেরই আরেক ”মহাজন” ৬৬০ মেগাওয়াট ক্ষমতার জীববৈচিত্র্য বিধ্বংসী আরেকটি কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র বসানোর পরিকল্পনা করেছে । বাংলাদেশের উপর সাম্রাজ্যবাদী ও আধিপত্যবাদী শক্তিসমূহের কয়লার ছোবলে এর ব্যবহার যত বাড়বে ততই তা এদেশের জীববৈচিত্র্য, প্রাণ-প্রকৃতি-পরিবেশ, নদ-নদী-জলাশয়-খালবিল, ভূমি-জমি-গাছপালা, জলজ প্রাণী ও মনুষ্যজীবন ধ্বংস করে এদেশের জীবনপ্রাণকে দুর্বিসহ করে তুলবে ।

বাংলাদেশে পরিকল্পিত কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র ও সম্ভাব্য বিপর্যয়

সরকার সম্প্রতি কয়রা ভিত্তিক বিদ্যুৎ কেন্দ্র বসানোর যে আশ্রাসী পরিকল্পনা ঘোষণা করেছিলো কোথায় এবং তার উৎপাদন ক্ষমতা কত ছিলো তা দেখে নেই।^১

পরবর্তীতে তার প্রতিক্রিয়া সম্পর্কে একটি বৈজ্ঞানিক পর্যালোচনা করতে চেষ্টা করবো।

- (১) মুন্সীগঞ্জ পরিকল্পিত ৫০০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (২) ঢাকায় পরিকল্পিত ২৫০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (৩) চট্রগ্রামের মহেশখালীতে পরিকল্পিত ১৩২০X ২ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (৪) আশুগঞ্জে পরিকল্পিত ১৩২০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (৫) চাঁদপুরে পরিকল্পিত ৭০০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (৬) উত্তরবঙ্গে পরিকল্পিত ১২০০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (৭) পটুয়াখালীতে পরিকল্পিত ১৩২০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (৮) মাওয়াতে পরিকল্পিত ৫০০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (৯) চট্রগ্রামে পরিকল্পিত ২৮০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (১০) খুলনাতে পরিকল্পিত ৫৬০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (১১) চট্রগ্রামের মাতারবাড়িতে নির্মিতব্য ১৪০০(৭০০X ২) মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (১২) চট্রগ্রামের রাউজানে ১৩২০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (১৩) বাগেরহাটের রামপালে নির্মানাধীন ১৩২০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (১৪) কক্সবাজারে পরিকল্পিত ১৩২০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (১৫) খুলনার পায়রাতে পরিকল্পিত ১৩২০ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র
- (১৬) বরগুনাতে ৩০৭ মেগাওয়াটের কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র

এ বিদ্যুৎ কেন্দ্রগুলো নির্মিত হলে অত্র অঞ্চলে ,সমগ্র দেশে এবং চূড়ান্ত বিশ্লেষণে সারা বিশ্বে যে কি ধরনের বিপর্য্যয়ের সৃষ্টি করবে এতক্ষণে আমরা নিশ্চয়ই তা উপলব্ধি করতে পেরেছি । তবে সুখের কথা সরকার হঠাৎ করে এর মধ্যে উপরে বর্ণিত ৮৫০০ মেঃওঃ ক্ষমতার প্রথম ১০টি বিদ্যুৎ কেন্দ্র উৎপাদন পরিকল্পনা বাতিল করেছে ।^২ এতে ভাবার কোন কারণ নেই যে কয়লা সম্পর্কে এবং এর দ্বারা সৃষ্ট বিপর্য্যয়ের বিষয়ে নীতিনির্ধারকদের মত পালটেছে । এর কারণগুলো হলো স্থানীয় ও আন্তর্জাতিক পর্যায়ে পরিবেশবাদীদের আন্দোলন, অর্থ প্রাপ্তিতে অনিশ্চয়তা, নিকট ভবিষ্যতে অব্যাহত কয়লা সরবরাহে অনিশ্চয়তা । বাকী বিদ্যুৎ উৎপাদন গুলো উৎপাদনে গেলে সম্ভাব্য বিপর্য্যয়গুলো সম্পর্কে সংক্ষেপে নীচে তুলে ধরা হচ্ছে ।

কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র থেকে উদগীরিত বর্জ্যসমূহ

আমরা জানি কয়লা ভিত্তিক বিদ্যুৎ উৎপাদন যে সব বায়ুদূষণকারী বর্জ্য নির্গত হয় সেগুলির কয়েকটি হলো CO_2 , SO_2 , SO_4 , CH_4 , NO_x , SO_x , CO , As , Pb , Cr , Ni ও Hg । নীচে সংক্ষেপে এগুলো সম্পর্কে বর্ণনা দেয়া হলো ।

(ক) CO_2 হচ্ছে ভূ-প্রকৃতির উষ্ণতা বৃদ্ধির জন্য শতকরা ৭০থেকে ৯০% দায়ী । এ CO_2 ভূ-মন্ডলকে বিনাশকারী অন্যান্য বর্জ্যেরও উৎপাদন সহায়ক । কয়লা ভিত্তিক বিদ্যুৎ উৎপাদন কেন্দ্র হচ্ছে CO_2 উদগীরনের প্রধান কেন্দ্র । কয়লা বিদ্যুৎ উৎপাদন কেন্দ্র থেকে উদগীরিত CO_2 প্রথমতঃ অত্র অঞ্চলে নির্মিত বিদ্যুৎ কেন্দ্রের চারদিকে ২০ থেকে ২৫ কিঃ মিঃ বিস্তৃত এলাকায় পরবর্তীতে সমগ্র দেশে এবং চূড়ান্ত বিশ্লেষণে সারা বিশ্বে প্রচুর পরিমাণে এই মানববিনাশী, প্রকৃতি বিনাশী ভয়ানক এক বর্জ্য

(খ) নির্মিত বিদ্যুৎ কেন্দ্রের চারদিকে ২০ কিঃ মিঃ বিস্তৃত এলাকায় জীববৈচিত্র্য যথা গাছ-পালা, ঝোঁপ-ঝাড়, বনজ গাছ-গাছালি, বন্যপ্রাণী, মাছ, সাপ, মাটি ও পানিতে জন্ম নেয়া জলজ উদ্ভিদ ও প্রাণী সময়ের বিবর্তনে ধ্বংস

হয়ে যাবে। অন্যান্য বায়ুদূষণকারী বর্জ্য ও SO_2 উদগীরনের ফলে বনজ গাছ-গাছালির বংশ বৃদ্ধি প্রচণ্ডভাবে হ্রাস পাবে এবং অত্র এলাকায় ১০ থেকে ১৫ বছরের মধ্যে মরুময় প্রক্রিয়া শুরু হবে।

- (গ) কয়লা ভিত্তিক বিদ্যুৎ উৎপাদন পার্শ্ব প্রতিক্রিয়া হিসেবে বায়ু মন্ডলে এবং ভূমিতে SO_4 জমে এসিড রেইনের (রাসায়নিক বৃষ্টি) উৎপত্তি হবে। এই এসিড রেইনের ফলশ্রুতিতে বিভিন্ন প্রাণী, পশু-পাখী, গাছ-গাছালী, নদী-খাল-বিলের পানি প্রায় সবকিছুই ক্রমশঃ বিলীন হয়ে যাবে। সবধরনের প্রাণী, পশু-পাখী, এদের বংশ বৃদ্ধি করার প্রজনন ক্ষমতা প্রচণ্ডভাবে হ্রাস পাবে। এসব প্রাণীকূল অস্বাভাবিক শারীরিক পরিবর্তনের সম্মুখীন হবে।
- (ঘ) নদীর পানির গুণাগুণ এবং নদীর ভূমিতলের ঋনাত্মক পরিবর্তনের ফলে সবধরনের মাছের সংখ্যা প্রচণ্ড হ্রাস পাবে। কয়লা থেকে উদ্ভূত বর্জ্য মাছের খাদ্য মান বিষক্রিয়া দ্বারা প্রভাবিত হবার ফলে এ মাছ ভক্ষণে মানুষ, ব্রঙ্কাইটিস্, হাঁপানি, শ্বাসকষ্ট, ফুসফুস, কিডনি, লিভার, শ্বাসনালীতে ক্যান্সার ও অন্যান্য দূরারোগ্য ব্যাধিতে আক্রান্ত হবে।
- (ঙ) এ কয়লা থেকে নির্গত ধাতব বর্জ্য যথা টিন, শীশা, ক্রোমিয়াম, নিকেল, পারদ (As, Pb, Cr, Ni, Hg) ইত্যাদি জমির সাথে মিশ্রনের ফলে জমির উর্বরতা প্রচণ্ড হ্রাস পাবে এবং উৎপাদিত ফসল মানুষের খাওয়ার উপযুক্ততা হারাতে পারে। এসব বর্জ্য থেকে শ্বাসনালী ও ফুস্ ফুসের ক্যান্সারসহ পঙ্গুত্বও নানারকম অনিরাশয়যোগ্য রোগ বালাইয়ের সৃষ্টি হবে। এসব বর্জ্যের পার্শ্ব প্রতিক্রিয়া হিসেবে গর্ভধারিণী মায়ের সন্তান বিকলাঙ্গ অথবা পঙ্গুত্ব বরন করতে পারে।
- (চ) এখনি সারাদেশে পানির স্তর অনেক নীচে নেমে গেছে। কয়লা ভিত্তিক বিদ্যুৎ উৎপাদন প্রক্রিয়া বয়লারের শীতলীকরণ প্রক্রিয়ায় প্রচুর পানি উত্তোলন করতে হবে বিধায় পানির স্তর আরও অনেক নীচে নেমে যাবে। ফলশ্রুতিতে সমগ্র এলাকায় পানির এক তীব্র সংকট দেখা দিবে।
- (ছ) কয়লা বিদ্যুৎ কেন্দ্র থেকে উদগীরিত দূষিত বর্জ্য বিশেষত Fly Ash ও Bottom Ash আমাদের জমি পলল বিধায় চুইয়ে চুইয়ে নদী-খাল-

বিলের পানিতে মিশে পানিকে ভয়ানক দূষিত করবে। নদী-খালে বসবাসকারী প্রাণীসমূহ যা লক্ষ লক্ষ বছর বিচরন করে পরিবেশ ও নদীর পানিকে মানব বান্ধব করে রেখেছে এ মানব বান্ধব জলজপ্রাণীগুলো সব বিনাশ হয়ে যাবে।

- (ঝ) কয়লা থেকে উদগীরিত ক্ষুদ্র ক্ষুদ্র হাজার হাজার টন দূষিত বর্জ্য যা মূলতঃ টিন, শীশা, ক্রোমিয়াম, নিকেল, পারদ ইত্যাদি। এগুলোর প্রতিক্রিয়ায় ফল-ফলাদির উৎপাদন অসম্ভব রকম হারে হ্রাস পাবে ফলে বেকারত্ব, দারিদ্র বৃদ্ধিসহ সমাজে নৈরাজ্য ও হতাশার সৃষ্টি হয়ে এক অস্থিতিশীল সমাজ গড়ে উঠবে।
- (ঞ) বিদ্যুৎ উৎপাদন জনিত কালো ধোঁয়া, H_2O দ্বারা আবৃত থেকে কুয়াশা ঝলমলে রোদ্দুর ঢেকে থাকার ফলে বাংলাদেশের বিভিন্ন এলাকা সর্বদাই কালে মেঘ দ্বারা আবৃত থাকবে।
- (ট) নির্মিত বিদ্যুৎ কেন্দ্রের চারদিকে ২০ কিঃ মিঃ বিস্তৃত এলাকায় উৎপাদিত ঘাস যা গরু-ছাগলের খাদ্য অর্থাৎ মূল খাদ্য- তা বিষযুক্ত হওয়ার ফলে দুধের মান যেমন হ্রাস পাবে তেমনি দুধের পরিমাণও অনেকাংশে কমে যাবে। ঐ সমস্ত গরু-ছাগলে মাংস ভক্ষনে মানুষের নানা রকম অনিরাশয়যোগ্য রোগব্যাধির সৃষ্টি হবে।
- (ঠ) উদগীরিত Green House Gas যথা CH_4 , NO_x এবং SO_2 বায়ুমন্ডলে সঞ্চিত হবে। এ সঞ্চিতবনের ফলে জাতীয় আবহাওয়ার বৈশিষ্ট্য ব্যাপক পরিবর্তন হবে যা কিছুতেই সার্বিক দৃষ্টিকোন থেকে জনগণের স্বাস্থ্য বিবেচনায় কল্যাণকর ও শুভ নয়।
- (ড) কয়লা ভিত্তিক উৎপাদন কেন্দ্র থেকে উদগত NO_x এবং SO_2 এর ফলে এসিড বৃষ্টির সৃষ্টি হবে। এই রাসায়নিক বৃষ্টি ভূমি, জমির উর্বরতা এবং পানির গুনাগুনের ব্যাপক পরিবর্তন ঘটাবে যা মানুষসহ সমস্ত প্রাণীকূলের বেঁচে থাকার এক বৈরী পরিবেশ সৃষ্টি হবে এবং ক্রমশঃ পরিবেশও অস্বাস্থ্যকর হয়ে প্রাণীকূলের দৈহিক গঠনে এক নেতিবাচক প্রভাব ফেলবে।

- (ঢ) প্রস্তাবিত বিদ্যুৎ কেন্দ্রের স্থানে কয়লা পরিবহন কালে বিশেষ করে নদী বন্দর, নৌপথসহ সড়কপথের সংলগ্ন সমস্ত এলাকা দূষিত হয়ে জীববৈচিত্র্য, প্রাণ-প্রকৃতি-পরিবেশ, নদ-নদী-জলাশয়-খালবিল, ভূমি-জমি-গাছপালা, জলজ প্রাণী ও মনুষ্যজীবনের জন্য ভয়ানক এক হুমকি হিসেবে দেখা দিবে।
- (ণ) কয়লা ভিত্তিক বিদ্যুৎ উৎপাদন কেন্দ্রে বিদ্যুৎ উদৎপাদনের জন্য যখন কয়লা পোড়ানো হবে তখন সেই কয়লা থেকে মানুষের স্বাস্থ্যের জন্য অত্যন্ত ক্ষতিকর ইউরেনিয়াম, থোরিয়াম এবং এ থেকে আরও কিছু রেডিও এ্যাকটিভ পদার্থ সৃষ্টি হয়। এগুলো পরিবেশকে মারাত্মকভাবে দূষন করে। যুক্তরাজ্যের একটি প্রখ্যাত বিশ্ববিদ্যালয়ের একজন গবেষকের একটি জরিপ থেকে জানা গেছে যে এ দূষণ প্রক্রিয়া একই ক্ষমতার একটি পারমানবিক বিদ্যুৎ উৎপাদন কেন্দ্র থেকে উদগত রেডিও এ্যাকটিভ ম্যাটেরিয়ালের বর্জ্য থেকে ৪০ থেকে ৮১ গুন বেশী। কাজেই মনুষ্যজীবনতো বটেই এদেশের গাছ-গাছালি, শস্য-শ্যামল জমি, নদ-নদী-জলাশয় ইত্যাদির উপর এসব বর্জ্য এক মারাত্মক হুমকি হিসেবে আর্বিভূত হবে।
- (ত) যে বৃষ্টির পানি সেচ ও পানের জন্য ব্যবহৃত হতো তা আর করা যাবে না- কারণ যে বায়ুমন্ডল থেকে বৃষ্টি পড়বে তা বিষাক্ত হয়ে উঠার ফলে এ পানি পানের ও সেচের জন্য উপর্যুক্ততা হারিয়ে ফেলবে।
- (থ) কয়লা থেকে উদগত আর্সেনিক দ্বারা ভূমি জলে আর্সেনিক দূষন শুধু বৃদ্ধিই পাবে না, তা ত্বরান্বিতও হবে। এতে সবাইরই স্বাস্থ্যহানি ঘটবে এবং শিশুদের শ্রবণ শক্তি প্রচণ্ড হ্রাস পাবে।
- (দ) এসব বৃহৎ কয়লা ভিত্তিক বিদ্যুৎ উৎপাদন কেন্দ্রে সৃষ্ট পরিবেশ দূষণকারী বর্জ্য উৎপাদনকারী হিসেবে বাংলাদেশ অচিরেই পরিবেশ দূষণকারী দেশ হিসেবে কালো তালিকাভুক্ত হবে।

বাকী যে ৬টি উৎপাদন কেন্দ্র থেকে যাবে হিসেব করে দেখা গেছে তাতে উৎপাদিত বিদ্যুৎ উৎপাদিত হবে প্রায় ৯০,০০০ GWh। বর্জ্য উদগীরনের পরিমাণ নির্ধারণে মার্কিন যুক্তরাষ্ট্রের একদল বিশেষজ্ঞ ঐ দেশের বেশ

কয়েকটি কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র পর্যবেক্ষণ করে কিছু বর্জ্য উদগীরনের পরিমানের গড় নির্ধারণ করেছে যা ছক-১এ দেয়া হলো।^৩ এ থেকে ৯০,০০০ GWh এর বার্ষিক বর্জ্য নির্গমনের পরিমান বের করা হয়েছে।

ছক-১: কয়লা থেকে উদগীরিত বার্ষিক বর্জ্যের পরিমান

CO ₂	NOX	CO ₂	Hg
Kg/MWh	Kg/MWh	Kg/MWh	Kg/MWh
৫.২১	২.৫৪	১১৮০	০.২৩
৯০,০০০ GWh/per year কয়লা থেকে উদগীরিত বর্জ্য দাঁড়ায়			
৫০০ টন	২৩০ টন	১ লক্ষ টন	২০ টন

ভূ-বিজ্ঞানীরা কি বলছেন

আমরা বর্জ্যের পরিমান দেখে খুব স্পষ্ট করে জানলাম যে কয়লা হলো এমন একটি জ্বালানী যা শুধু জীব-বৈচিত্র্যকেই ধ্বংস করেছে না। এটি জমি ও পানির উর্বরতাকে ধ্বংস করে বিষাক্ত করে তোলে, বায়ু দূষণে অত্যন্ত তৎপর, প্রাণী ও মানুষের দেহে অনিরাময়যোগ্য রোগ বীজানু যেমন ব্রঙ্কাইটিস, কিডনী ও শ্বাসনালীর ক্যান্সার, অন্ধত্ব, নিইরোলজী, হাঁপানী ইত্যাদি সংক্রমণ করে, জলকে দূষিত ও জলজ প্রাণীসহ গাছ-গাছালি ও ফসলের ব্যাপক ক্ষতি সাধন করে। কয়লার আচরণগত বৈশিষ্ট্য সমূহ দেখে ইতোমধ্যে ভূ-বিজ্ঞানীগণ শুধু কয়লার ব্যবহার বন্ধই নয়, কয়লাকে ভূতল থেকে উঠিয়ে আনাতেও প্রবল আপত্তি জানাচ্ছেন। ভূ-বিজ্ঞানীগণ হিসেব কষে, বিজ্ঞানের উপর ভিত্তি করে বিশ্লেষণ করে বলছেন যে, যে নির্মল আবহাওয়া, সুন্দর বাতাস, সৃষ্টি পানি, এ উর্বরা শস্য ক্ষেত, জীব-বৈচিত্র্যের প্রচণ্ড অভিজাত্য নিয়ে এ ধরাকে এগিয়ে এসেছিলো-তার অন্যতম কারণ হলো ভূ-তলে নানারকম খনিজ পদার্থসহ কয়লার সহ-অবস্থান। এ পৃথিবী ভূ-তলে কয়লা ও অন্যান্য জ্বালানীগুলোকে তার বুকে ধারণ করেই জীব-বৈচিত্র্যের নানারকম বৈশিষ্ট্যগুলো পেয়েছে। এ যেন অনেকটা মানুষের দেহের মতো। মানুষ যেমোন তার প্রতিটি অঙ্গ নিয়ে একটি পূর্ণ দেহের সুস্থ মানুষ হয়ে উঠে, তার কোন অঙ্গ যেমন কিডনী, চোখ

কিংবা হাত কাউকে দিয়ে দেবার পর সে বেঁচে থাকলেও আর পূণার্জ মানুষ কিংবা পূর্ণ সুস্থতার দাবী করতে পারে না তেমনি ভূ-বিজ্ঞানীগণের বিশ্লেষনে কয়লাসহ যাবতীয় জ্বালানী উত্তোলনে এ সুন্দর পৃথিবীর ও এ অবস্থাটাই তুলে ধরা হয়েছে। একেতো এসব জীবাস্ব জ্বালানী (বিশেষতঃ তেল, কয়লা) কে ভূ-তল থেকে উঠালে এ সুন্দর পৃথিবী “মানুষের অঙ্গহানি দেহের মতো” পঙ্গুত্ব বরন করে, পরবর্তীতে আবার যখন ঐ সব জীবাস্ব জ্বালানী ব্যবহারের জন্য পোড়ানো হয় আমরা সেতো দেখলামই কিভাবে এ সুন্দর পৃথিবীর নদ-প্রকৃতি-পরিবেশ-জীববৈচিত্র্য ধ্বংসের কিনারায় এসে দাঁড়ায়।

ভূবিজ্ঞানীরা আরো বলছেন, যা ক্ষতি হবার তাতো হয়েই গেছে। আর কয়লা উত্তোলন নয়! কয়লাসহ নানান ধরনের জীবাস্ব জ্বালানী উত্তোলন ও ব্যবহারের ফলে পৃথিবীব্যাপী সমস্ত ক্রিয়া প্রতিক্রিয়া যাচাই করে আর কয়লা উত্তোলন নয় বলে পৃথিবীর সচেতন দেশপ্রেমিক, গণমানুষের বন্ধু, প্রকৃতি প্রেমিকদের কয়লা উত্তোলন ও ব্যবহারের বিরুদ্ধে এক তীব্র আন্দোলন গড়ে তুলতে আহ্বান জানিয়েছেন।

কয়লা ব্যবহারের পরিণতি

চীনের বেইজিং কিংবা গুয়াংজু ও অন্যান্য শহরে অথবা ভারতের মুম্বাই কিংবা দিল্লীসহ বিভিন্ন শহরগুলো কিংবা অস্ট্রেলিয়ার শহরগুলোর তাপমাত্রা বৃদ্ধিসহ বনে যে আগুন লাগার (বুশ ফায়ারিং) ঘটনা ঘটছে কিংবা অতি সম্প্রতি মার্কিন যুক্তরাষ্ট্রের শহর বা স্টেটগুলোতে প্রচণ্ড সুনামী, জলোচ্ছাস কিংবা গ্রীষ্মকালে প্রচণ্ড তাপমাত্রা বৃদ্ধি আবার উল্টোদিকে ভারী তুষারপাত হচ্ছে তাকি শুধুই বিদ্যুৎ কেন্দ্রে কয়লা ব্যবহারের ফলেই হচ্ছে! সামগ্রিক বিষয়টির ব্যাপারে আমাদের আরো স্বচ্ছ ধারণা থাকা দরকার। এসব রাষ্ট্রগুলোতে শহরভিত্তিক কর্মকাণ্ডের ব্যাপকতার ফলে এমনিতেই প্রচুর জ্বালানী শক্তির ব্যবহার, হাজার হাজার গাড়ীর নির্গত ধোঁয়া, শিল্পায়নের ব্যাপক বিস্তৃতি, পরিমিত পরিমাণে গাছপালা না থাকা, নদী-নালা, পুকুর, দিঘী ও জলাশয় ভরাট হওয়ার ফলে বিষাক্ত চেম্বার হয়ে উঠেছে। এরই মধ্যে ঐ দেশে কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্রের উদগীরিত CO_2 , SO_2 , CO , NO_x ইত্যাদি “গোঁদের উপর বিষফোড়া”র

মতো ঐ শহরগুলোর অবস্থা এতোটা দূর্বিসহ করে তোলে যে এগুলো বসবাসের সম্পূর্ণ অযোগ্য হয়ে উঠে। আরো পরিষ্কার করে বললে যা দাঁড়ায় তা হলো এসব বসবাসের অযোগ্য শহরগুলোতে ১০০% ভাগ বর্জের মধ্যে জ্বালানী শক্তি, গাড়ীর ধোঁয়া ইত্যাদি থেকে আসে ৩০% আর কয়লা বিদ্যুৎ কেন্দ্রের কয়লা থেকে আসে ৭০%। এখোন যদি এসব দেশে কয়লা বিদ্যুৎ কেন্দ্র বন্ধ করে দেয়া যায় তাহলে ঐ ৩০% বায়ু দূষণের বর্জ শহরগুলোর এতো বিপর্যয় কিংবা বিশ্বব্যাপী তাপমাত্রা বৃদ্ধি পেয়ে এতো সুনামী, এতো তুষারপাত, এতো বিপর্যয় হতো না। শহরবাসীগনও এ নরক থেকে রক্ষা পেতেন। বিশ্বের সর্বত্রতো বটেই বাংলাদেশের বিশেষ ভূগঠনের বৈশিষ্ট্যের জন্য কয়লা ভিত্তিক কেন্দ্র কেন হতে দেয়া যাবে না তার কারন যে অধিকাংশ দেশের সাথে বাংলাদেশের ভূগঠনের মৌলিক কতগুলো পার্থক্য রয়েছে আর সেগুলো হলো :

- (ক) এখানকার ভূমি পললমাটি দিয়ে গঠিত বিধায় অত্যন্ত নরম। এ মাটিতে যে কোন ধরনের বর্জ থেকে উদগীরিত জীবানু সহজেই অন্যান্য অংশে বাহিত হয়।
- (খ) এ দেশে জলা আবৃত অংশের পরিমান ভূমির পরিমানের চেয়ে বিশ্বের যে কোন দেশের জল ও ভূমির আনুপাতিক হারের চেয়ে অনেক বেশী। আমাদের নদী খালের জলপথের দৈর্ঘ্য ২৪,০০০ কিলোমিটার। হাওর জলাভূমি নিয়ে দেশের প্রায় ১০-১২% অঞ্চল জলাভূমি। কাজেই কয়লা থেকে উৎগীরিত মারাত্মক সব বর্জ জলের সাহায্যে জমিতে, খালে, বিলে, হাওড়ে ও আমাদের উর্বরা সব ক্ষেতসমূহে অতি সহজেই ছড়িয়ে পড়বে।
- (গ) আমাদের দেশটি একটি অখন্ড হোমোজিনিয়াস অঞ্চল। পাহাড়-পর্বত দিয়ে বিভক্ত নয়। কাজেই কয়লা থেকে উৎগীরিত মারাত্মক সব বিষাক্ত বর্জ এক অঞ্চল থেকে অন্য অঞ্চলে অতি সহজেই ছড়িয়ে পড়বে।

কয়লার উপর ভূবিজ্ঞানীদের বিজ্ঞান ভিত্তিক বিশ্লেষনের পর কয়লাব্যবহার না করতে তাঁদের সাবধান বানী ও কয়লা ব্যবহারে এ পর্যন্ত ঘটে যাওয়া নানা বিপর্যয় পর্যবেক্ষন করে আমাদের কি এ উপলব্ধি আসে নি যে যদি এদেশকে

বাঁচাতে চাই তাহলে আর বিলম্ব না করে প্রস্তাবিত কয়লা বিদ্যুৎ কেন্দ্রগুলোর নির্মান বন্ধ করা খুব জরুরী হয়ে পড়েছে !!

কয়লা ব্যবহারে সৃষ্ট বিপর্যয়

মার্কিন যুক্তরাষ্ট্র, অস্ট্রেলিয়া, নিউজিল্যান্ডে ইতালি সহ প্রায় সারা ইউরোপে বন্যা ও তুষারপাত, মালয়েশিয়া, ইন্দোনেশিয়া ও থাইল্যান্ডের সাম্প্রতিক প্রচণ্ড খরা ও দাবদাহ, আয়ারল্যান্ডের বন্যা, অতি সম্প্রতি ভারত, চীন ও পাপুয়া-নিউগিনির ভয়াবহ বন্যা ও জলোচ্ছাস বিশ্বব্যাপী আহাওয়া পরিবর্তনের সুস্পষ্ট ইঙ্গিত দেয়।

জ্বালানী বিষয়টি বর্তমানে আরো বেশী গুরুত্বপূর্ণ হয়ে উঠেছে এজন্যে যে ইতিধ্যেই উন্নত বিশ্ব কর্তৃক অতিরিক্ত এবং কিছু কিছু ক্ষেত্রে অনাকাঙ্ক্ষিত অস্বাস্থ্যকর জ্বালানী ব্যবহারের ফলে সারা বিশ্বে বায়ু-দূষণ ও আবহাওয়ার বিপর্যয় মানব জীবনের জন্য এক মারাত্মক হুমকি হিসেবে প্রতিফলিত হয়ে উঠেছে। এবং সবচেয়ে হুমকি হিসেবে যা উদ্ভূত তাহলো উন্নত বিশ্ব এসব অস্বাস্থ্যকর ও নোংরা জ্বালানী যা প্রধানতঃ কয়লা থেকে উদ্ভূত তা চাপ প্রয়োগ কিংবা কৌশলে আমাদের মতো দেশগুলোতে স্থানান্তর করতে উদগ্রীব হয়ে উঠেছে। কয়লাকে কেন্দ্র করে মার্কিনীরাসহ ধনীদেশগুলোর যে ব্যবসা তা কিন্তু যতো না নিজের দেশে কয়লা নিয়ে গিয়ে ব্যবহার করে বিদ্যুৎ উৎপাদন করার জন্যে, তার চেয়ে ভিন দেশের কয়লা দখল করে সেখানেই বিদ্যুৎ উৎপাদন করা। তাতে হাজার কোটি টাকার ব্যবসাও যেমন হবে আবার বায়ু-দূষণকারী নোংরা জ্বালানী কয়লাকে অন্য দেশে রেখেই ঐ দেশের ভূমি, বায়ু, নদী, পানি সব ধ্বংস করাও যাবে। আর এতে তাদের হয়ে দেশ ধ্বংস, দেশের অর্থনীতি ধ্বংস করার জন্য আমাদের মতো দেশগুলিতে ক্ষমতাসালী রাজনীতিবিদরাসহ ব্যবসায়ী গোষ্ঠীতো মুখিয়েই থাকে। তারই প্রতিফলন দেখি আমরা ফুলবাড়িয়াতে এশিয়া এনার্জির প্রচণ্ড লম্প-বাম্প। সাথে ব্যস্ত দেখলাম এদেশের একদল তথাকথিত “জ্বালানী” বিশেষজ্ঞ, একদল বিকিয়ে যাওয়া সাংবাদিককে, আর দেশবিরোধী ব্যবসায়িক গোষ্ঠী, কর্মকর্তারাতো আছেনই। অবৈধ অর্থের মোহে তাঁদের এ জ্ঞানটিও উবে গেছে যে বাংলাদেশ বিশ্বের এমন একটি ব্যতিক্রমি দেশ যার ভূমির প্রায়

১০% পানি দ্বারা আবৃত এবং সারা দেশ (পার্বত্য চট্টগ্রাম ও সিলেটের সামান্য কিছু অংশ ছাড়া) নদী ও খাল দ্বারা সংযুক্ত। সাধারণ বুদ্ধি সম্পন্ন যে কোন লোকের পক্ষেই এটা উপলব্ধি করা সম্ভব যে কয়লা দিয়ে বিদ্যুৎ উৎপাদন করলে এদেশের মূল্যবান সব সম্পদ যেমন নদী, পানি, ভূমি, জীব-বৈচিত্র্য, পরিবেশ, মৎস্য, ফসল সব ধ্বংস হয়ে যাবে।

উন্নত বিশ্বে শিল্পায়ন ও বিদ্যুৎ উৎপাদনে জ্বালানীর অপব্যবহারের ফলে প্রতিনিয়ত উৎপীড়িত সীসা, পারদ, CO₂, SO₂, CO ইত্যাদি প্রকৃতিকে অব্যাহতভাবে দূষিত করছে। আবহাওয়া ও পরিবেশ দূষণ যখন বিশ্বব্যাপী ক্ষরা, অতিবর্ষণ ও বন্যাসহ নানা রকম জটিলতার সৃষ্টি করছে তখন আবহাওয়া বিজ্ঞানীগণ কোন্‌ রাষ্ট্র কি পরিমাণ পরিবেশে সম্ভাব্য বিষাক্ত পদার্থ দিচ্ছে এবং ভবিষ্যতেও দিবে তার একটি তালিকা নির্ধারণ করেছে, যা ছক-২এ দেওয়া হলোঃ^৪

ছক-২: বিদ্যুৎ উৎপাদনজনিত কারণে কার্বন উদগীরন (মিলিয়ন মেট্রিক টন)

রাষ্ট্র	পরিমাণ				সম্ভাব্য পরিমাণ
সাল	১৯৯৫	২০০০	২০০৫	২০১০	২০১৫
মার্কিন যুক্তরাষ্ট্র	৫১১	৫৭৪	৬১৯	৬৬৩	৭০৪
চীন	২৫৬	৩১২	৪২৯	৫৭৪	৭৭২
ভারত	৯১	১১৫	১৩৯	১৬৬	১৯০
মালয়েশিয়া	৭.৩	৯	১১	১৪	১৬
বাংলাদেশ	১.৫	১.৮	২.৪	২.৮	৩.২

উৎপীড়ন কার্বন উৎসরণ ও জমা :^৫

বায়ুমন্ডলে জমা থাকে	-	৭৫০ মিলিয়ন টন
সাগর জলে জমা থাকে	-	৩৫০ ট্রিলিয়ন টন
বার্ষিক উদগীরণ	-	৭ বিলিয়ন টন
বার্ষিক বৃদ্ধি	-	৩ বিলিয়ন টন

একথা আজ সর্বজনবিদিত যে সারা বিশ্বে বায়ুমন্ডলে উষ্ণতা বৃদ্ধি পাচ্ছে। কিন্তু আমাদের তা জানতে হবে এ উষ্ণতা বৃদ্ধি কিসের জন্য? তথাকথিত উন্নয়নের জন্য সীমাহীন শিল্পায়ন ও কয়লা দিয়ে বিদ্যুৎ উৎপাদন বৃদ্ধিতে। প্রচুর CO₂ উদগীরনের ফলে এবং মূলতঃ এর জন্য দায়ী শিল্পোন্নত ও ধনী দেশসমূহ। আবহাওয়ার উষ্ণতা বৃদ্ধি পাচ্ছে, বৃষ্টির পরিমাণ বাড়ছে। এই CO₂ কমানোর জন্য আমরা প্রচুর গাছ লাগাতে পারি। শিল্পায়ন ও নগরায়নের ফলে গাছও কমে যাচ্ছে। গাছের অভাবে পলিমাটি আত্মা হয়ে যাচ্ছে এবং নদীতে বা খালে বিলে মাটি জমছে এবং প্রাকৃতিকভাবে তৈরী নদীর বাঁকে বাঁকে মাটি জমা হবার ফলে যখন পানি বেড়ে যায় তখন তা এসে আঘাত করে পাড়গুলো ভেঙ্গে তার মাটি নদীর ভরাটকে আরও বাড়িয়ে দেয়। যা পৃথিবীকে প্রায় ধ্বংসের পথে নিয়ে যাচ্ছে, কয়লা দিয়ে বিদ্যুৎ উৎপাদন হলো তার অন্যতম একটি অনুঘটক। সুতরাং আমাদের এবং বিশ্বের তাবৎ জনতার আজ সমস্বরে আওয়াজ তুলতে হবে, কয়লা নয় বিকল্প পদ্ধতিতে বিদ্যুৎ উৎপাদন করতে হবে। বর্তমান বিশ্বে বিদ্যুৎ উৎপাদনে বিভিন্ন জ্বালানীর ব্যবহারের পরিমানের হিসেব নিম্নের ছক-৩এ দেয়া হলো ^৬ :

আজ আমরা জীবন দিয়ে এবং অভিজ্ঞতা দিয়ে উপলব্ধি করছি যে, জৈবিক জীবাস্ম অর্থাৎ তেল, গ্যাস ও কয়লা দিয়ে বিদ্যুৎ উৎপাদন করা ও কলকারখানায় এসব জ্বালানীর অপরিমিত ও বহুল ব্যবহারে কিভাবে পরিবেশের এক মারাত্মক বিপর্যয় ঘটছে এবং জীব বৈচিত্র্য ধ্বংস হয়ে যাচ্ছে। ইতিমধ্যেই বিশ্বে পরিবেশ বিপর্যয়ে যে ধ্বংস লীলা শুরু হয়েছে তা আনবিক যুদ্ধ পরবর্তী প্রতিক্রিয়ার চেয়েও ভয়ঙ্কর ও সর্বনাশ। তাই উন্নয়নের সাথে সাথে মানুষম, সমাজ ও জীব-বৈচিত্র্যকে রক্ষা করার আন্দোলন আজ সমার্থক হয়ে উঠেছে। যে সমাজে মানুষ থাকবে- সে সমাজে বিদ্যুতও থাকবে। এ প্রশ্নগুলোর সমাধান করেই জ্বালানী ব্যবহার ও বিদ্যুতের পরিকল্পনা করতে হবে। এ বিষয়ে জানার জন্য পরিবেশ বিপর্যয়কারী পদার্থ যথা CO₂, SO₂ এবং অন্যান্য বর্জ্য কোন জ্বালানী থেকে কি পরিমান নিঃসৃত হয় তার একটি ছক-৩ এ নীচে দেয়া হলো ^৭ :

ছক-৩: বিশ্বে বিদ্যুৎ উৎপাদনে বিভিন্ন জ্বালানীর ব্যবহারের পরিমানের হিসেব

ক্রমিক নং	জ্বালানী	পরিমান (১০° গিগা ওয়াট ঘন্টা)	শতকরা হারে
০১	কয়লা	৩৮.৪৯৭	২৬.৮০%
০২	ডিজেল/ফার্নেস ওয়েল	৪৮,২০৪	৩৩.৫০%
০৩	প্রাকৃতিক গ্যাস	৩০,১৩৪	২০.৯০%
০৪	নিউক্লিয়ার	৮,২৮৩	০৫.৮০%
০৫	হাইড্রো	৩,২০৮	০২.২০%
০৬	সূর্য, বায়ু, বায়োমাস, জিওথার্মাল	১৫,২৮৪	১০.৬০%
০৭	অন্যান্য	২৪১	০.২০%
	মোট	১,৪৩,৮৫১	১০০%

ছক থেকে এটা অত্যন্ত পরিষ্কার যে কয়লা হলো এমনই একটি জ্বালানী যা ব্যবহারে পৃথিবীতে চরম বায়ু দূষণ ঘটায়। আর্থ-সামাজিক উন্নয়নে বিদ্যুৎ অপরিহার্য। তা হলে কি কয়লা বাদে অন্যান্য বিকল্প জ্বালানী দিয়ে বিদ্যুৎ উৎপাদন সম্ভব? অবশ্যই সম্ভব এবং অনেক শাশ্বতী ও টেকসইভাবেই সম্ভব। আজ তা হচ্ছে না অথবা ইচ্ছে করে হতে দেয়া হচ্ছে না। ঘটনাগুলো বিশ্লেষণ করলে পষ্ট দেখবেন কেউ যেন আমাদের মতো জনস্বার্থবিরোধী সরকারচালিত দেশগুলোতে শাশ্বতী, টেকসই, পরিবেশ বান্ধব জ্বালানী ও বিদ্যুৎ উৎপাদনের বাধা দিয়ে পরিবেশ ধ্বংসকারী জ্বালানী প্রকল্প গ্রহণ করাচ্ছে। ফলশ্রুতিতে আমরা যেমন অধিক ব্যয়ও করছি, তেমনি আবহাওয়ারও বিপর্যয় ঘটাইছি।

ছক থেকে এটা অত্যন্ত পরিষ্কার যে কয়লা হলো এমনই একটি জ্বালানী যা ব্যবহারে পৃথিবীতে চরম বায়ু দূষণ ঘটায়। আর্থ-সামাজিক উন্নয়নে বিদ্যুৎ অপরিহার্য। তা হলে কি কয়লা বাদে অন্যান্য বিকল্প জ্বালানী দিয়ে বিদ্যুৎ উৎপাদন সম্ভব? অবশ্যই সম্ভব এবং অনেক শাশ্বতী ও টেকসইভাবেই সম্ভব।

আজ তা হচ্ছে না অথবা ইচ্ছে করে হতে দেয়া হচ্ছে না। ঘটনাগুলো বিশ্লেষণ করলে পষ্ট দেখবেন কেউ যেন আমাদের মতো জনস্বার্থবিরোধী সরকারচালিত দেশগুলোতে সাস্রয়ী, টেকসই, পরিবেশ বান্ধব জ্বালানী ও বিদ্যুৎ উৎপাদনের বাধা দিয়ে পরিবেশ ধ্বংসকারী জ্বালানী প্রকল্প গ্রহণ করাচ্ছে। ফলশ্রুতিতে আমরা যেমন অধিক ব্যয়ও করছি, তেমনি আবহাওয়ারও বিপর্যয় ঘটাইছি।

ছক-৪ : জ্বালানী থেকে নিঃসৃত CO₂, SO₂ এবং অন্যান্য বর্জ্য পরিমাণ

ক্রমিক নং	জ্বালানী	১ মিলিয়নে বর্জ্য সংখ্যা (PPM)		
		SO ₂	NO ₂	আবহাওয়া দূষণকারী অন্যান্য বর্জ্য
০১	কয়লা	১৭,৪০০	১৮,৩৪০	১,১৭,৩০০
০২	ডিজেল/ফার্নেস ওয়েল	২২,৩০০	১৪,৮০০	১,৪২০
০৩	প্রাকৃতিক গ্যাস	৩০৩	৮	১,৮৯০
০৪	নিউক্লিয়ার রিএ্যাকটর	--	--	৬৮০
০৫	পানি	--	--	--
০৬	সূর্য তাপ	--	--	--
০৭	বায়ু	--	--	--
০৮	বায়োমাস	--	--	--

বিদ্যুৎ উৎপাদন জনিত কারণে আবহাওয়ায় বিষাক্ত কার্বন-ডায়-অক্সাইড(CO₂) উদগীরন করে বিশ্বের এমন কয়েকটি দেশের নাম নীচে ছক-৫এ দেয়া হলো ^৮ ৪

ছক-৫: বিদ্যুৎ উৎপাদন জনিত কারণে কয়েকটি দেশের CO₂ উদগীরনের পরিমান

মেধা ক্রম	দেশ	CO ₂ উদগীরন (হাজার টন)	জনপ্রতি CO ₂ উদগীরন(হাজার টন)	সূত্র
১.	চীন	৯,৭০০,০০০	০৭.২০	ইউরোপীয় ইউনিয়ন এবং নেদারল্যান্ড এনভারমেন্ট এসেসমেন্ট কর্তৃক সরবরাহ কৃত ডাটা বেসের ভিত্তিতে “এনগার” এটি প্রকাশ করে
২.	যুক্তরাষ্ট্র	৫,৪২০,০০০	১৭.৩০	
৩.	ভারত	১,৯৭০,০০০	০১.৬০	
৪.	রাশিয়া	১,৮৩০,০০০	১২.৮০	
৫.	জাপান	১,২৪০,০০০	০৯.৮০	
৬.	জার্মানী	৮১০,০০০	০৯.৯০	
৭.	দক্ষিণ কোরিয়া	৬১০,০০০	১২.৬০	
৮.	কানাডা	৫৬০,০০০	১৬.২০	

রামপালে ১৩২০ মেঃ ওয়াটের কয়লা বিদ্যুৎ উৎপাদন কেন্দ্র কেন বন্ধ করতে হবে পাঠকবৃন্দ আশা করি এতোক্ষণে অনুধাবন করতে পেরেছেন ।

এসব তথ্য থেকে আমরা স্পষ্টতই অনুমান করতে পারি আজকে যে পরিবেশ বিপর্যয় তার অন্যতম কারণ হলো মূলত: কয়লা দিয়ে বিদ্যুৎ উৎপাদনের প্রতিফল । তরল জ্বীবাশ্ম জ্বালানী ও নিউক্লিয়ার বিদ্যুৎ কেন্দ্র থেকে বর্জ্য নিঃসরণকেও এ দায় থেকে মুক্তি দেয়া যায় না ।

যথেষ্ট কয়লা ব্যবহারের পরিনতিতে COP-এর বক্তব্য

প্যারিস কনফারেন্সে COP21-এ প্রকাশিত সনদটি স্বাক্ষরের পর্যায়ে ৪টি দেশে তথা চীন, ভারত, মার্কিন যুক্তরাষ্ট্র ও অষ্ট্রেলিয়ার কয়লার বহুল ব্যবহারের বিষয়টি উঠে আসে এবং তা নিয়ে ব্যাপক আলোচনাও হয় । প্রকৃত পক্ষে এ

৪টি দেশই ব্যাপক কয়লা ব্যবহার করছে। নীচের ছক-৬ দেখলেই এটি খুব পরিষ্কার হয়ে উঠবে^৯।

ছক-৬: ব্যাপক কয়লা ব্যবহারকারী ৪ টি দেশ

দেশ	বিদ্যুৎ উৎপাদন (বিলিওকিলো- ওয়াট ঘন্টা)	কয়লা (%)	প্রাকৃতিক গ্যাস (%)	জ্বালানী তেল (%)	জলবিদ্যুৎ (%)	অন্যান্য নবায়ন যোগ্য (%)	আনবি ক বিদ্যুৎ (%)
অস্ট্রেলিয়া	২৫২.৬	৬৮.৬	১৯.৭	১.৬	৬.৬	৩.৫	০
চীন	৪৭১৫.৭	৭৯	১.৮	০.২	১৪.৮	২.২	১.৮
ভারত	১০৫২.৩	৬৭.৯	১০.৩	১.২	১২.৪	৫	৩.২
মার্কিন যুক্তরাষ্ট্র	৪৩২৬.৩	৪৩.৩	২৪.২	০.৯	৭.৪	৪.৮	১৯

COP21 যাকে CMP11 হিসেবেও অভিহিত করা হয় যা প্যারিসে ৩০ নভেম্বর ২০১৫ ইংরেজীতে শুরু হয়ে ১২ ডিসেম্বরে ২০১৬ ইংরেজীতে শেষ হয়। এই কনফারেন্সে সর্বসম্মতিক্রমে গৃহীত সিদ্ধান্তগুলির উপর একটু চোখ বুলিয়ে নেই। এটি ছিল Conference of Parties (COP) এর ২১ তম সভা যা মূলতঃ পরিবেশ এবং টেকসই (Sustainable) উন্নয়নের কথা আলোচিত হয়েছে। COP বিভিন্ন বিষয়ে সভা করে। সভার ক্রম নাম্বার ঠিক রেখে যে বিষয় আসে তার নামে সভাটি অনুষ্ঠিত হয়। সভার ক্রম ঠিক রেখে এ সভা পরিবেশ বিষয়ে হয়েছে বিধায় মোটা দাগে এর নাম বলা যেতে পারে COP21 UNFCCC[UN Frame on Convention for Climate Change]। জাতিসংঘের পরিবেশ সংক্রান্ত এ কমিটি শুরু হয় ১৯৯২ ইংরেজীতে রিও তে রিও আর্থ কনফারেন্সের নামে। বিশ্বের উষ্ণতা বৃদ্ধি সহ পরিবেশ দূষণের নানা ক্রিয়া-প্রতিক্রিয়ার বিষয়গুলো রোধে কতগুলো নিয়ম মেনে স্ব স্ব রাষ্ট্রের করণীয়গুলো খুব জরুরি ভিত্তিতে পদক্ষেপ নিতে জাতিসংঘের এই সভায় পরামর্শ দেয়া হয়। এ সভায় পূর্বের বিভিন্ন সভায় গৃহীত পরামর্শগুলো বাস্তবায়নের অগ্রগতি পর্যবেক্ষণ ও ভবিষ্যৎ পরিকল্পনার বিষয়ে ১৯৯৭ ইংরেজীতে জাপানে কোয়োটো প্রটোকল নামে একটি সভা হয়।

কার্বন উদগীরনকারী বড় রাষ্ট্রগুলো কার্বন নিয়ন্ত্রনে কোন ধরনের পদক্ষেপ না নেওয়ার দরুন ভূমন্ডলের উষ্ণতা কিন্তু নিত্যদিন বেড়েই চলছে । আবহাওয়ার বিপর্যয়ে খরা, অতিবৃষ্টি, অনাবৃষ্টি, ঝড়, সুনামী, অনিয়মিত বন্যা, জলোচ্ছাসের ফলে বিশ্ব ভ্রম্যাণ্ড বিপর্য্যন্ত অবস্থায় নিপতিত হয়েছে । এ অবস্থায় ২০০৯ ইংরেজীতে কোপেনহেগেনে এ অনালুত উষ্ণতা বৃদ্ধি রোধে করণীয় বিষয়গুলো আরো সুস্পষ্ট করা হয় । COP10 ও COP11 এর Conference দুটো ডারবান ও কানকুনে যথাক্রমে ২০১০ ও ২০১১ ইংরেজী সালে অনুষ্ঠিত হয় । বিভিন্ন পদক্ষেপ গ্রহণে আশানুরূপ ফল না পাওয়ায় উষ্ণতা বৃদ্ধি ও নানা রকম দূষিত বর্জ্য নির্গত হওয়ার কারনে বিশ্ব ক্রমেই বসবাসের অনুপোযোগী হয়ে উঠছে বিধায় দোহাতে ২০১২ ইংরেজী সালে পূর্বের করণীয় পরামর্শগুলো আরো গ্রহণযোগ্য করে আরো সহজবোধ্য করা হয় । পরবর্তী COP19 এর সভা ২০১৩ ইংরেজীতে ওয়ারশতে এবং COP20 এর সভা ২০১৪ ইংরেজীতে লিমাতে অনুষ্ঠিত হয় । COP21 এর সভার কথা যা প্যারিসে অনুষ্ঠিত হয়েছে তা আগেই বলা হয়েছে । এ সভাতে অত্যন্ত সুস্পষ্ট ভাবে সমস্যাগুলোকে উল্লেখ করে সমাধানের লক্ষ্যমাত্রাও নির্ধারণ করে দেয়া হয়েছে । এ সুপারিশগুলোকে সংক্ষিপ্ত আকারে নীচে উল্লেখ করা হলো :

(১) ভূমন্ডলের উষ্ণতা বৃদ্ধি ২°সেলসিয়াসের নীচে, যা শিল্প বিপ্লবের পূর্ববর্তী সময় যে তাপমাত্রা অনুভূত হতো সে মাত্রায় তাপমাত্রা নিয়ন্ত্রন রাখার বিষয়ে এ সভায় সর্বসম্মতিক্রমে সিদ্ধান্ত গৃহীত হয়েছে । স্বাক্ষরকারী সমস্ত রাষ্ট্র সার্বিকভাবে "শূন্য" এনথ্রোপেজেনিক গ্রীন হাউস গ্যাস নিঃস্বরণের পদক্ষেপ নিয়ে উষ্ণতা হ্রাসের পদক্ষেপ নিতে সম্মত হয়েছে যা একুশতম শতাব্দীর মাঝামাঝি সময়ের মধ্যে বাস্তবায়নের পদক্ষেপ নিবে ।

(২) উপস্থিত পার্টিগুলো এবিষয়ে সম্মত হয়েছে যে পরিবেশের উষ্ণতা বৃদ্ধি রোধে সামর্থ্য ও সক্ষমতা অনুযায়ী কার্বন উদগীরন হ্রাসের স্বার্থে বিভিন্ন প্রকল্প গ্রহণ করবে যা খাদ্য উৎপাদনকে ব্যাহত করবে না । এ কথা SDG তে সুস্পষ্টভাবে উল্লেখিত আছে ।

(৩) কার্বন উদগীরন হ্রাস পায় এমন ধরনের প্রকল্প বাস্তবায়নে অর্থ প্রবাহ বাড়ানো এবং জরুরী ভিত্তিতে এ ঘোষণা বাস্তবায়নে পদক্ষেপ নিতে স্বাক্ষরকারী রাষ্ট্রগুলো সম্মত হয়েছে ।

(৪) ১৯৯২ ইংরেজী সনে রিও-তে স্বাক্ষরিত "আর্থ সামিট" COP15 যে সনদপত্রে ১৯৬টি রাষ্ট্র স্বাক্ষর করেছে । এটা উল্লেখ করা যেতে পারে ৫৫টি রাষ্ট্র যেগুলো বিশ্বের শতকরা ৫৫% কার্বন উদগীরন করে তাদেরকে একটি অঙ্গীকার স্বাক্ষর করানো গেলো । আরো উল্লেখ করা যেতে পারে যে ১৭৪টি দেশ যারা প্রথম দিকে অর্থ্যাৎ ২২ এপ্রিল ২০১৬ ইংরেজীতে সম্মতিপত্র স্বাক্ষর করেছে, যার মধ্যে বাংলাদেশ অন্যতম । এটা বিশ্বমানবতার একটি বিরাট বিজয় হিসেবে চিহ্নিত হবে ।

(৫) চীন, ভারত, মার্কিন যুক্তরাষ্ট্র ও যুক্তরাজ্য এ ৪টি রাষ্ট্র সর্বশেষ গোষ্ঠী যারা স্বাক্ষর করেছে মে ২০১৬ ইংরেজীতে । সুতরাং এটা নির্দিধায় বলা যে ভূমণ্ডলে আজ অনিয়ন্ত্রিত কার্বন নিঃস্বরণ ও উষ্ণতা বৃদ্ধির ফলে এ বিশ্ব-ভ্রম্যাণ্ড বসবাসের অনুপযোগী হয়ে উঠেছে এটা বিশ্বসভায় স্বীকৃত হলো । এটা COP21 নামে অভিহিত । COP21-এ অত্যন্ত স্পষ্ট করে সংকটগুলোকে চিহ্নিত করে করণীয় সম্পর্কে সুস্পষ্টভাবে পরামর্শ বা নির্দেশনা দিয়েছে । তাই বলা যায় এ সনদ আজ বিশ্বের তাবৎ বিজ্ঞানী, সচেতন বিশ্ববাসী, মানবপ্রেমী, জীববৈচিত্র্য প্রেমী, পরিবেশ প্রান-প্রকৃতি-পরিবেশ প্রেমীদের বিজয় ।

(৬) প্রধান ৪টি দেশসহ আরো কিছু দেশ অতিরিক্ত কার্বন উদগীরন করে এ বিশ্ব-ভ্রম্যাণ্ডকে বসবাসের অযোগ্য করে তুলেছে ইতোমধ্যে এ রাষ্ট্রগুলো কার্বন উদগীরনের প্রধান উপাত্ত , কয়লা বিদ্যুৎ কেন্দ্র ক্রমান্বয়ে বন্ধ করার কর্মসূচী দিয়েছে । এরইমধ্যে মার্কিন যুক্তরাষ্ট্র ২০১৫ ও ২০১৬ ইংরেজী সালে প্রায় ২০,০০০ মেগাওয়াট কয়লা বিদ্যুৎ বন্ধ করে দিয়েছে । চীন ১০০,০০০ মেগাওয়াট বন্ধ করেছে । ভারত ৫৫,০০০ মেগাওয়াট বন্ধ করে দিয়ে একই সংগে নবায়নযোগ্য জ্বালানীতে প্রায় ১৭,০০০ মেগাওয়াট নির্মানের ঘোষণা দিয়েছে । এই সময়ে যুক্তরাজ্য ৪৫৬৫৪৩ মেগাওয়াট কয়লা বিদ্যুৎ উৎপাদন ও কানাডা তার ১৯টির মধ্যে ১৬টি কয়লা বিদ্যুৎ কেন্দ্র বন্ধ করে দিয়েছে ।

(৭) COP26 যা ২০২১ নভেম্বরে গ্লাসগোতে সকল দেশের স্বাক্ষরে গৃহীত হয়েছে তা COP15-এ গৃহীত ১.৫ কে জীবিত রাখার এক মহা প্রয়াস বলা

যায় । তার মর্মার্থ হলো সকল দেশ শপথ নিচ্ছে যে বিশ্বের জীবাত্ম জ্বালানী উদগীরন আগামী ২০৫০ সনের মধ্যে "নেট জিরো"তে নিয়ে আসবে । আরো সহজ কথায় জাতিসংঘ বলছে যে এর চেয়ে বেশী উদগীরনের অর্থ হলো ভূমন্ডলের গড় উষ্ণতা শিল্পযুগপূর্ব ১.৫ সেঃ এর চেয়ে বেশী ।

কিন্তু আমরা দেশে কি করছি । প্রমানিত সত্য ও বিজ্ঞানের বিরুদ্ধে অন্যায় লড়াই করে কি জয়লাভ করা যায় । মনে রাখতে হবে বিদ্যুত আমাদেরও চাই । অর্থনৈতিক উন্নয়নে প্রয়োজন মানসম্পন্ন, নির্ভরযোগ্য, সাশ্রয়ী জ্বালানী ও বিদ্যুৎ । প্রায় সবধরনের সম্পদে পরিপূর্ণ বাংলাদেশ একটি সৌভাগ্যবান দেশ । নবায়নযোগ্য জ্বালানীর বহুল প্রাপ্যতায় ও কারিগরী মান বিবেচনায় এদেশে হাজার হাজার মেগাওয়াট বিদ্যুৎ সূর্য্য, বায়ু প্রবাহ, বর্জ্জ ও বায়োমাস দিয়েই উৎপাদন করা যায় ।

আনবিক বিদ্যুতকে কেন না বলবো !

২০১১ সালে জাপানের ফুকুশিমা আনবিক বিদ্যুৎ কেন্দ্রে দুর্ঘটনার পর প্রভাবশালী মার্কিন ম্যাগাজিন "দি ইকোনোমিস্ট" এক বিস্তারিত প্রতিবেদনের সমাপ্তি টানেন এই বলে যে ---" আনবিক বিদ্যুৎ উৎপাদন কেন্দ্র খুবই ভয়ানক, অপ্রিয়, অত্যন্ত ব্যয়বহুল এবং প্রচণ্ড ঝুঁকিপূর্ণ ।" প্রশ্ন আসে যদি অন্য উপায়ে বিদ্যুৎ উৎপাদন করা যায় তাহলে আমরা কেন এ ধরনের বিদ্যুৎ উৎপাদন কেন্দ্র নির্মাণে যাবো ? প্রায় একই সময়ে ফুকুশিমা দুর্ঘটনার পর বিনিয়োগ প্রবন একটি প্রভাবশালী সুইস ব্যাঙ্কের বিশ্লেষণে প্রশ্ন রাখা হয়, "ফুকুশিমা আনবিক বিদ্যুৎ কেন্দ্রের ৪টি রিয়েক্টরে ত্রুটি পরিলক্ষিত হওয়ার পর অত্যন্ত উচু কারিগরী কৌশল প্রয়োগ করে বেশ কয়েক সপ্তাহের প্রচেষ্টায়ও তা নিয়ন্ত্রনে আনা সম্ভব হয়নি । একটি সুশৃঙ্খল প্রশাসন, অর্থনীতি ও কারিগরীতে অত্যন্ত উচুমানের রাষ্ট্রেরও আনবিক বিদ্যুৎ কেন্দ্রের ঝুঁকি নিয়ন্ত্রণে সক্ষমতার বিষয়ে এটি সুস্পষ্টভাবে ব্যর্থতাকেই চিহ্নিত করে । আমাদের সুস্পষ্ট মতামত ফুকুশিমা দুর্ঘটনাটি আনবিক বিদ্যুৎ কেন্দ্র স্থাপন বন্ধ করার বিষয়ে একটি চূড়ান্ত হুশিয়ারী " । এরপরও বাংলাদেশ সেই বিনাশী পথেই পা বাড়চ্ছে ! হায় সেলুকাস, কি বিচিত্র এই দেশ !! একই সময়ে জার্মানীর প্রখ্যাত

ডয়েটস ব্যাক্সের বিশ্লেষক ফুকুশিমা দূর্ঘটনার উপর এক প্রতিবেদনে এই বলে প্রশ্ন রাখেন যে, ” ফুকুশিমা দূর্ঘটনা নিশ্চয়ই দেশে দেশে নীতিনির্ধারকদের এই বলে জানান দিয়ে গেলো যে জ্বালানী পরিকল্পনা ও স্থাপনে গুরুত্ব নির্ধারণে কোনটি অধিক মূল্য পাবে ? জনগণের জীবনের নিরাপত্তা, জন-জীবনের ঝুঁকি, জন-স্বাস্থ্য, জীব-বৈচিত্র্য, প্রাণ-প্রকৃতি-পরিবেশ নাকি আনবিক বিদ্যুৎ কেন্দ্র স্থাপন ? এর সুস্পষ্ট উত্তর হলো, আর নোতুন কোন আনবিক বিদ্যুৎ কেন্দ্রতো নয়ই, বরং পুরোনোগুলো উপরে ফেলার ত্বরিত পদক্ষেপ নিতে হবে এক্ষুনি । ” জানামতে এসব বিশ্লেষকেরা সবাই প্রায় অত্যন্ত উচ্চমানের বিশেষজ্ঞ । তাহলে আমাদের দেশের নীতিনির্ধারকেরা কি রূপপুর আনবিক বিদ্যুৎ কেন্দ্র স্থাপন করে সজ্ঞানেই এ মৃত্যুফাঁদে পা দিচ্ছেন !! আমরা কেন রূপপুর আনবিক বিদ্যুৎ কেন্দ্র স্থাপনে বিরোধিতা করছি ! এবার আসা যাক স্থাপিতব্য ২৪০০ মেগাওয়াট ক্ষমতা সম্পন্ন রূপপুর আনবিক বিদ্যুৎ কেন্দ্রের বিষয়ে ।

(ক) এ অত্যন্ত ব্যয়বহুল । আন্তর্জাতিক বাজারে মূলধনী ব্যয় বিবেচনায় প্রতি মেগাওয়াটে আনবিক বিদ্যুতে পড়ে ১৬ (ষোলো) কোটি, কয়লাতে ৯(নয়) কোটি, গ্যাস ভিত্তিক কন্সাইন্ড সাইকেলে পড়ে মাত্র ৪ (চার) কোটি । যদিও চুক্তি অনুযায়ী রূপপুর আনবিক বিদ্যুৎ কেন্দ্র স্থাপনে মূলধনী ব্যয় পড়বে প্রায় ৪৩ (বিশ) কোটি টাকা ! এমনিতেই আনবিক বিদ্যুৎ কেন্দ্রের স্থাপনা মূল্য অন্যান্য ধরন থেকে বেশী তারপরও প্রতি মেগাওয়াটে আরও প্রায় ২৭ (সাতাশ) কোটি টাকা বেশী ধরা হয়েছে!!(খ) রূপপুরের কেন্দ্রটি ১৯৭০ ইংরেজীর জেনারেশন-২ এর ভার্সন । এটি অনেক পুরোনো এবং এর রিয়েক্টরটি হচ্ছে ভিভিইআর-১০০০ (VVER-1000) যা অনিরাপদ ও ঝুঁকিপূর্ণ বিধায় এই ভিভিইআর-১০০০ রিয়েক্টরটি ইতোমধ্যেই হাঙেরীতে ২টি, ইউক্রেনে-৩টি, জার্মানীতে-৪টি ও চেক রিপাবলিকে ৪টির স্থাপন চুক্তি রাশিয়ার সাথে বাতিল করে । তারা সুস্পষ্টভাবে রাশিয়াকে জানিয়ে দেয় যে এই রিয়েক্টরকে ইউরোপিয়ান মান ও দক্ষ করে নিরাপদ ও ঝুঁকিমুক্ত না করলে তাদের দেশে স্থাপন করতে দেয়া হবে না ।

(গ) প্রায় একই সময়ে ইরানে একই ভার্সানের রিয়েক্টর- ভিভিইআর-১০০০/৪৪৬ ও রাশিয়ার বালাকোভাকে ভিভিইআর-১০০০/৩২০ স্থাপন অনেকদূর এগিয়ে কারন না জানিয়ে মাঝপথে বন্ধ করে দেয়া হয় ।

(ঘ) এই একই ধারার জেনারেশন-২ এর ভার্শনের রিয়েক্টর- ভিভিইআর-১০০০/৪১২ ভারতের তামিলনাডু কুদানকুলামে ২০০১ ইংরেজী সালে শুরু হয় যা দীর্ঘসময় ধরে নির্মানাধীন অবস্থায় আছে । ২০১১-তে ফুকুশিমা দূর্ঘটনার পর ভারতের আনবিক এনার্জি কমিশনের একদল বিশেষজ্ঞ এ উপকেন্দ্র পরিদর্শন করে একে অনিরাপদ ও ঝুঁকিপূর্ণ বলে চিহ্নিত করেন এবং নক্সায় ১৭টি ব্যাপক পরিবর্তনের শর্ত সাপেক্ষে এটি চালু করার সুপারিশ করা হয় যা অদ্যাবধি চালু হয়নি ।

(ঙ) রাশিয়াতে ২০১০-এ জেনারেশন-২ এর চেয়ে একটু উন্নত ধরনের ধরনের রিয়েক্টর নির্মান করা হয়েছে যা জেনারেশন-৩ নামে অভিহিত । ফুকুশিমা দূর্ঘটনার পর যুক্তরাজ্যে, তাদের দাবী অনুযায়ী, অতি সম্প্রতি ইউরোপিয়ান প্রেসারাইজড রিয়েক্টর (ইপিআর) নামে একটি অনেক নিরাপদ ও স্বল্প বর্জ্য ত্যাগী আনবিক বিদ্যুৎ কেন্দ্র নির্মান করা হয়েছে যা অদূর ভবিষ্যতে বিদ্যুৎ উৎপাদনে কার্যকরী অবদান রাখতে পারবে । যদিও বিশেষজ্ঞরা এ কথাকে খুব একটা আমলে নিচ্ছেন না । আরও একটি উল্লেখযোগ্য বিষয় হচ্ছে যে এ নোতুন ধরনের আনবিক কেন্দ্রে বর্জ্য ব্যবস্থাপনা, যা একটি অত্যন্ত গুরুতর বিষয়ে সে বিষয়ে পরামর্শ নেই

(চ) আনবিক বিদ্যুৎ কেন্দ্র থেকে নিত্য যে সর্বনাশা পারমানবিক (তেজস্ক্রিয়) বর্জ্য পরিবেশের সঙ্গে যুক্ত হয় তা এতই ভয়ানক যা মানুষের বিভিন্ন অনিরাময়যোগ্য রোগ ব্যাধি সৃষ্টি সহ জমির উর্বরতা ধ্বংস, পানি ও বায়ু দূষণ সহ জীববৈচিত্র্য অচিরেই ধ্বংস করে । এক্ষেত্রে বাংলাদেশের জমি ও ভূ-গঠনের বিশেষ বৈচিত্র্যের বিষয়ে অবহিত হওয়া অত্যন্ত প্রয়োজন । যা এদেশের দেশপ্রেমিক ও বামপন্থীদের মাঝে প্রচন্ড ভাবে অনুপস্থিত বিধায় দেশ ও নিপীড়িত জনগণের সঠিক সমস্যা নিয়ে তাঁরা আন্দোলন গড়ে তুলতে স্পষ্টতঃই ব্যর্থ হচ্ছে ! বাংলাদেশের জমিই যে প্রধান সম্পদ ও কৃষি-সমস্যাই যে প্রধান সংকট তা কিন্তু ফুলবাড়ী আন্দোলনে স্পষ্টতঃই প্রমানিত । এ কথা কি কম্যুনিষ্টদের জ্ঞানকে একটুও চাঙা করেনি যে ফুলবাড়ীতে কয়লা খনি হলে ঐ এলাকার জমি ও জমি চাষের জন্য জল বিনাশ হয়ে যাবে বিধায় হাজার হাজার কৃষক ঝাঁপিয়ে পড়ে যে এক আকাশ-কাঁপানো গণ-অভ্যুত্থান সৃষ্টি করে এদেশের বিপ্লবী আন্দোলনে যে ইতিহাস সৃষ্টি করলো , রামপাল ও রূপপুরে

কেন তা হচ্ছে না? অথচ পরিবেশ বিধ্বংসী, জীব-বৈচিত্র্য বিনাশী প্রতিক্রিয়ার কথা বিশ্লেষণ করলে দেখা যায় রামপাল ও রূপপুরে তা হবে আরো ভয়ানক। এখানে কথিত প্রকল্প বাস্তবায়িত হলে কৃষকরাই তাঁদের জমি হারাবে, ঐ এলাকার জমির উর্বরতা শক্তি ধ্বংস হবে, জল ভয়ানক দূষিত হয়ে যাবে, পানি ও বায়ু দূষণ সহ জীববৈচিত্র্য অচিরেই ধ্বংস হয়ে যাবে। ফুলবাড়ীতে যে কম্যুনিষ্টরা কৃষকদের এ তথ্যটি দিতে পারলো সেই কম্যুনিষ্টরাই রামপালে, রূপপুরে, মাতারবাড়ীতে, সাতক্ষীরায়, রাউজানে, সেন্ট মার্টিনে কিংবা যে সব স্থানে প্রচলিত পদ্ধতির কয়লা ভিত্তিক বিদ্যুৎ উৎপাদন কেন্দ্র ও আনবিক বিদ্যুৎ কেন্দ্র হলে প্রতিটি কেন্দ্রের ১০/১২ কিলোমিটার ব্যাপী বসবাসরত কৃষক পরিবারসমূহকে ঐ সব এলাকায় অনিরাশয়যোগ্য রোগ ব্যাধি সৃষ্টি, জমির উর্বরতা ধ্বংস, পানি ও বায়ু দূষণ সহ জীববৈচিত্র্য ধ্বংস হয়ে বসবাসের অযোগ্য হয়ে যাবে বিধায় বসতভিটা ছেড়ে চিরতরে বাস্তুহারা হতে হবে। আর বাংলাদেশ হারাবে অনেক মূল্যবান জমি, নদী-খাল-বিল সহ ভূ-গর্ভস্থ পানি, জলজ ও বনজ প্রাণী! তো আর রইলো কি!! বিদ্যুৎ জলবে অথচ কোন জন-মানুষ নেই, কোন প্রাণীও নেই!!.

(ছ) এ উপকেন্দ্র আনবিক ক্রিয়ায় অতি উচ্চ তাপমাত্রা (1600° থেকে 2000° সেলসিয়াস) সৃষ্টি করে যা শীতলীকরণে প্রচুর পানির প্রয়োজন। ফলে ঐ এলাকার নদী-খাল-বিল সহ ভূ-গর্ভস্থ পানি শুকিয়ে অচিরেই মরুভূমি প্রক্রিয়া শুরু হবে।

(জ) কয়লা বিদ্যুৎ ও আনবিক বিদ্যুৎ কেন্দ্র যে কত ভয়ঙ্কর তা জ্বালানী বিষয়ক তথ্য ঘাটলেই স্পষ্ট হয়ে উঠে। আজ বিশ্বে বায়ু দূষণ, এ্যাসিড বৃষ্টি, জীব বৈচিত্র্য ধ্বংস, এ্যাজমা, হাপানী, পঙ্গুত্ব, ক্যানসার সহ আরো নানাধরনের অনিরাশয়যোগ্য রোগ ব্যাধির মূল উৎসই হলো কয়লা ভিত্তিক ও আনবিক বিদ্যুৎ কেন্দ্র।

(ঝ) আনবিক বিদ্যুৎ কেন্দ্রের ভয়াবহ দিকটি হলো এর পরিত্যক্ত তেজস্ক্রিয় বর্জ্য। এ বর্জ্যগুলো এতো দীর্ঘজীবী যে যুগ যুগ ধরে ধরিত্রীসহ জীববৈচিত্র্যের ধ্বংসলীলায় মেতেই থাকে। এর একটি হচ্ছে অতি মারাত্মক টেকনোটিয়াম-৯৯ যার অর্ধজীবন হচ্ছে ২ লাখ ২০ হাজার বছর। আরেকটি হলো আয়োডিন-

১২৯, যার অর্ধজীবন হচ্ছে ১ লাখ ৫০ হাজার বছর। এছাড়াও নেপটুনিয়াম-২৩৭, পুটোনিয়াম-২৩৯ লক্ষ লক্ষ বছর বেঁচে থাকে যা সবগুলিই নানারকম অনিরাময়যোগ্য রোগ ব্যাধি সৃষ্টি, জমির উর্বরতা, পানি ও বায়ু দূষণ সহ জীববৈচিত্র্য ধ্বংস করতেই থাকে।

(এ৩) আনবিক বিদ্যুৎ কেন্দ্রে প্রতি ১২ মাস থেকে ১৮ মাসের মধ্যে এ ধরনের বর্জ্য তৈরী হয়। এ বর্জ্য জমা করার জন্য কোন নিরাপদ ব্যবস্থাপনা আজো প্রস্তুত করা হয়নি। আন্তর্জাতিক পরমানু কমিশন (আইইসি) কর্তৃক বিশ্বের ১৬টি স্থানে এ পরিত্যক্ত বর্জ্যগার নির্মাণের কথা ছিলো যা আজও নির্মিত হয় নি। সুতরাং এ অবস্থায় নিশ্চিত বাংলাদেশে এ কেন্দ্র নির্মাণ করা মানে আরেকটি ভয়ানক তেজস্ক্রিয় মৃত্যুফাঁদ বানানোর পদক্ষেপ নেয়া ছাড়া একে অন্য কিছু হিসেবে অভিহিত করা যায় না।.....

বিদ্যুতের গুরুত্ব ও নোতুন জ্বালানী ভাবনা

ইতোমধ্যেই আমরা দেখেছি যে জ্বালানী হচ্ছে একটি দেশের চালিকা শক্তি। একটি রাষ্ট্রের শিল্পোন্নয়নের সূচক ঐ রাষ্ট্রের বিদ্যুতায়নের পরিমাপ দিয়ে নির্ধারণ করা হয়। কিন্তু প্রশ্ন হলো- জ্বালানী ও বিদ্যুৎ কাদের জন্য উৎপাদন করবো। সমাজ ও মানুষের জন্য। জ্বালানী ও বিদ্যুৎ উৎপাদন করতে গিয়ে যদি মানুষের জীবন বিপন্ন হয়ে উঠে, জীববৈচিত্র্য ধ্বংস হয়ে যায়, মানুষের শারিরীক অক্ষমতা বৃদ্ধি পেয়ে আয়ু হ্রাস পায়, পরিবেশ ধ্বংস হয়ে মনুষ্যজীবন হুমকি হয়ে উঠে- সে বিদ্যুৎ ও জ্বালানীতো মানুষের কাম্য হতে পারে না। তাহলে প্রয়োজনীয় বিদ্যুৎ কিভাবে উৎপাদন করতে হবে। সমাজ সচেতন ব্যক্তিদের এ বিষয়ে স্পষ্ট ধারণা থাকতে হবে এবং সে দিক লক্ষ্য রেখেই কাজে অগ্রসর হতে হবে।

বিশ্বে যে সব জ্বালানী দিয়ে বিদ্যুৎ উৎপাদন করা হয় পাঠকদের অবগতির জন্যে নীচে তার একটি তালিকা দেয়া হলো।

- ১) তরল জ্বালানী
- ২) নিউক্লিয়ার রিএ্যাক্টর
- ৩) কয়লা

- ৪) গ্যাস
- ৫) সূর্যের তাপ ও আলো
- ৬) পানি প্রবাহ
- ৭) বায়ু বেগ
- ৮) বজ্র
- ৯) সমুদ্রের ঢেউ

উপরে বর্ণিত ৩ থেকে ৯ পর্যন্ত প্রতিটি জ্বালানীর প্রাপ্যতায় বাংলাদেশ বিশ্বে ঈর্ষনীয় স্থানে অবস্থান করা স্বত্তেও অজানা কারনে আমরা নবায়নযোগ্য জ্বালানীতে বেশ পিছিয়ে আছি ।

বিশ্ব আবহাওয়ার এ তান্ডব থেকে মানবসমাজ এখন মুক্তি চাচ্ছে । বিদ্যুৎ ও জ্বালানী যদি মানুষ, পরিবেশ ও জীববৈচিত্র্যকে ধ্বংস করে মানুষের স্বাস্থ্যহানি ঘটায় সে বিদ্যুৎ দিয়ে দেশ ও জাতির ইঙ্গিত উন্নয়ন মুখ খুবরে পড়বে । ইতোমধ্যেই যে সব দেশ এ ধরনের বিষাক্ত জ্বালানী ব্যবহার করে শনৈঃ শনৈঃ উন্নয়নের শীর্ষে আরোহন করেছিলো, আজ শেষ বিকেলে এসে এটা স্পষ্টতই: উদ্ভাসিত যে এ উন্নয়ন স্থায়ী নয় । এসব লক্ষন স্পষ্টভাবে প্রতিফলিত । তখনই প্রশ্ন এলো “পরিচ্ছন্ন জ্বালানী ও বিদ্যুৎ” আমরা কি ভাবে পেতে পারি ! বিজ্ঞানী ও প্রকৌশলীরা পৃথিবীকে, পৃথিবীতে বসবাসকারী মানবজীবনকে, পরিবেশ ও জীববৈচিত্র্যকে বাঁচাতে সবচেয়ে বিষাক্ত জ্বালানী কয়লার ব্যবহার পরিহার করে সূর্যের তাপ ও আলো, পানি প্রবাহ, বায়ু বেগ ও বজ্রকে ব্যবহার করে বিদ্যুৎ উৎপাদনের কৌশল বের করে বাস্তবায়নও শুরু করেছে । এ পদ্ধতি প্রয়োগ করা হলে কয়লা দিয়ে বিদ্যুৎ উৎপাদন করতে গিয়ে পৃথিবী যে বিষাক্ত বজ্র দ্বারা ধ্বংসের কিনারায় এসে পড়েছিলো তা থেকে পৃথিবী এবং পৃথিবীতে বসবাসকারী মানবসমাজ এক পরিবেশবান্ধব সুন্দর পৃথিবীতে বাঁচার সুযোগ পাবে ।

বিশ্বে কয়লা ভিত্তিক বিদ্যুৎ উৎপাদনে শীর্ষে অবস্থানকারী দেশ যুক্তরাষ্ট্র, রাশিয়া, চীন, ভারত ও অস্ট্রেলিয়া নিজেদের দেশ ও পৃথিবীকে ধ্বংসের হাত থেকে রক্ষার জন্য ইতোমধ্যেই তাদের কয়লা ভিত্তিক বিদ্যুৎ উৎপাদন কেন্দ্রগুলোকে বন্ধ করার পদক্ষেপ গ্রহন করেছে ।

পরিবেশ ও বায়ুদূষণকারী বর্জ্য কোন দেশের সীমান্তে এসে থমকে দাঁড়াবে না। সীমানা পেরিয়ে সারা বিশ্বেই এ বর্জ্য দূষিত করবে। কয়লা দিয়ে বিদ্যুৎ উৎপাদনকারী দেশ যুক্তরাষ্ট্র, চীন, অষ্ট্রেলিয়া ও ভারত পৃথিবীকে দূষণের অপরাধে শুধু নিজেদের দেশের পরিবেশবাদীদের দ্বারাই নয় সারা বিশ্বের পরিবেশবাদীদের তীব্র বিরোধিতার মুখে পড়ে এ কর্মসূচী গ্রহন করতে বাধ্য হচ্ছে।

তেমনি আনবিক বিদ্যুৎ কেন্দ্রের পরিত্যক্ত (উৎপাদিত) তেজস্ক্রিয় বর্জ্য ও সম্ভাব্য দূর্ঘটনাজনিত বিষাক্ত বর্জ্যের ভয়াভয়তা ইতোমধ্যেই উদ্ভাসিত। বিশ্বব্যাপী এর প্রতিক্রিয়া হিসেবে তীব্র গণআন্দোলনের মুখে আনবিক বিদ্যুৎ কেন্দ্রের উপর নির্ভরশীল অধিকাংশ দেশ আগামী এক থেকে দুই দশকের মধ্যে তাদের আনবিক বিদ্যুৎ কেন্দ্রগুলো বন্ধ করে দেবার পরিকল্পনা গ্রহন করেছে।

কয়লা ভিত্তিক ও আনবিক বিদ্যুৎ কেন্দ্র পরিত্যাগ করা হলে তাবৎ পৃথিবীর বিদ্যুৎ চাহিদা মিটবে কি করে? ভুক্তভোগী এসব দেশ ইতোমধ্যেই পরিচ্ছন্ন (নবায়নযোগ্য) জ্বালানী দিয়ে বিদ্যুৎ উৎপাদনের লক্ষ্যমাত্রা ভিত্তিক পরিকল্পনা ও গ্রহন করেছে। বায়ু দিয়ে বিদ্যুৎ উৎপাদনে বিশ্বের শীর্ষ ১০ দেশ (ছক-৭)^{১০} :

ছক-৭: বায়ু দিয়ে বিদ্যুৎ উৎপাদনে বিশ্বের শীর্ষ ১০ দেশ

মেধা ক্রম	দেশ	সাল	মেগাওয়াট
১.	চীন	২০১২	৭৫,৫৬৪
২.	যুক্তরাষ্ট্র	২০১২	৬০,০০৭
৩.	জার্মানী	২০১২	৩১,৩৩২
৪.	স্পেনের সমীক্ষ বরানো	২০১২	২২,৭৯৬
৫.	ভারত	২০১২	১৮,৪২১

বিদ্যুৎ সংকট সমাধান ও টেকসই বিদ্যুৎ ব্যবস্থার প্রবর্তন।

বিশ্বে বিদ্যুৎ উৎপাদনে যে সব প্রাথমিক জ্বালানী মূখ্য উপাদান হিসেবে ভূমিকা রাখে,সৌভাগ্যের বিষয় বাংলাদেশে তার সবগুলোই শুধু অটেলই নয়,এ পর্যন্ত প্রাপ্ত তথ্য অনুযায়ী বাংলাদেশে আবিষ্কৃত প্রায় সমস্ত জ্বালানীই অত্যন্ত উঁচুমানের। যে সব জ্বালানী ব্যবহারের মাধ্যমে প্রাথমিকভাবে বিদ্যুৎ উৎপাদন করে সম্ভাবনাময় বাংলাদেশ গঠনের পদক্ষেপ নিতে সুপারিশ করা হচ্ছে সে গুলি হলো :

- (ক) প্রাকৃতিক গ্যাস
- (খ) সূর্যরশ্মি এবং সূর্য্যতাপ
- (গ) বাতাস
- (ঘ) পানি
- (ঙ) বায়োমাস

সূর্যরশ্মি ও বায়ু দিয়ে বিদ্যুৎ উৎপাদনের পরিমান নির্ধারনে বাংলাদেশে ২টি আন্তর্জাতিক মানের সমীক্ষা কারনো হয় । একটি সৌরবিদ্যুতের উপর Identifying High Priority Clean Energy Investment Opportunities for Bangladesh ,February, 2018 ^{১১} যাতে বিধুত আছে বাংলাদেশ অত্যন্ত সাশ্রয়ী মূল্যে স্বল্প সময়ে প্রায় ৫০,০০০ মেগাওয়াট সৌর এবং অন্যটি বায়ু বিদ্যুতের উপর Wind Power Potentiality in Bangladesh in May 2018 ^{১২} যাতে বর্ণিত আছে স্বল্প উচ্চতায় বাংলাদেশ অত্যন্ত সাশ্রয়ী মূল্যে স্বল্প সময়ে প্রায় ৩৪,০০০ মেগাওয়াট ও বেশী উচ্চতায় প্রায় ৬৪,০০০ মেগাওয়াট ক্ষমতার বায়ু বিদ্যুৎ উৎপাদন করতে পারবে । এছাড়াও আরোও কিছু মূল্যবান এদেশে সম্পদ এদেশে রয়েছে যা থেকে বিদ্যুৎ উৎপাদন হয় যেমন সমুদ্রের ঢেউ,নদীর জোয়ার-ভাটা ইত্যাদি। কিন্তু বাংলাদেশে আজকের প্রকৃত রিসার্চ ওয়ার্কের অপ্রতুলতা, দেশের রাজনৈতিক বাস্তব অবস্থা,সরকারসমূহের জনবিরোধী দর্শন এবং বিশেষজ্ঞদের সক্ষমতা এধরনের জ্বালানী ব্যবহারের মাধ্যমে এখনই বিদ্যুৎ উৎপাদন করাকে সমর্থন দেয় না । তবে সুখের কথা উপরে উল্লিখিত সূর্যরশ্মি এবং সূর্য্যতাপ, বাতাস, জল, বায়োমাস ইত্যাদিকে ব্যবহার করে বিদ্যুৎ উৎপাদন করতে অন্যান্য

যেসব খনিজ সম্পদ প্রয়োজন প্রাপ্ত তথ্য অনুযায়ী তার অধিকাংশই অত্যন্ত উঁচুমানের ও অচেল পরিমানে এদেশে পাওয়া যায় ।

কারিগরী বিশ্লেষণে বিদ্যুৎ উৎপাদনে যে দিকটির দিকে বিশেষ দৃষ্টি দিতে হয় তা হলো লোড সেন্টার । অর্থাৎ বিদ্যুৎ উৎপাদন কেন্দ্র কোন স্থানে বসাতে হবে । কাজেই যে সব জ্বালানী এলাকা ভিত্তিক (Site Specific), অর্থাৎ বাতাস, জল ও বায়োমাস ইত্যাদি যেখানে প্রাপ্য সেখানে উক্ত জ্বালানী দিয়েই সম্ভাব্য সর্বোচ্চ বিদ্যুৎ উৎপাদনের হিসেব করে উক্ত Site এ উৎপাদিত বিদ্যুতের সাথে যদি প্রয়োজন হয় অন্যান্য জ্বালানী দিয়ে আরও বিদ্যুৎ উৎপাদনের পরিকল্পনাসহ দেশের অন্যান্য এলাকার প্রয়োজন অনুযায়ী বিদ্যুৎ উৎপাদনের মহাপরিকল্পনা গ্রহণ করা হয় তাহলে আজকের বিদ্যমান সংকট কাটতে সর্বোচ্চ ১ থেকে ২ বছর সময় লাগতে পারে ।

টেকসই জ্বালানী(Sustainable Energy) ব্যবহারের স্বার্থে এবং জ্বালানী নিরাপত্তার কথা বিবেচনা করে প্রতিটি জ্বালানী ব্যবহার করে সম্ভাব্য কি পরিমাণ বিদ্যুৎ উৎপাদন করা সম্ভব, তাতে কত ব্যয় এবং সম্ভাব্য নির্মাণ সময়, জ্বালানীর মজুদ ও উক্ত জ্বালানী দিয়ে উৎপাদিত বিদ্যুৎ প্রাপ্তির ব্যাপ্তিকালের একটি ছক দিয়ে প্রতিবেদনটি শেষ করা হলো ।

ছক-৮: বাংলাদেশে বিভিন্ন উৎস সম্ভাব্য বিদ্যুৎ প্রাপ্তির পরিমাণ

ক্রমঃ নং	জ্বালানীর উৎস	সর্বমোট বিদ্যুৎ উৎপাদন [মেগাওয়াট]	প্রতিমেগা- ওয়াট স্থাপনে ব্যয় [কোটি টাকা]	মোট নির্মাণ ব্যয় [কোটি টাকা]	জ্বালানীর অবস্থান	ক্রমিক উৎস	জ্বালানীর উৎস
১	প্রাকৃতিক গ্যাস	৫,০০০	১৫	৭৫,০০০	৩৫,০০০ কোটি ঘনফুট (১মে: ওয়াট/বার্ষিক =৭ কোটি ঘনফুট)	১০০,০০ ০,০০ কোটি ঘনফুট (সাগরব ক্ষ ও ভূমির গ্যাস ধরে)	সমুদ্রে ১২ নং গভীর কূপে সম্ভাব্য ১০০ টিসিএফ গ্যাস প্রাপ্তির সম্ভাবনা আছে

৩	বায়ু	১৫,০০০	৮	১,২০,০০০	বায়ুর গতির প্রয়োজন: ৩.২ মিটার/সেকেন্ড বাংলাদেশে গড়বায়ুর গতি: ৪.৬মিটার/সেকেন্ড	অনাদিকাল
৪	সূর্যরশ্মি	১৫,০০০	৮	১,২০,০০০	বাংলাদেশে সূর্যরশ্মির বিদ্যুৎ উৎপাদন ক্ষমতা=৬.৮ বিদ্যুৎ ইউনিট/বর্গমিটার বিশ্বের গড়=৪.৮ বিদ্যুৎ ইউনিট/বর্গমিটার	অনাদিকাল
৫	বায়োমাস	১০০০	১০	১০,০০০		অনাদিকাল
সর্বমোট		৩৬,০০০		৩,২৫,০০০		

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METEOROLOGICAL INFLUENCE ON AIR QUALITY INDEX (AQI) IN DHAKA CITY

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Abstract

Dhaka, being the core of all economic, political, and cultural activities, has been on the path of urbanization, modernization, and development race with the rest of the world. Increase in unplanned urbanization, and industrialization, and additional anthropogenic activities, increased the amount of air pollutants. Air pollution has become a massive issue to deal with since it not only risks human health but also the surroundings. This study aims at investigating the temporal variation of AQI of PM_{2.5} in Dhaka city, and the relationship between AQI of PM_{2.5} and meteorological characteristics of Dhaka city from the year 2016 to 2020. AQI of PM_{2.5}, from the year 2016 to 2020, was collected from World's Air Pollution: Real-time Air Quality Index Project. Temperature, and precipitation data were collected from National Oceanic and Atmospheric Administration (NOAA), and relative humidity and windspeed, from Power Data Access Viewer. The overall result of the study suggested that AQI was highest during the dry winter season, that is, in months like December and January. Moreover, meteorological parameters have negative relationship with AQI, and tend to be more effective with seasonal influence. Out of the selected years (2016-2020), 2018 had the highest annual average AQI. During 2016 to 2020 the AQI category was mostly either "Unhealthy for sensitive group" or "Unhealthy", which means air

quality is not recovering and this needs serious attention by not only the government but also the common people.

Keywords: Air pollution, PM_{2.5}, AQI, Dhaka, Meteorological parameter, Seasonal variation

INTRODUCTION

Air pollution and its effect on the surrounding have become the prime concern and the most exigent issue to deal with (Kumar and Dash, 2018). Around 46,000 deaths are due to air pollution in Bangladesh each year, as per a report of World Bank's Country Environmental Analysis (CEA) 2018 (Hossain et al., 2019). The human lungs are exposed to more than 7000 litres of air in a day, among it contains many types of gases, organic and inorganic particles (Katara et al., 2017). Although a handful of pollutants are in the air, but fine particulate matters give rise to more harmful effects on human health. Particulate matters are a complex mixture of particles that can be solid, liquid or both and can vary in size, composition and origin (Majumder et al., 2020a). These do not settle down and tend to remain suspended in air. Particulate matters (PM) are fine and coarse particles, where PM₁₀ are coarse particles that have the aerodynamic diameter of $\leq 10 \mu\text{m}$ and PM_{2.5} are the fine particles that have the aerodynamic diameter of $\leq 2.5 \mu\text{m}$ (Nayeem et al., 2020c). Degrading air quality stands as one of the major reasons behind Dhaka being the second-most uninhabitable city in the world (Nayeem et al., 2019). Dhaka has become one of the 20 mega-cities in the world, with 20 million people living in it while facing dire consequences of air pollution. This makes it one of the most densely populated and air polluted cities in the world (Nayeem et al., 2020c). In order to assess the quality of environmental air, a measure is used that is called Air Quality Index (AQI), which can notify the public to take protective measures and also help the governing bodies to prepare corresponding pollution regulations (Wang et al., 2018). The AQI

have advanced and been used in many developed countries for the past 30 years. It works by categorizing an area as good, satisfactory, moderately polluted, poor, very poor and severe. Sources of pollution are mostly in areas where there are more housing, traffic and industries and if there is less control over pollution measures (Krzyzanowski et al., 2014). In 2010, ambient air pollution was responsible for 92,000 premature deaths, in Bangladesh, of which 55% were associated with daily household energy usage like cooking and heating (Rana and Khan, 2020). Adverse effects of air pollution on humans, climate, wildlife and the ecosystem are very critical (Hossain et al., 2019). For the last three-decade air pollution has become a significant health hazard. Studies indicate air pollution contributes to approximately 3,580 premature deaths in Dhaka city in a year. Air pollution and the health disorder it causes, is also responsible for the decreasing GDP and dropping economy in many countries (Nayeem et al., 2020c). The two major objectives of this study are: (1) to find out the temporal variation of AQI in Dhaka city from 2016 to 2020. And (2) to assess the relation between AQI and meteorological characteristics in Dhaka city.

METHODOLOGY

Ground Level PM_{2.5}

The U.S. Environmental Protection Agency's (EPA) AQI system was used to determine the AQI in this study (Table 2.1). PM_{2.5} data were collected from January 1, 2016 to December 31, 2020, of Dhaka city to investigate the relationship between temporal variation of AQI of PM_{2.5} and meteorological characteristics. World's Air Pollution: Real-time Air Quality Index Project (www.aqicn.org), which is a publicly available air quality data, provided daily AQI based on 24 hours average on the hourly reading for PM_{2.5}. Ground based PM_{2.5} monitoring station, situated near/at the US embassies and consulates of each country, records these data.

DATA ANALYSIS

SPSSv20 and Microsoft Excelv10 were used for data processing, analysis and preparing tables and graphs.

Air Quality Index (AQI)

AQI is used as a daily reporting of air quality. It measures how clean or polluted the air is and the health impacts related to it (EPA, 2014) (Kumar and Dash, 2018). A certain segment of population, who might be sensitive to excess level of pollution, could be guided earlier by the help of AQI. AQI standards have been established by USEPA to express how polluted the present air is or how much polluted it can get (Nayeem et al., 2020b). Based on population density and exposure, each country consists of its own national AQI. Moreover, the following equation was used to establish the daily (24 hours) PM_{2.5} based AQI (Razib, 2020).
$$I_P = \frac{(I_{HI} - I_{LO})}{(BP_{HI} - BP_{LO})} (C_P - BP_{LO}) + I_{LO}$$

Where, I_P = Index value for PM_{2.5}; C_P = Rounded concentration of PM_{2.5}; BP_{HI} = Higher breakpoint value of C_P ; BP_{LO} = Lower breakpoint value of C_P ; I_{HI} = Index breakpoint value of BP_{HI} ; I_{LO} = Index breakpoint value of BP_{LO}

The breakpoints for PM_{2.5} concentrations along with the ranges of PM_{2.5}-AQI category are stated in Table 1.

Table 1: Breakpoint of PM_{2.5} (revised) with AQI category (Source: Mintz, 2012)

Break Points of PM _{2.5} (µg/m ³)	AQI	Category
0-12	0-50	Good
12.1-35.4	51-100	Moderate
35.5-55.4	101-150	Unhealthy for sensitive group
55.5-150.4	151-200	Unhealthy
150.5-250.4	201-300	Very unhealthy
250.5-500.4	301+	Hazardous

RESULT AND DISCUSSION

Dhaka is the second most polluted city of the world, in terms of $PM_{2.5}$. Due to unplanned urbanization, industrialization and motorization, degree of air pollution has risen (Rahman et al., 2020). Meteorological factors also have crucial relationship with air quality through secondary PM formation and downwind transportation (Afrin and Islam, 2020). However, concentration of pollutants not only fluctuates due to meteorological factors but also because of seasonal variation (Razib et. al., 2020).

Monthly Average AQI of $PM_{2.5}$

Table 2 and Figure 1 reveals that the monthly average AQI was the highest on the month of January throughout each year from 2016 to 2020, the AQI has been 90 which was the lowest in comparison to the rest of the months. In addition to that in 2018, the average AQI for this month was 83.77 which was least of all the monthly average AQI. During this five year course January has maintained an average AQI above 235; moreover in 2018 this had the highest monthly average AQI out of all five years that is 256.

Table 2: Monthly average AQI of Dhaka city from 2016-2020

Year					
Month	2016	2017	2018	2019	2020
January	DNA	247.77	256.00	240.00	235.10
February	DNA	207.78	224.18	234.57	220.52
March	174.70	169.77	182.90	191.13	175.23
April	129.03	135.63	144.37	144.40	122.93
May	122.16	123.58	109.06	130.21	111.75
June	106.60	91.93	94.23	86.73	92.00
July	85.81	83.77	86.32	87.13	87.77
August	97.23	94.13	99.22	77.81	77.16
September	100.03	101.88	DNA	95.73	91.23
October	132.45	114.52	DNA	130.87	127.84
November	169.40	178.41	196.55	159.00	147.21
December	220.35	203.90	211.48	204.83	231.68

The trend shows a rise in the average AQI from the month of July to December and January, then again a downfall from January to June and July. This is because December and January are in the winter season and during this time there is a rise in the level of emission and the lower-mixing layer height which in addition to thermal inversion in brick kilns industry. This expands the amount of particular matter, resulting in higher AQI (Rahman et al., 2020). Brick kilns are one of the industries that operate only during the drier season and not at the monsoon, therefore, in months like June and July there are less activities within those industries, less emission and thus, lower AQI. Although some data is missing but it can be neglected in terms of the total outcome.

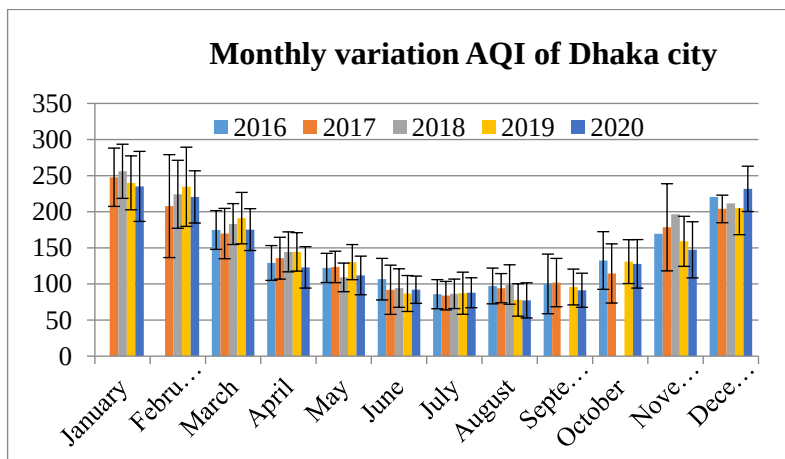


Figure 1: Monthly variation in AQI of Dhaka city from 2016-2020

Seasonal Average AQI of PM_{2.5}

Dhaka city from 2016-2020. Horizontal black lines within the boxes mark the median; the lower boundary of the boxes indicates the 25th percentile and the upper boundary of the boxes indicates the 75th percentile. The whiskers represent the maximum (upper whisker) and the minimum value (lower whisker). Points above the whiskers indicate outliers. Figure 2

displays that AQI has been greater during the winter season and the lowest during the monsoon season (out of the four). During winter when the season is dry, due to scant rainfall and the temperature, humidity, and windspeed is low as well, there is increase in dust suspension. Moreover the lower mixing layer height, including thermal inversions and emissions from brick manufacturing are responsible for the buildup of PM concentration (Rahman et al., 2020) (Rana and Khan, 2020). As the mixing layer height lowers, particles get trapped closer to the ground level which amplifies their concentration (Majumder et al., 2020b), In addition to that PM is transported from India, by seasonal wind that blows from north and northwestern side, which results in higher AQI during the winter and proves that it is also influenced by transboundary air pollution (Rahman et al., 2019) (Nayem et al., 2020a) (Razib et al., 2020). Although the pre-monsoon and post-monsoon are in the medium range but during the post-monsoon of 2018, it is clearly vi

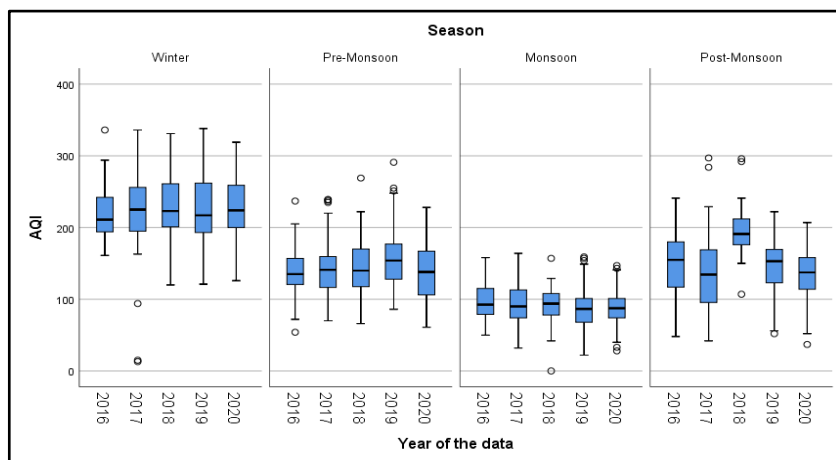


Figure 2: Box and whisker plot representing seasonal variation in AQI of sible that the AQI has amplified more than the rest of the selected years.

Annual Average AQI of PM_{2.5}

Table 3 represents the annual average AQI of Dhaka city from the year 2016 to the year 2020. In 2016 the annual average was the least out of the five years, with AQI 132.78, and in 2018 it was the most with AQI 161.57. The annual average AQI of 2017, 2019, and 2020 was 142.96, 147.86, and 143.52, respectively. The table also displays the percentage of variation among the average AQI within the years. From 2016 to 2017 and 2017 to 2018 there has been an increase in the annual average AQI, of 7.66%, and 13.02%, respectively. But from 2018 to 2019, and 2019 to 2020, there has been a reduction in the average annual AQI, of 8.48%, and 2.93%, respectively. However, the annual average AQI has shown a growth of 8.09% from 2016 to 2020.

Table 3: Annual average and change in percentage of AQI in Dhaka city from 2016-2020

Year	Mean	Year interval	Percentage difference in AQI
2016	132.78	2016-2017	+7.666666
2017	142.96	2017-2018	+13.02248
2018	161.57	2018-2019	-8.4893
2019	147.86	2019-2020	-2.93302
2020	143.52	2016-2020	+8.090985

Figure 3 exhibits that there is slight rise in the annual average AQI from 2016 to 2017, then again from 2017 to 2018. It shows steeper trend and gradual increase. This is because of the rapid growth in population, which leads to uncontrollable urbanization and industrialization that is responsible for the deterioration of air quality (Islam et al., 2020) (Hoque et al., 2020b).

However, from 2018 to 2019, the average annual AQI starts to drop and further decline from the year 2019 to 2020. Since in 2020 lockdown was activated due to the Covid-19 pandemic, and

some of the pollution sources were shutdown. The overall graph indicates that there is growth in AQI along the five years.

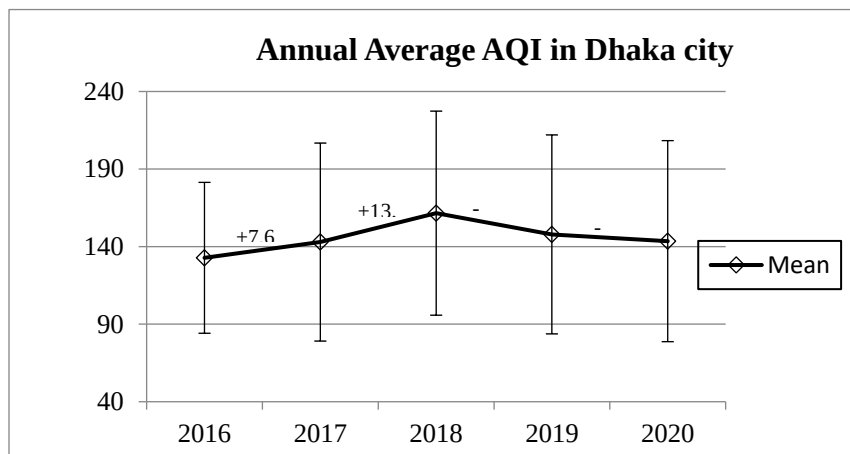


Figure 3: Annual variation in AQI of Dhaka city from 2016-2020

Pearson Correlation between AQI and Meteorological Parameters

Table 4 represents that there is negative Pearson correlation between AQI and the meteorological parameters. Specifically, AQI has a significantly inverse correlation ($r=-0.698$) with temperature across the years. When there is high temperature causes the atmospheric pressure to be low and there is atmospheric instability which helps pollutant dispersion over large area and reduces AQI (Hoque et. al., 2020b). The correlation between the AQI and precipitation, is negative, however, it is not consistently significant ($r=-0.249$). Precipitation is known to reduce $PM_{2.5}$ load through wet deposition (Hoque et. al., 2020b). Relative humidity and windspeed are also inversely correlated ($r=-0.588$, and -0.433 , respectively) to AQI of $PM_{2.5}$. Relative humidity influences particle movement since it can make the particulate matter to settle down at the ground, lower their concentration and AQI (Kayes et al., 2019).

Table 4: Correlation between AQI and selected meteorological parameters

Correlations						
		AQI	Temperature	Precipitation	Relative Humidity	Wind speed
AQI	Pearson Correlation	1	-.698**	-.249**	-.588**	-.433**
	Sig. (2-tailed)		0.000	0.000	0.000	0.000

** Correlation is significant at the 0.01 level (2-tailed).

Regression Analysis of AQI and Meteorological Parameters

Table 5 shows linear regression analysis, where the AQI of Dhaka city was the dependent variable and the meteorological parameters (temperature, precipitation, relative humidity, windspeed) are the independent variable. It has been observed that there was 48.7% variation in dependent variable due to the influence of the independent variable, temperature, since the R^2 was found to be 0.487. In terms of precipitation, relative humidity, and windspeed, the R^2 is 0.062, 0.345, and 0.187, respectively, which causes the variation in AQI of $PM_{2.5}$.

Table 5: Significant parameters of the AQI regression model considering only the linear terms of all meteorological parameters as predictor variables

Model Summary				
Variable	R	R Square	Adjusted R Square	Std. Error of the Estimate
Temperature	0.698 ^a	0.487	0.487	41.276
Precipitation	0.249 ^b	0.062	0.061	55.820
Relative Humidity	0.588 ^c	0.345	0.345	50.608
Windspeed	0.433 ^d	0.188	0.187	56.369
a. Predictors: (Constant), Temperature				
b. Predictors: (Constant), Precipitation				
c. Predictors: (Constant), Relative Humidity				
d. Predictors: (Constant), Windspeed				

Correlation of AQI of PM_{2.5} with Meteorological Parameters and Season

Figure 4 exhibits a negative relationship between the two variables that is AQI against temperature. The diagram reveals clearly that in the winter season when the temperature was 15⁰ to 20⁰ C the AQI was the highest. During winter when the temperature is low, there is high pressure in the atmosphere which causes little or no dispersion among the particles of PM_{2.5}. This means they can not disperse over large area and remain concentrated in close vicinity, which results in higher AQI (Hoque et. al., 2020b). During winter, at about 25⁰ C it can be observed that the AQI was still very high. In the pre-monsoon, and the post monsoon, the AQI started to drop steadily, when the temperature was found to be 23⁰ to 28⁰ C. However, when the temperature was the highest, about 28⁰ to 33⁰ C, during the monsoon, the AQI was recorded to be the lowest of all.

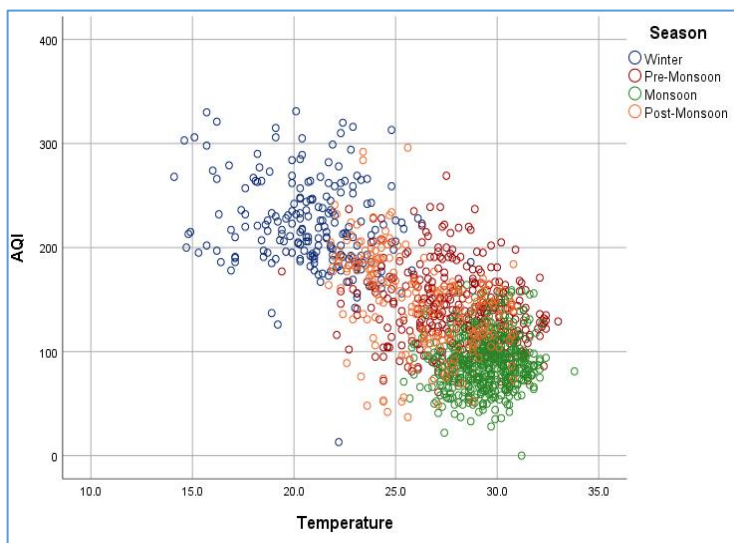


Figure 4: Correlation of AQI variation with temperature and seasons in Dhaka from 2016-2020

Figure 5 shows that during most of the time there was no precipitation which caused the dots to be placed together in the same vicinity. This is mostly during the winter, and post monsoon season. As the amount of precipitation increased, the AQI kept decreasing; this indicates that there is a negative relationship between the two variables. Precipitation is always associated with the reduction in pollution level from the atmosphere especially during the monsoon (Majumder et. al., 2020b). Particulate matter, which consists of soil and road dust, absorbs water vapor from the atmosphere and easily get deposited on the ground, reducing pollutant from the atmosphere and AQI as well (Kayes et al., 2019). Wet deposition reduces the amount of PM during precipitation (Hoque et. al., 2020b). Although in the monsoon, and sometimes post-monsoon, the AQI was quite low even when there was no precipitation.

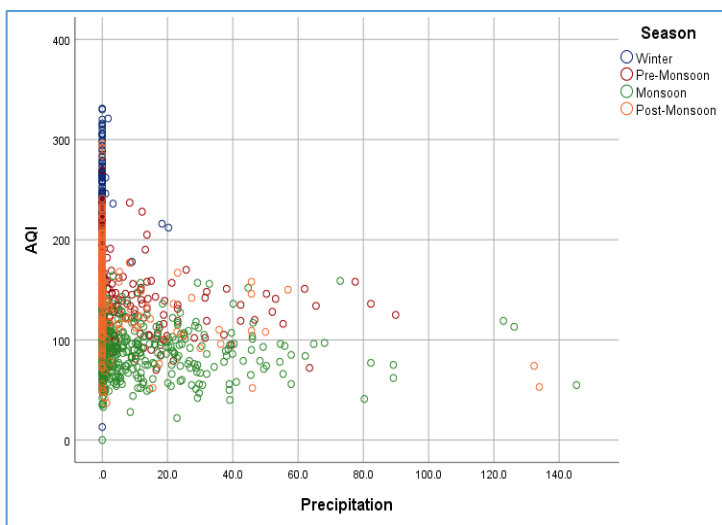


Figure 5: Correlation of AQI variation with precipitation and seasons in Dhaka from 2016-2020

Although Figure 4.6 does not show a simple trend, but the overall diagram indicates that as the relative humidity grew, there was reduction in AQI, showing negative relationship between the two. Particles become more prone to different processes of the atmosphere when there is more moisture in the air, and tend to settle down and decrease in concentration (Afrin and Islam, 2020). However, the point to be noted is that with the same amount of humidity in the winter, the AQI was so much more in comparison to pre-monsoon. During monsoon, the relative humidity was higher and the AQI also fell steadily.



Figure 6: Correlation of AQI variation with relative humidity and seasons in Dhaka from 2016-2020

Figure 7 does not reveal a clear trend, although it can be observed that as the windspeed became higher, the AQI also started to drop. However, this fall was mostly during the monsoon because this same windspeed during the pre-monsoon had higher AQI. In the winter, the windspeed was the lowest and AQI was highest which reflects negative relationship among the two. During winter the north-westerly wind transports particulate matter from that the brick kilns of that area. And in this time of

the year most of the construction activities, open stubble and garbage burning, etc. take place due to the dry (suitable) weather condition that exists (Kayes et al., 2019) (Rana and Khan, 2020).

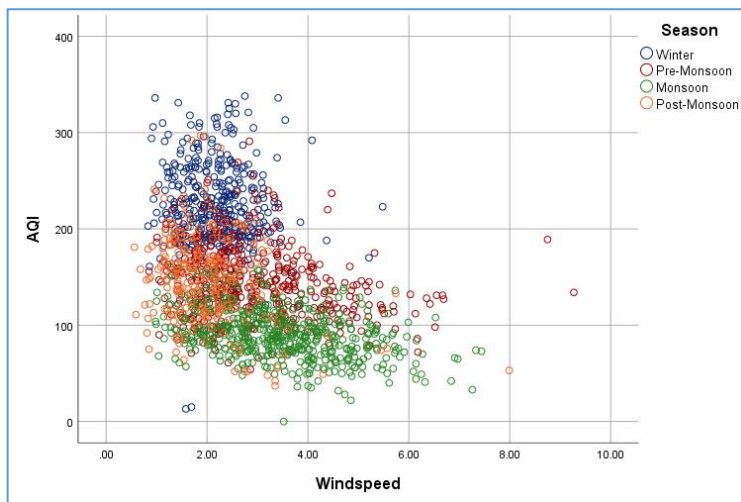


Figure 7: Correlation of AQI variation with windspeed and seasons in Dhaka from 2016-2020

Frequency of AQI Category of $PM_{2.5}$

Table 6 shows that from 2016 to 2020, the number of days that AQI was in the “Good” category was no more than 10, which was on 2017. The number of days with AQI category “Moderate” was 88 to 109, but in 2018 it saw a sharp decline with only 58 days. The AQI category “Unhealthy for sensitive group” mostly dominates the year, since around 70 to 120 days it existed during 2016 to 2020 and with the highest percentage in 2016, 2017, and 2020. “Unhealthy” category resided more than 60 days in a year in Dhaka city and in 2019 there were 100 days with this category. “Very unhealthy” category has the same traits as “Unhealthy” category, although, in 2016 there were only 26 days of it. Although the number of days of “Hazardous” category is very few, but there has been steady increase in this number from the year 2016 to 2020.

Table 6: Frequency of days of different AQI category from 2016-2020

AQI Category	Number of days in year				
	2016	2017	2018	2019	2020
Good	2	10	3	9	6
Moderate	82	88	58	93	109
Unhealthy for sensitive group	122	106	73	92	96
Unhealthy	65	62	68	100	60
Very unhealthy	26	64	79	60	69
Hazardous	1	5	6	6	7
Total	298	335	287	360	347

In Figure 8, it can be seen that the highest percentage of AQI category were “Unhealthy for sensitive group” and “Unhealthy” and the lowest were “Good” and “Hazardous”. In 2018 the AQI category “Very unhealthy” was highest among all, which is 28%. This clearly proves that the people of Dhaka city are consistently inhaling unhealthy air, which not only poses a threat to their health but also cause economic damage. Due to unplanned urbanization, industrialization and motorization, the air quality is deteriorating (Rahman et al., 2020).

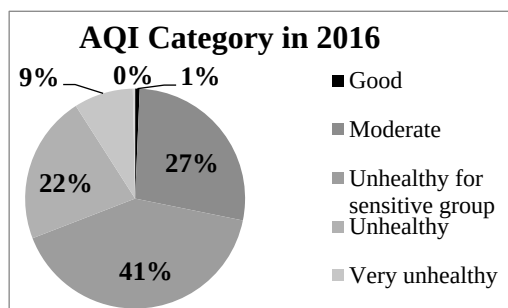


Figure: 8a: AQI category in Dhaka City (%) in 2016

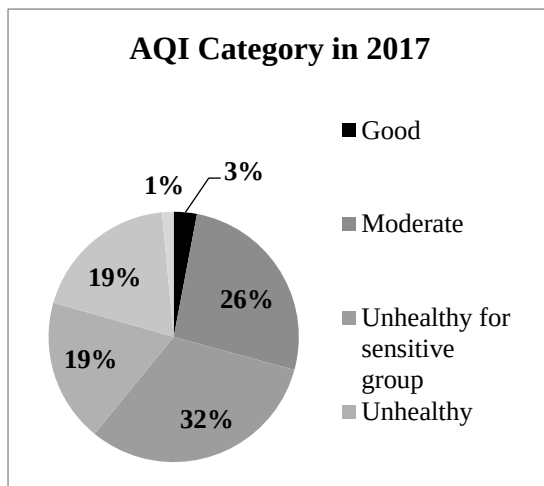


Figure: 8b: AQI category in Dhaka City (%) in 2017

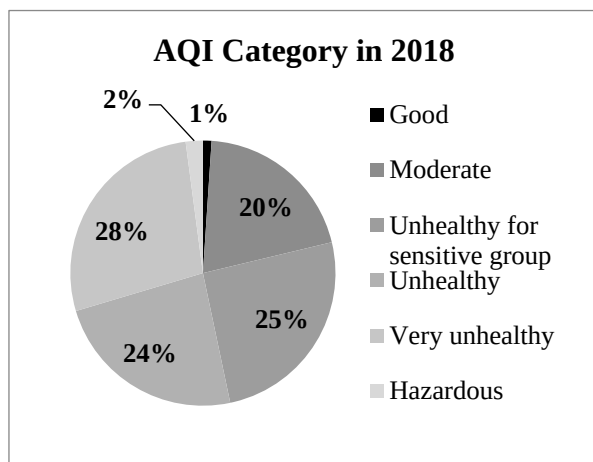


Figure: 8c: AQI category in Dhaka City (%) in 2018

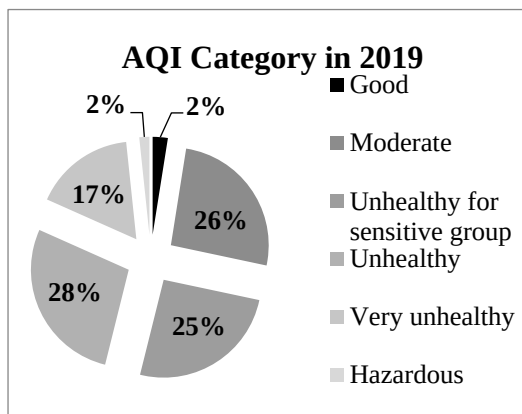


Figure: 8d: AQI category in Dhaka City (%) in 2019

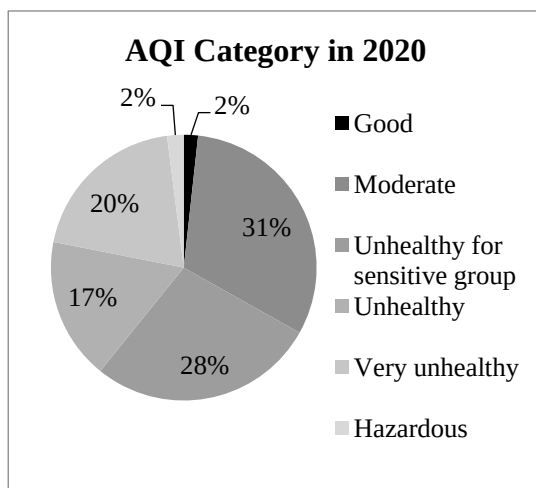


Figure: 8e: AQI category in Dhaka City (%) in 2020

CONCLUSION

The capital of Bangladesh, Dhaka (Latitude: N23°43'40"; Longitude: E90°23'52") is one of the biggest and lead growing cities of South Asia (Razib et al., 2020). The population density of Dhaka is about 28,000/km², the fourth most densely populated city around the globe. (Bangladesh Bureau of Statistics 2014), (Rahman et al., 2020).

It is the centre for all the economic, political, and cultural activities of Bangladesh. The city is bounded by four rivers since it is part of the Bengal plain (Razib et al., 2020). Population expansion, uncontrollable urbanization and industrialization, have accelerated the deterioration of air quality (Hoque et al., 2020b). Moreover, meteorological factors, along with seasonal influence contributed to the enhancement of PM_{2.5} concentration, leading to higher AQI. (Afrin and Islam, 2020). This study investigated the variation in AQI, due to meteorological factors which are temperature, precipitation, relative humidity, and windspeed, in Dhaka city. It is found that during winter in December-January AQI reaches the highest value and during monsoon in July AQI falls to a minimum value. Between the years 2016 to 2020, 2018 had the highest average AQI of 161.57. In the five years period, there was 8.09% rise in AQI of PM_{2.5} in Dhaka city. Among meteorological factors, temperature had a stronger negative correlation with AQI, than others like precipitation, relative humidity, and windspeed, that also have negative relationship. However, with seasonal influence, meteorological parameters show greater result. From 2016 to 2020, it can be summarized that very few number of days the AQI category was "Good" and the city was mostly ruled by "Unhealthy for sensitive group" and "Unhealthy" category. Constant worsening of air quality has become a crucial issue because of its threat to human health (Masum and Paul et al., 2020) and the environment (Hoque et al., 2020b).

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COP26: POSTSCRIPT AND CLIMATE ACTION FOR BANGLADESH

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Abstract

The catastrophic impacts of climate change have put the world in a state of perpetual emergency and humanity faces an existential threat to its survival. The much-anticipated COP26 UN Climate Change Conference did not accomplish enough to alleviate the threat.

The demand to “phase out” coal was watered down to “phase down”, with some countries to build additional coal-powered plants. The \$100 billion annual climate finance fund for developing countries lingered and a compensation fund for developing countries for loss and damage from climate disasters failed to be launched. Pledges to reduce CO₂ emissions through “Nationally Determined Contributions” lacked establishing enforcement or accountability criteria.

Activists, including researchers united as “Scientist Rebellion”, acknowledged marginal success on some grounds but criticized COP26 for its failure to agree on an action plan to limit warming to 1.5° C by 2030. U.N. Secretary-General António Guterres remarked, “It is an important step but is not enough.”

However, the nuclear industry and advocates succeeded in propagandizing nuclear power as “carbon-free” or “zero-carbon” and calling for its revival as an absolutely necessary alternative to coal. Also, they reductionistically bypassed other inherent problems such as no permanent solution to mounting nuclear waste; runaway construction, maintenance, as well as spent fuel reprocessing costs; depletion of a nonrenewable fuel source; bomb-making by-product of plutonium and theft; weapons proliferation; decommissioning challenges and costs; and security.

By allowing coal to continue and choosing one disaster over another (nuclear as an alternative to coal), COP26 cleared the path for countries to entrench deeper into a dead-end path that already seems to be near impossible to pull out of.

So, what can Bangladesh—one of the worst victims of climate change and a minimal emitter of CO₂—do for its own future, as well as to gain a stronger voice and role in the global pursuit of the climate goal? The paper addresses both the challenges and prospects through an overview of the country's renewable energy potential, as assessed by several research reports; the government's pledges, policies, practices and accomplishments; and civil society's response, role and activism in the pursuit.

Keywords: COP26, Climate Change, Economy, Nuclear, Renewable Energy, Sundarbans

THE COP26

A catastrophic scenario impacted by climate change is growing worse beyond the most dire scientific projections. Greater frequency and magnitudes of hurricanes, tornadoes, cyclones, typhoons, rising sea levels, floods, droughts, desertification, forest fires, heatwaves, freakish weather patterns, climate migration, destruction of biodiversity, outbreaks of new infectious diseases (such as coronavirus and its variants) and deaths due to climate change, and the Arctic and Antarctica melting—there's no respite. Globally, we are in a state of *perpetual* emergency and humanity faces an existential threat to its survival.

The much-anticipated COP26 UN Climate Change Conference, held in Glasgow, Scotland, during October 31, 2021 - Nov 12, 2021, hailed as “Humanity's last chance to save the planet” from catastrophic impacts of climate change, did not accomplish enough to alleviate the threat.

UK's Member of the Parliament and COP26 President Alok Sharma's appeal to national leaders to “consign coal power to history” did not happen. Thanks to over 500 lobbyists representing the fossil fuel industry, along with political leadership with vested

interest in, or under the thumb of, the industry, the demand to “phase out” coal was watered down to “phase down,” with some countries maintaining that they will build additional coal-powered plants.

Acknowledging that phasing out would have to be a process and not an overnight change, still—with all the scientific knowledge and evidence we have at hand about the catastrophic and cataclysmic consequences of burning coal—to not decide on phasing out coal with the utmost urgency and allowing instead to build more coal-powered plants amounted to nothing short of consigning the future of the Earth—juxtaposed by scorching, freezing and drowning—to a hell. Human greed, hubris and moral bankruptcy have never spoken louder. So, on September 28, 2021, Greta Thunberg was on point in her speech at the opening session of a Youth4Climate event at the UN Climate Change pre-Conference preceding COP26 held in Milan, Italy, when she criticized global leaders over their promises to address the climate emergency, dismissing them as “blah, blah, blah.”¹

Furthermore, the lingering commitment from the developed countries to a \$100 billion annual climate finance fund for developing countries did not progress any further and a compensation fund for developing countries for loss and damage from climate disasters failed to be launched. Pledges from countries to reduce CO₂ emissions through “Nationally Determined Contributions” (NDCs)—not legally binding—lacked establishing enforcement or accountability criteria.

What is also disappointing is that the conference lacked any conversation about the over-consumption patterns and practices that are characteristic of “developed” countries and their economies—long equated with social and economic progress, but which have increasingly led to negative environmental and social consequences, such as “Affluenza” (“The All-Consuming Epidemic” which is “a painful, contagious, socially transmitted condition of overload, debt, anxiety, and waste resulting from the dogged pursuit of more,” as authors John De Graaf, David Wann and Thomas Naylor coined it in their book, *Affluenza: How Overconsumption Is Killing Us—and How to Fight Back*).²

There was very little indication, or consideration, of the awareness that *the first and fundamental condition of sustainability is to live within the limits and renewability of natural resources* and not by continuing to deplete the nonrenewables, i.e. oil, coal, natural gas and uranium—resources for fossil fuels and nuclear power, and that both the cause of, and solutions to, climate change must be understood and addressed within this context.

Thousands of activists of all ages from around the world, including researchers united as “Scientist Rebellion,” acknowledged marginal success on some grounds but criticized—even condemned—COP26 for its failure to agree on an action plan to limit warming to 1.5° C by 2030.³ In closing, U.N. Secretary-General António Guterres remarked. “It is an important step but is not enough. We must accelerate climate action to keep alive the goal of limiting global temperature rise to 1.5 degrees.”

Amitav Ghose, a novelist and author of many books including *The Great Derangement: Climate Change and the Unthinkable* and *The Nutmeg's Curse: Parables for a Planet in Crisis*, offered a more sobering assessment: “Cop26 really underlined that all those political mechanisms and institutions of liberal world governance that we rely on have failed us, and they’re going to fail more and more in the future.”⁴

What was accomplished, however, through exploiting the concern over the coal-climate change connection, was the nuclear industry and advocates successfully pushing through nuclear power as a viable alternative to coal, maintaining that nuclear power is absolutely necessary to cope with the climate crisis.⁵ They succeeded mainly by propagandizing nuclear power as a “zero-carbon” or “carbon-free” alternative—which is not true. Less emission of carbon, compared to burning fossil fuels, does not make nuclear power “zero-carbon” or “carbon-free.” As the physicist and systems theorist Fritjof Capra and Pier Luigi Luisi, Professor of Biochemistry at the University of Rome 3, put it: “Nuclear energy creates significant greenhouse gases and pollution. When the entire fuel cycle is considered, a nuclear plant emits 27% of the CO₂ emitted from a coal plant.”⁶

Moreover, the pro-nuclear push also suppressed or reductionistically bypassed other inherent problems such as having no permanent solution to mounting nuclear waste; runaway construction, maintenance, as well as spent fuel reprocessing costs; depletion of a nonrenewable fuel source (uranium); bomb-making by-product of plutonium and theft; weapons proliferation; decommissioning challenges and costs; and security. All these fundamental concerns in varied degrees remain valid not only related to conventional nuclear power plants, but also to the much-touted innovation in nuclear technology and a new generation of plant designs, such as Small Modular Reactors (SMR). The big push and propaganda for SMRs minimize or avoid questions such as: what are the consequences of mass production ("economy of multiples," which would be necessary to make them viable) and widespread dissemination (touted as an advantage) of these reactors—in terms of less waste from each but what about the total accumulation from all, safety and security, and cost (economic, social, medical, political and environmental)? On these and other grounds the Union of Concerned Scientists (UCS), in an aptly titled report, "Small Isn't Always Beautiful: Safety, Security, and Cost Concerns about Small Modular Reactors," concluded: "Unless a number of optimistic assumptions are realized, SMRs are not likely to be a viable solution to the economic and safety problems faced by nuclear power."⁷

From a sustainability perspective, by *choosing one disaster over another*, the nuclear push cleared the path for countries to entrench deeper into a dead-end path, a quagmire, that already seems to be near impossible to pull out of. And the "Super Powers" who have already embarked on a race for superiority in nuclear power—in a sort of nuclear cold war (both for its environmental and weapons proliferation implications)—would have to be justifiably labelled as potential "Super Destroyers." This is in addition to the nuclear arms race—MAD (Mutually Assured Destruction)—that the Super Powers as well as some other countries are already engaged in, threatening the survival of the whole world. Driven to the brink of extinction today,⁸ with nuclear holocausts and a contaminated Earth in between, what have we learned since the 1953 speech by

President Dwight D. Eisenhower, “Atoms for Peace,” a proven oxymoron, and the blunderous claim by Lewis Strauss, then the Chairman of the United States Atomic Energy Commission (1954), that nuclear power will usher in a future in which “Our children will enjoy in their homes electrical energy too cheap to meter” which, in succeeding years, boosted the sales of nuclear power reactors, both in the United States and around the world? “Those who cannot remember the past are condemned to repeat it,” said American philosopher George Santayana in 1905. Do we remember?

The inability to phase out coal, stop further entrenchment into the fossil fuel-nuclear path, and the regressive diversion into this dead-end path—however rationalized—also raises a fundamental question: so deeply entrenched into the fossil fuel-nuclear path, are the “developed” countries even capable of transitioning out of it? Floods, droughts, forest fires, heatwaves, crop losses, cyclones, blizzards, extreme weather, infectious diseases—climate change impacts on “developed” countries across Europe and North America continue to accelerate, some causing irreparable damages, which the countries seem to be ill-equipped, even incapable, to deal with. These impacts also incur enormous economic costs. Had these countries not been able to push most of these costs onto future generations—born and unborn, by all accounts they would have to be declared bankrupt—today. The compounding impact of these assaults is leading to a systems collapse, crippling infrastructures which hold societies together and, in an increasingly interdependent world, beyond national boundaries or economies. George Monbiot, environmental campaigner, journalist and author of *How Did We Get Into This Mess?: Politics, Equality, Nature* warns we are reaching a systems tipping point—and the collapse of our liveable planet.⁹

What are the ramifications of all these not only for the future of the “developed” countries themselves, but also the future of the “developing” countries—which, fortunately, are much less entrenched into the fossil fuel-nuclear path and are mostly located in regions that are richly endowed with renewable energy resources with practically untapped revolutionary potential—but, unfortunately, which are getting increasingly entrenched into the

nonrenewable path, thereby also turning into dumping grounds for fossil fuel-nuclear powered technologies that are being rejected around the world?

As we strive to counter the threat and survive the catastrophic consequences of climate change—unforgiving, universal and borderless—from a *holistic, ecological* and *global* perspective, these questions must be addressed. And if we *choose*, for it is a choice—both as a country, as well as a global community—not to succumb to these challenges, then *together* we must—without any further entrenchment into the unsustainable and dead-end fossil fuel-nuclear path—expedite the transition to renewables much faster than ever. The revolutionary developments with renewable energy technologies with an incredible range of options and designs that are both economically and environmentally responsible, along with numerous scientific studies based both on practical evidence and projections—among the latest being *100% Clean, Renewable Energy and Storage for Everything* by Mark Jacobson, professor of civil and environmental engineering at Stanford University and director of its Atmosphere/Energy Program—confirm that such a transition is indeed possible.¹⁰

Without undermining any of the positive outcomes—mostly pledges to be authenticated through action—this, to me, is the most important message—also a warning—from an overall assessment of the failures and accomplishments of COP26 Climate Change Conference: Engaging people from all walks of life, of all ages, in every possible ways and across the world, who care about the future we are headed for and the future we would like to create—and with the utmost urgency keeping in mind that time is of the essence—this is also a call for action—*now!*

The good news is such a transition is happening. Some of it shows on the surface, and much of it behind the scene. The global energy scenario is undergoing a transition toward renewables with growing opportunities and advantages: plummeting costs; record investments; innovation in manufacturing, efficiency, durability, designs, storage, transmission and applications; job creation; affordable financing; cultural demand; and global accessibility of renewable energy technologies. Together, these are transforming

the conventional fossil fuel-nuclear energy-based economic infrastructure toward a paradigm-shifting renewable energy-based infrastructure necessary for the transition to flourish and *sustain*. Simultaneously, an unprecedented coalescing of environmental, scientific, technological, economic, educational, academic, religious, political, legal, healthcare, business, governmental and cultural movements, engaging people from all walks of life and across all ages, is creating a synergy to fuel the revolution both with immediate results as well as the potential for a renewable energy future of economic prosperity, equity, environmental justice, safer and healthier humans, regenerated flora and fauna, environmental stewardship and peace.

Several scientific analyses of the potential and projections—and the experience gained from implementation of renewable energy technologies over recent decades, driven by major advancements and breakthroughs—have prompted some countries such as Germany, Denmark, Sweden, Switzerland, Austria, Iceland, Norway, Portugal, Uruguay and Costa Rica to even set their goals of transitioning to 100% renewable energy within a foreseeable future. Other countries are following.

The future will tell how well we succeed, but the choice of educating ourselves about the transition and expediting it with the utmost urgency is in the present. H. G. Wells put it well: “Human history becomes more and more a race between education and catastrophe.” We can either resign to fear and hopelessness, or act courageously on the revolutionary potential of renewable energy fueling a global, participatory and people-powered movement—which has already spread its wings—making it unstoppable. The choice is that clear. Today, that choice of action is also our greatest moral imperative—and hope!

CLIMATE ACTION FOR BANGLADESH

Bangladesh is one of the worst victims of climate change. Climate experts predict that rising sea levels will submerge some 17 percent of the nation’s land by 2050 and displace about 20 million people. Others predict that as much as one-third of Bangladesh will be under water permanently due to rising sea levels by the end of

the century. These predictions warn against worsening national catastrophes of unprecedented magnitude impacting every aspect of the nation's survival.

Fortunately, Bangladesh is also naturally endowed with a rich combination of renewable energy sources such as light, heat, wind, water movement and photosynthesis. Sunlight is abundant year-round in this semi-tropical region. Even during the monsoon season the solar radiation is as good as the annual average. In addition to ample light and heat, the 710 km (441 miles) of the country's coastline, which includes the 120 km (75 mile) long unbroken stretch of beach in Cox's Bazar, hilly sections, and islands provide plenty of wind for wind turbines—both onshore and offshore; waterways of varied forms and speed provide sufficient wave and gravity driven water flow for ecologically balanced hydro-electric generators; and the lush vegetation provides rich photosynthesis and biomass for fuel for a variety of purposes—such as heat and biogas for cooking and electricity. Compared to Germany—an inspiring example of a country set on a 100% transition to the renewable energy path—Bangladesh receives twice the amount of solar radiation than Germany. Bangladesh is truly an exceptional, naturally endowed and integrated, renewable “energy mine”—practically untapped! Judiciously harnessed, this energy mine has an inexhaustible capacity far beyond meeting the country's energy needs, now and in the future. It is a country with a revolutionary potential for benefitting from a wide range of types, designs and scales of cost-advantageous, appropriate and ecologically implemented renewable energy technologies. Furthermore, compared to industrially developed countries, as of now Bangladesh is minimally entrenched into the fossil fuel-nuclear path, which gives the country enormous cost, technological and socio-political advantages to lay down and build upon a renewable energy infrastructure.

Multiple scientific, economic and environmental research and analysis of international stature—combined with the field results of renewable energy applications in Bangladesh since the 1990s—confirm this potential. Among these are the joint report of the Renewable & Appropriate Energy Laboratory at the University of

California—Berkeley (RAEL) and the International Centre for Climate Change and Development (ICCCAD, Bangladesh);¹¹ the report of the Institute for Energy Economics and Financial Analysis (IEEFA, USA);¹² and the joint report of the National Renewable Energy Laboratory (NREL, USA), Harness Energy and National Centre for Atmospheric Research on the wind energy potential in Bangladesh.¹³

Add to this “The Alternative Power and Energy Plan for Bangladesh,” a meticulously researched proposal for Bangladesh to make a transition to a 100% renewable energy path by 2050.¹⁴ released (both in English and Bangla) in 2017 by the National Committee to Protect Oil, Gas, Mineral Resources, Power and Ports, under the leadership of Professor of Economics at Jahangirnagar University Anu Muhammad.

But the potential is barely tapped. The earlier proposed target of generating only 10% of its power from renewable resources by 2020 was a gross underestimate of the potential. Even at that, with barely 4% of the country’s current total energy production generated from renewable sources, the government failed to meet the target. Add to that, inefficiency, corruption and a lack of both transparency and accountability. At COP26, Prime Minister Sheikh Hasina announced, “We hope to have 40 percent of the country’s energy from renewable sources by 2041.”¹⁵ Indeed, this is a promising step, awaiting action and performance.

Fortunately, mainly due to anti-fossil fuels and pro-renewables demands from civil society including environmentalists, academics, educators, scientists, public officials, NGOs, businesses, entrepreneurs and journalists, as well as expatriate Bangladeshis and other supporters around the world, the need for a transition to a paradigm-shifting renewable energy future is gaining ground.

The world is realizing that, no matter how you dress it, cover it up, propagandize it, or kick it, you simply cannot make a dead horse run. A growing number of banks and other financing agencies will not finance coal-fired power plants and insurance companies will not take the risk of insuring them. Globally, an increasing number of coal-fired power plants have been shut down or are being slated to shut down. Predictably, as coal production dwindles and coal-

fired power plants are shut down or face deadlines while many world economies remain entrenched in the fossil-fuel path, there'll be a desperate demand for coal, even some desperate boost in coal production. But that's short-term, at best. The Age of Coal is over, with a lingering legacy. Period. In short, the empire of "King Coal," the main fuel behind the beginning of the Industrial Revolution in the 18th century, then spreading worldwide, is shrinking and the King is on his death bed.

There is a growing global awareness that fossil fuels have already lost the economic battle to a rapidly expanding renewable energy market. Coal's losing economic battle against renewable alternatives, combined with diminishing international financial institutions' support for coal production and unwillingness of insurance companies to take the risk of insuring coal-fired plants, is also impacting Bangladesh. It is compelling the government to move away from coal. At first as a proposal in November 2020,¹⁶ then, in June 2021, as a decision to cancel 10 out of 18 of the country's planned coal plants due to environmental, climate, and financial concerns.¹⁷ Until this time, the government has been aggressively pushing for a series of coal-powered plants across the country, which would intensify carbon emission and pollution. So, the decision is a good sign. However, by still planning to construct the rest of the coal plants, and to compensate for the cancelled ones, shifting mainly to liquefied natural gas (LNG) and petroleum for electricity generation, the country remains entrenched in the fossil fuel path. This simply means *choosing one disaster over another*. As Jonathan Buonocore, an environmental health researcher at the Harvard T.H. Chan School of Public Health, puts it, "Swapping out one combustion fuel for another is not a pathway that's going to get us to a healthy energy system."¹⁸

Furthermore, against global opposition, the government still plans to complete the construction of a 1320-megawatt coal-fired power plant in Rampal Upazila in Bagerhat District of Khulna. In charge of the project is BIFPCL (Bangladesh India Friendship Power Company Limited), a 50:50 joint venture between India's

state owned National Thermal Power Corporation (NTPC) and Bangladesh's Bangladesh Power Development Board.(BPDB)

According to multiple scientific and environmental analyses, the Rampal plant will have disastrous consequences on both the economy and ecology of the Sundarbans, the largest mangrove forest in the world, an officially declared Reserve Forest since 1875, sanctuaries to be protected under several wildlife preservation acts both in Bangladesh and India, and (both the Indian and Bangladeshi portions) an UNESCO World Heritage Site of Outstanding Universal Value (OUV), declared in 1985 and 1997, respectively.¹⁹

The Sundarbans are a natural protective barrier—enduring over centuries—against cyclones, floods, sea storms and, more recently—rising sea levels due to global warming, to which Bangladesh is especially vulnerable. But the Sundarbans' own survival is now threatened by the rising sea level due to global warming.²⁰

Also, the Rampal coal plant is a high-cost, high-carbon and high-pollution plant that has no adequate mechanisms to prevent mercury contamination of the aquatic food chain, toxic coal ash spills into the Passur River, and worsening the pollution level of the air that millions of people breathe.

The Sundarbans provide a livelihood for 3 million people, including honey collectors, fishermen, woodcutters, roof thatchers using golpatas, and mat weavers using grass. They live mostly in the surrounding villages. There's also a small population of gypsies, living in their boats. Poverty alleviation is a sustainable development goal (UN-SDG), but the Rampal plant, as a threat to their livelihoods, is a violation of their human rights to economic survival and a healthy environment.

Biodiversity loss, too, is a part of the Sundarbans' history, and it's a growing threat. The International Union for Conservation of Nature (IUCN) reported that 1,619 animal species, including the Asian rhinoceros and marsh crocodile, have become extinct from the Sundarbans (IUCN 2015). The Sundarbans and its adjacent areas are one of the major sanctuaries of two globally endangered river dolphins, Ganges River Dolphin and Irrawaddy Dolphin which

will be affected by the coal plant. The study, titled “Combined effects of climate change and sea-level rise project dramatic habitat loss of the globally endangered Bengal tiger in the Bangladesh Sundarbans” has predicted that the Sundarbans’ iconic “Royal Bengal Tigers” could become an extinct species within 50 years, especially from the Bangladesh part due to climate change.²¹

Because of its thriving greenery absorbing huge quantities of pollution, while releasing oxygen to the entire region, the Sundarbans has been called “The lung of South Asia.”

To take one critical lesson from the coronavirus pandemic experience—the end of which we have not seen yet—disrupting the ecology and biodiversity of the Sundarbans also poses the threat of outbreaks of new infectious zoonotic diseases and deaths.

Bangladesh’s official justification for the Rampal plant—as well as for fossil fuels in general—has been riddled with political demagoguery, autocratic decision-making, propaganda, corruption, fabrication, contradictions, threats, ineptitude in addressing the potential catastrophic consequences of the power plant, disregard for scientific reports, a lack of transparency, a lack of accountability, a blatant dismissal of public opinion, refusal to engage in dialogue with civil society and including civil society input, aggressive lobbying, disregard for the requirement of the completion—or manipulation—of the Strategic Environmental Assessment (SEA) for the region from the UNESCO World Heritage Committee, a misconceived notion of *sustainable* development, and severely lacking education in the advancements of renewable energy technologies.²²

The government officials or spokespersons keep rehashing “clean coal,” an oxymoron and which the National Committee for Saving the Sundarbans of BAPA calls a “dirty lie.” Furthermore, the officials keep insisting on unsubstantiated and compartmentalized justification of using “ultra-supercritical technology “ for its *comparative* advantages—such as higher efficiency and less pollution—as an answer to the environmental risks and impacts associated with the Rampal plant.²³ While the use of ultra-supercritical technology has set a standard in modern coal plant design, the comparative advantages are not sufficient to

compensate for the fundamental disadvantages and critical consequences of coal plants. That's why an increasing number of countries, including Germany and the UK, who have been heavily dependent on coal and who are at the forefront of technological development, are moving away from coal and transitioning toward a 100 percent renewable energy future.

There's also a bitter irony at play here. Emphasizing the critical significance of protecting the Sundarbans, on July 16, 1972, in his Tree Plantation Week inaugural speech at Suhrawardy Udyan in Dhaka, Bangladesh's first President and later the Prime Minister Bangabandhu Sheikh Mujibur Rahman (1920-1975) said:

“আমরা গাছ লাগাইয়া সুন্দরবন পয়দা করি নাই। স্বাভাবিক অবস্থায় প্রকৃতি এটাকে করে দিয়েছে বাংলাদেশকে রক্ষা করার জন্য। বঙ্গোপসাগরের পাশে দিয়ে যে সুন্দরবনটা রয়েছে এইটা হলো বেরিয়ার। এটা যদি রক্ষা করা না হয় তাহলে একদিন খুলনা, বরিশাল, পটুয়াখালী, কুমিল্লার কিছু অংশ, ঢাকার কিছু অংশ এ পর্যন্ত সমস্ত এরিয়া সমুদ্রের মধ্যে চলে যাবে এবং এগুলো হাতিয়া, সন্দ্বীপের মতো আইল্যান্ড হয়ে যাবে। একবার যদি সুন্দরবন শেষ হয়ে যায়—তো সমুদ্র যে ভাঙন সৃষ্টি করবে সেই ভাঙন থেকে রক্ষা করার কোনও উপায় আর নাই।...”

(“We did not create Sundarban by planting trees. Nature has done this on its own to protect Bangladesh. The Sundarban which exists along the Bay of Bengal is a barrier. Unless it can be protected, then one day some parts of Khulna, Barisal, Patuakhali, Comilla, some parts of Dhaka—all these areas will go under the ocean and will turn into islands like Hatia and Sandip. If Sundarban disappears, the havoc of erosion that the ocean will unleash, there'll be no way to survive it.”)²⁴

But under the current ruling party, the Awami League, of which Bangabandhu Sheikh Mujib was a founding member and a leader, and now headed by his daughter, Prime Minister Sheikh Hasina, the visionary warning of Sheikh Mujib seems to have no meaning and the Sundarbans face an unprecedented

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threat to its survival. Consequently, threatening the survival of Bangladesh, as well.

It's also a concern that Bangladesh has ventured into building a nuclear power plant. The Russian-made 2.4 GWe, now costing \$12.65 billion (with a 90% loan from the Russian government), is under construction in Rooppur village in Pabna. At the time of the signing of the Memorandum of Understanding (MoU) in May 2009, the construction cost announced by the government was between \$1.5 billion to \$2 billion for one 1,000MW plant. The construction period was estimated at least five years.²⁵

This is happening at a time when an increasing number of the countries with nuclear power plants—Austria, Belgium, France, Germany, Italy, the Netherlands, the Philippines, Sweden—are phasing them out or minimizing dependency on them, both as economically and environmentally disastrous technologies, while also facing the enormous costs of decommissioning plants and storing nuclear waste—for which no permanent solution has been found while accumulation continues to pile up and the temporary storage facilities run out of space. The most touted propaganda that burying nuclear waste underground in “secure” capsules or other containers, in deep geological repositories, is a permanent solution to waste storage is reductionistic and shortsighted and not a permanent solution.

The attempt to phase out nuclear power (or fossil fuels) is not easy, especially if a country is deeply entrenched in this path, and the tendency—fueled by pressures and propaganda by those with a vested interest—to revert back to that dependency can take the upper hand. This point—or warning—came through clearly during the COP26 Climate Change Conference by falsely propagandizing nuclear power as “zero-carbon” or “carbon-free” and, thereby, a viable alternative to coal.²⁶

This tendency to divert, or regress, to nuclear power also raises a fundamental question: so deeply entrenched into the fossil fuel-nuclear path, are the “developed” countries even capable of transitioning out of it without further catastrophic collapse—the evidence of which is surfacing daily? What are the ramifications of this possibility not only for the “developed” countries themselves,

but also for the world? As we keep exploring for solutions, from a holistic perspective, these questions must be addressed. And if we *choose*, for it is a choice—both as a country, as well as a global community—not to succumb to these questions, then together we must expedite the transition to renewables much faster than ever—a loud and urgent message following an overall assessment of the accomplishments of COP26 Climate Conference. And that must include no further entrenchment into the unsustainable and dead-end nonrenewable fossil fuel-nuclear energy path.

Let's look at some of the nuclear legacies—off the headlines or out of sight, but continuing to be both deadly and costly, nevertheless. Nuclear advocates and propagandists will tend to dismiss these legacies as somethings of the past, relevant to traditional plant technologies and designs, etc. But let that not confuse or deceive us: in spite of all the modifications and innovations, the inherent risks and problems with this technology remain unsolved.

The Three Mile Island nuclear power plant partial meltdown in the USA in 1979—the impact of which continues to haunt today;²⁷ the 1986 Chernobyl disaster due to a reactor explosion in Ukraine where radioactivity is still circulating, fires burning, and a huge section of the country remaining indefinitely uninhabitable as the radioactive “Exclusion Zone”;²⁸ Fukushima Daiichi nuclear disaster in 2011 continues with the latest report of Japan's decision to dump more than a million tons of radioactive water into the Pacific Ocean in two years.²⁹ In the meantime, reported or suppressed—a string of nuclear accidents or near-accidents, radioactive spills, theft or disappearance of the by-product and bomb-making material like plutonium: the writing is on the wall.

(Reiterating in this context) Nuclear advocates desperately push for nuclear power plants through propaganda, ornamental modifications, Small Modular Reactors (SMRs), innovation, claiming less waste production, and reductionistic rationalization—such as nuclear power is “zero-carbon” or “carbon-free”—which is not true. Less emission of carbon, compared to fossil fuel powered plants, does not make a nuclear power “zero-carbon” or “carbon-free.” As the physicist and systems

theorist Fritjof Capra and Pier Luigi Luisi, Professor of Biochemistry at the University of Rome 3, put it: "Nuclear energy creates significant greenhouse gases and pollution. When the entire fuel cycle is considered, a nuclear plant emits 27% of the CO₂ emitted from a coal plant. Within only one or two decades it will produce as many emissions as conventional sources of energy, as the concentration of available uranium ore declines and uranium becomes more and more difficult to extract and refine."³⁰

The big push and propaganda for SMRs minimize or avoid questions such as: what are the consequences of mass production (which would be necessary to make them viable) and widespread dissemination (touted as an advantage) of these reactors—in terms of less waste from each but what about the total accumulation from all, safety and security, and cost (economic, social, medical, political and environmental)? On these and other grounds the Union of Concerned Scientists (UCS), in an aptly titled report, "Small Isn't Always Beautiful: Safety, Security, and Cost Concerns about Small Modular Reactors," concluded: "Unless a number of optimistic assumptions are realized, SMRs are not likely to be a viable solution to the economic and safety problems faced by nuclear power."³¹

Also, a European Union appointed committee of experts assessing the risks of nuclear power concluded: "While nuclear energy is consistently acknowledged as a low-carbon energy source, opinions differ notably on the potential impact on other environmental objectives, such as the environmental impact of nuclear waste."³²

A nuclear power plant—especially in a geographically small country with a high population density—fueling runaway costs, debt traps, nuclear waste, dependence on a nonrenewable fuel source, possibility of accidents, security threats, political tension, civil unrest, industrial murders, predictable environmental disasters—however rationalized, is playing with fire, putting the country's future at risk.

By entrenching itself into the fossil-nuclear path, Bangladesh—along with some other developing countries—is turning into a dumping ground for these technologies that are being rejected by an increasing number of industrially developed countries that are

simultaneously setting the goal of meeting 100% of their energy needs from renewable energy sources by 2050. But the government's rationalization of fossil-nuclear technologies strikingly lacks any significant knowledge or acknowledgement of the critical concerns associated with these technologies, as well as the global transition toward renewables. They keep parroting the same dated argument that "the developed countries are using them (fossil fuel-nuclear energy), so we must, too." Instead of forward-looking "think globally, act locally," it seems to be "think backward, dig deeper" into the dead-end path of nonrenewables.

Professor Anu Muhammad has been a leading voice against such destructive entrenchment:

If development means people's blood, their lives, their sufferings, if development means the destruction of people's shelter, biodiversity, rivers, and forests, we will continue to oppose this, will call on everybody in the world to make this opposition stronger, will create noise to bring a real change in development thinking. We must give strength to collective voices to bring real development vision in our political agenda.

As long as assault, land grab, eviction of people, and threats continue in the name of development, discontent will prevail. The government must change their attitude of hiding, twisting and denying facts, should move fast to conduct an independent inquiry to ensure exemplary punishment for the people responsible for killing innocent unarmed people in 2016 and 2021. It should also abandon its blind alliance with greedy interest groups. Finally, the government must scrap projects of mass destruction, projects with irregularities and corruption, and projects that are a threat to human livelihoods and the environment including the coal-fired power plants in Banskali and Rampal, and the deadly nuclear power plant in Rooppur.³³

As a relatively low energy consuming country, contributing less than 0.5 percent of global greenhouse gas emissions, Bangladesh cannot and should not be held solely responsible for tackling its

climate change problem, much of which is caused by the fossil fuel-intensive industrially developed countries, impacting the entire world. With this awareness, in recent years Bangladesh has raised, and gained, a voice on the world stage on behalf of the developing countries that are increasingly being impacted by climate change, at the same time, rightfully, demanding assistance from the international community to fight the crisis. On April 22, 2021, at the virtual Leaders Summit on Climate, convened by the US President Joe Biden,³⁴ as well as the COP26 Climate Summit in Glasgow, Scotland, in November 2021,⁵¹ Prime Minister Sheikh Hasina raised such a voice. As the Chair of The Climate Vulnerable Forum (CVF) and The Vulnerable Twenty—a global partnership of countries that are disproportionately affected by the consequences of climate change—she put forward four proposals: cut global carbon emission to limit temperature rise to 1.5 degrees Celsius; ensure the annual target of 100 billion US dollars, as committed by developed countries, to be spent equally between adaptation and mitigation measures; major economies, international financial institutions and private sectors to come forward for concessional climate financing as well as innovation; and focus on green economy and carbon neutral technologies with provision of technology transfer among nations. Furthermore, Prime Minister Sheikh Hasina has announced a national “Mujib Climate Prosperity Plan to help mobilise resources for the implementation of a new pathway to secure our future” by targeting climate resiliency by 2030.³⁵

These plans and proposals, rightfully, deserve support from the international community. Prime Minister Sheikh Hasina deserves both congratulations and appreciation for placing them on a global platform. But the moral legitimacy of that demand, as well as the possibility of the demand’s being responded to favorably by the international community, will rest on Bangladesh’s own national policy and practice to fight climate change and be a model for the world. To be that model it must urgently transition away from the fossil-fuel sources and transition to renewable energy. A demand from the civil society toward such a transition is growing louder, but a political, governmental will or commitment—both in *policy*

and practice—is still lacking, compared to what's urgently needed and possible to make the transition. The same criticism has been heard repeatedly on a global stage from activists at COP26 demanding governments and policy makers to expedite the global transition. Bangladesh can set an example.

On March 14, 2021, the government signed a joint agreement with the Japan International Cooperation Agency (JICA) to develop a master plan with “a vision to promote a low or zero-carbon transformation of the total energy supply and demand system.”³⁶ It's a welcome step that will be another test of the government's integrity, political rhetoric, accountability and ability to conceive and implement such a plan successfully and through an equitable partnership.

At the same time, it raises the question: if Japan is sincere about its commitment to a low or zero carbon transformation, then why is it investing in the economically and environmentally disastrous Matarbari coal plan—despite protest from environmentalists? At a protest rally jointly organized by Bangladesh Working Group on External Debt (BWGED) and Youth Net for Climate Justice, along with demanding to cancel the power plant project, the organizers also called for compensating locals of Matarbari in Cox's Bazar for environmental pollution, providing proper rehabilitation, and setting up a solar or wind power plant there.³⁷

The same drama is being played out in regard to the under-construction Banskhalī Coal Power Plant project in Chattogram. In June 2021 One hundred twenty-nine individuals and 74 organizations from 21 countries including Bangladesh wrote a letter to Chinese Minister of Commerce Wang Wentao calling upon him to withdraw and end provision of finance and technical support for the project. They also urged all companies involved to withdraw support from the project. Among the signatories were advocate and human rights activist Sultana Kamal, president, Bangladesh Poribesh Andolon (BAPA); Shaheen Anam, executive director, Manusher Jonno Foundation (MJF); Dr Zafrullah Chowdhury, health rights activist and trustee, Gonoshasthaya Kendra; Khushi Kabir, coordinator of Nijera Kori; Anu Muhammad, Professor, Department of Economics, Jahangirnagar University;

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and Syeda Rizwana Hasan, chief executive, Bangladesh Environmental Lawyers Association (BELA).

The letter pointed out how such support contradicts President Xi Jinping's speech at the second Belt and Road Forum in 2019 where he said, "We need to pursue open, green and clean cooperation. We may launch green infrastructure projects, make green investments and provide green financing to protect the Earth which we all call home," and what, in February 2021, Economic and Commercial Counselor (ECCO) of China in Bangladesh said in a letter to the Bangladesh's Ministry of Finance stating that "the Chinese side shall no longer consider projects with high pollution and high energy consumption, such as coal mining and coal-fired power station."

Especially due to the autocratic imposition of power plants, typically the projects sites around the country teem with clashes with the local population, political tension and violence. Calling the Banskhal Coal Power Plant project "A Blood-coloured BRI project", the opponents report, "Since the beginning of the project in 2016, 12 people have lost their lives, more than 100 got injured and harassment cases have been filed against over 6,000 workers and villagers in three different incidents around this power plant."³⁸

In the face of the borderless catastrophic consequences of not transitioning to a renewable energy path, we need to collaborate and welcome international cooperation, for mutual benefit. At the same time, it's critical that we remain on the alert that such cooperation does not provide inroads for dumping onto Bangladesh technologies that are being rejected in other countries, including their own. As it is obvious with the fossil fuel-nuclear technologies in Bangladesh, with such dumping come inroads for power and control of the dumping countries—or multinational corporations who own those resources—into the national fabric. Energy being a lifeline of the economy, such external control also leads to sacrificing Bangladesh's revolutionary potential for energy independence through renewable energy, and modern-day revival and expansion of techno-colonialism.

The path to so-called "Development" that's fossil fuel-nuclear based, even with an economic boom, ultimately, is not only both

reductionistic and short-sighted, but also suicidal—*both* economically and environmentally. Furthermore, such “Development” practices are in gross violation of the UN Sustainable Development Goals (SDGs), which require that economic development and environmental conservation be mutually enhancing factors, and not at the expense of each other.

“Development”, or growth, to be *sustainable*, is a *holistic* process of going forward, not backward; it’s progress, not regress—what the fossil fuel-nuclear power-based “Development” or “Progress” implies. And we want development—development that’s sustainable; we want to make progress—by going forward; and we want to be energy secure to fuel development—energy that’s renewable, economically and environmentally advantageous—which Bangladesh has in abundance—practically untapped!

We cannot, or need to, turn back the clock, nor should we underestimate the benefits of the economic progress or development achieved thus far. But—at this celebrative juncture of the country’s 50th year since its blood-drenched birth—to go forward, to continue to make economic progress or development that’s sustainable, and to fuel it with the appropriate energy sources, we must think holistically and reevaluate the past and reject the destructive and dead-end fossil-nuclear energy path; put a moratorium on further entrenchment into this path, combined with disincentives such as reduction of subsidies for nonrenewables and a progressive carbon tax and cap on carbon production; and chart a new path by urgently tapping into Bangladesh’s revolutionary potential to fuel the transition to a renewable energy future that’s economically prosperous, environmentally congruent, healthy, equitable and sustainable. It’s a responsibility for both the government and civil society. In the best interest of the country, it behooves us to engage in a participatory and transparent dialogue to act on that responsibility with the utmost urgency. Energy is the lifeline of the economy. The choice Bangladesh makes today will define the country’s future.

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ANALYSIS BETWEEN POWER DEVELOPMENT PLANS AND PROPOSED MITIGATION ACTIONS IN THE UPDATED NATIONALLY DETERMINED CONTRIBUTIONS (NDC) OF BANGLADESH FOR THE POWER SECTOR

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Abstract

Bangladesh submitted an updated Nationally Determined Contribution last August. In the updated Nationally Determined Contribution (NDC) of Bangladesh, the country proposed reducing 43.74 Mt CO₂e (combined scenario) in the power sub-sector by 2030 which is about 48.9 percent of the total emission reduction targets. To achieve those reduction targets, Bangladesh also proposed some mitigations actions – implementation of 911.8 MW renewable-based new power plants in the unconditional scenario and 5026 MW renewable-based new power plants in the combined scenario by 2030. Based on the current policies, Bangladesh has the potential to reduce 9.10 Mt CO₂e emissions by 2030. While the Policy in Action scenario complies with the unconditional scenario of NDC, the combined scenario requires some significant interventions. Bangladesh will fall 34.64 Mt CO₂e emissions short of the target proposed in the combined scenario based on the current power development plans.

Keywords: NDC, Power Development Plan, Renewable Energy, Clean Energy, Emission Reduction

BACKGROUND OF THE STUDY

“Paris Agreement” marks the historic achievement in response to climate change. According to the agreement, global leaders agreed to keep the global average temperature to well below 2°C and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels. Parties agreed on communicating successive emission reduction targets in limiting the global temperature rise. All parties to the agreement will come out with an enhanced ambition every five years (e.g. 2020, 2025) regardless of their respective time frames. Bangladesh submitted an updated Nationally Determined Contribution (NDC) in August 2021 according to that.

Bangladesh Power Development Board (BPDB) is responsible for planning and developing power infrastructure in Bangladesh and the power sector is guided by Power System Master Plans. Currently, the Government of Bangladesh (GoB) formulating a new power sector master plan. The last one was Power System Master Plan 2016 (PSMP 2016). Since PSMP 2016, there have been some strategic shifts in terms of the fuel mix in Bangladesh. Those strategic shifts are usually get reflected in the BPDB’s power development plan. Since the new power master plan is not ready yet, BPDP’s power development plan is the policy in action scenario of Bangladesh’s power sector.

The criticism for the first NDC of Bangladesh was that it wasn’t adopted in the national policies of Bangladesh. Now, the question is how will the just submitted NDC will be reflected in our country-level policies. This paper aims to identify the gap between the BPDB’s power development plan and proposed mitigation actions in the updated Nationally Determined Contributions (NDC) of Bangladesh for the Power Sector.

Two sets of gap analyses have been conducted in this paper: one in terms of renewable-based generation capacity additions and the other in terms of emission reductions. Both of them have been compared with the two scenarios of the NDC. The generation capacity addition data has been taken from the BPDB’s plans and

added annually to get the cumulative installed capacity of the power system of Bangladesh. The power plants that will expire in those years also have been deducted to get a more accurate projection. The target year for the submitted NDC is 2030, hence the projection has been also conducted till the year 2030. Estimation of emission has been conducted by multiplying the projected generation for each technology with the mean emission data for that technology based on literature.

NATIONALLY DETERMINED CONTRIBUTIONS (NDC) OF BANGLADESH

Bangladesh submitted an Intended Nationally Determined Contribution (INDC) in 2015 that become NDC after the Paris Agreement came into force. In the 2015 submission, Bangladesh proposed to reduce GHG emissions in three sectors: power, transport, and industry. An unconditional reduction of GHG emissions by 5% from the Business As Usual (BAU) scenario and a conditional – contribution assuming additional international support – reduction of 15% GHG emissions was proposed in these three sectors. The updated NDC (submitted in 2021) addresses additional sectors following the previous one. It covers Energy, Industrial Processes & Product Use (IPPU), Agriculture, Forestry, & Other Land Use (AFOLU), and Waste sectors. The energy sector includes Power, transport, energy use in industry, residential, commercial, agriculture, brick manufacturing, F-gases, and Fugitive emissions. The updated NDC proposed a 6.75% Greenhouse Gas (GHG) emissions reduction in unconditional and an additional 15.12% reduction in the conditional scenario by 2030 from the Business As Usual (BAU) level considering 2012 as the base year. While these reduction targets may appear similar to the previous one, the updated NDC of Bangladesh is a very ambitious one. In the revised NDC, Bangladesh proposed reducing 27.56 Million tonnes (Mt) CO₂e Greenhouse (GHG) emissions in a conditional scenario where it was 12 Mt CO₂e in the previous one. In the conditional scenario, it is now 89.47 Mt CO₂e where it was 36 Mt CO₂e before.

Table 1: Comparison of submitted NDCs of Bangladesh

Scenario	NDC 2015 (Mt CO ₂ e)	NDC 2021 (Mt CO ₂ e)	Comparison
Unconditional	12	27.56	Increased by 130%
Conditional	36	89.47	Increased by 149%

Sources: Ministry of Environment, Forests and Climate Change

The most ambitious target has been observed in the power sub-sector where Bangladesh is aiming to reduce about 43.74 Mt CO₂e emissions by 2030 in both scenarios combined.

Mitigation Actions for the Power sub-sector in the Unconditional Scenario

Bangladesh proposed reducing 8.01 Mt CO₂e emissions in the unconditional scenario for the power sub-sector. The country intends to develop new renewable-based power plants with a capacity of 911.8 MW in the unconditional scenario by 2030 as part of the mitigation actions within the power sub-sector. The technology-wise distribution of those proposed mitigation actions is given in table 2.

Table 2: Proposed mitigation actions in the unconditional scenario

Technology	Capacity (MW)
Solar PV	637.8
Wind	149
Biomass	20
Biogas	5
Hydro	100
Total	911.8

Sources: Ministry of Environment, Forests and Climate Change

Mitigation Actions for the Power sub-sector in the Conditional Scenario

Bangladesh proposed reducing an additional 35.73 Mt CO₂e emissions in the conditional scenario – contribution assuming additional international support – for the power sub-sector. The country intends to develop new renewable-based power plants with a capacity of 4114.3 MW in the conditional scenario by 2030 as part of the mitigation actions within the power sub-sector. The technology-wise distribution of those proposed mitigation actions is given in table 3.

Table 3: Proposed mitigation actions in the conditional scenario

Technology	Capacity (MW)
Solar PV	2333.8
Wind	597
Biomass	50
Biogas	5
Hydro	1000
Waste-to energy	128.5
Total	4114.3

Sources: Ministry of Environment, Forests and Climate Change

Mitigation Actions for the Power sub-sector both Scenarios Combined

Bangladesh is planning to establish 2972 MW Solar Photovoltaic (Solar PV), 746 MW Wind, and 1100 MW Hydro-based power plants in the combined scenario. In total, the country proposed developing 5026 MW new clean energy projects in the combined scenario of the updated NDC. Those projects are expected to be completed by 2030 and contribute to reducing 43.74 Mt CO₂e GHG emissions within the power sub-sector by the same year.

Table 4: Proposed mitigation actions both scenarios combined

Technology	Capacity (MW)
Solar PV	2972
Wind	746
Biomass	70
Biogas	10
Hydro	1100
Waste-to energy	129
Total	5026

Sources: Ministry of Environment, Forests and Climate Change

BPDB'S POWER DEVELOPMENT PLAN

According to the Bangladesh Power Development Board (BPDB), the installed capacity of the Bangladesh power sector is 22,066 MW till 13 December 2021. It will be around 52,273 MW in 2030 based on the current power development plan (10 January 2022 update). While the share of renewables will increase from the existing condition, still it will be very low (figure 1). In 2030, 82 percent of the installed capacity will be based on fossil fuel and only 7 percent from renewables (Figure 2).

If we look into the year-wise capacity additions of the power development plan, it is evident that priority has been given to fossil-fuel-based power plants. In this year (2022) alone, about 7,000 MW of fossil-fuel-based power plants will be added to the grid according to the plan.

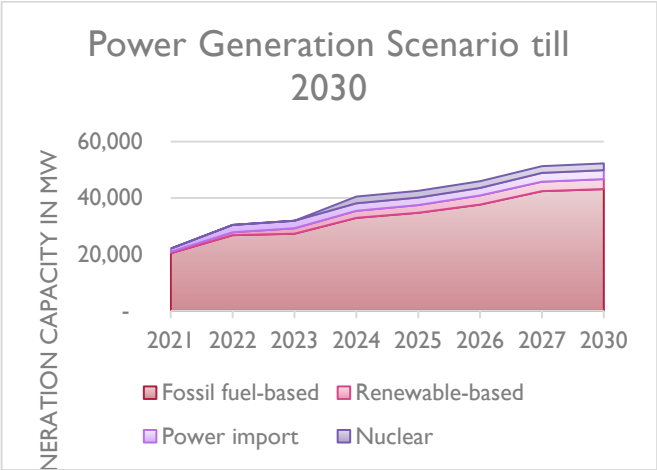


Figure 1: Power Generation Scenario till 2030 based on Power Development Plan,
Source: Bangladesh Power Development Board

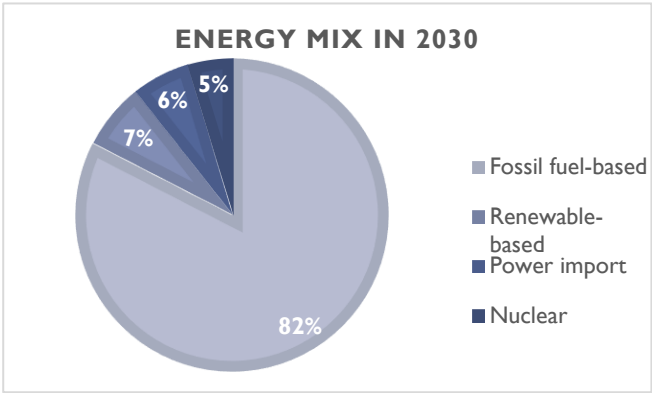


Figure 2: Energy Mix in 2030 based on Power Development Plan:
Source: Bangladesh Power Development Board

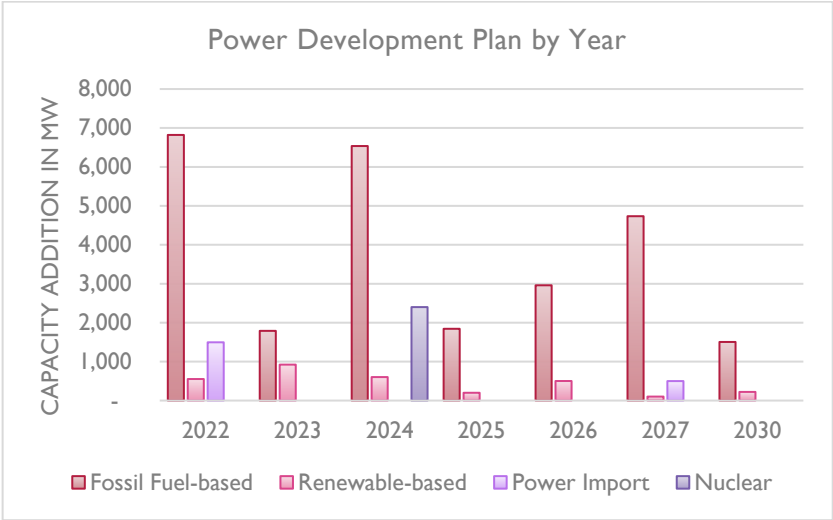


Figure 3: Capacity Addition in Power Development Plan from 2022 to 2030 : **Source: Bangladesh Power Development Board**

Fossil Fuel-based Capacity Addition

There are plans to build 26,189 MW new fossil-fuel-based power plants from 2022 to 2030. The majority of those planned power plants are gas-based (15,758 MW). While the whole world is planning to phase out the existing coal-based power plants, Bangladesh is planning to add another 9,611 MW coal-based power plants by 2030. There are still plans in action to add another 820 MW of oil-based power plants in the energy mix of Bangladesh.

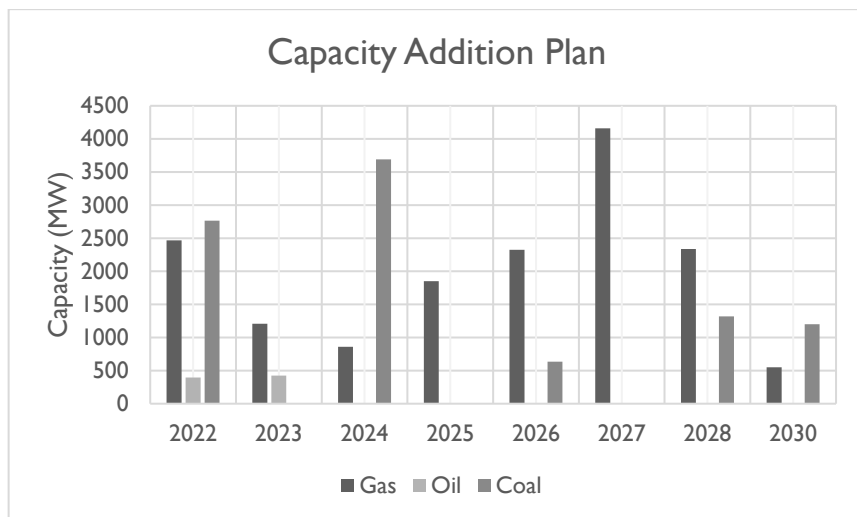


Figure 4: Fossil Fuel-based Capacity Addition in Power Development Plan from 2022 to 2030

Source: Bangladesh Power Development Board

Clean Energy-based Capacity Addition

In the capacity addition plan of the Bangladesh Power Development Board (BPDB), there are now projects to implement about 500 MW of Solar PV every year from 2022 to 2024. There is not much after 2026 in Solar PV. In fact, there is not much for any clean energy deployment after 2026. There is only 324 MW worth of clean energy projects in the pipeline for the years 2027 to 2030. One significant addition is the nuclear power plant that is to be added in the year 2024. The clean energy-based capacity addition in the power sector based on the power development plan from 2022 to 2030 is presented in figure 5.

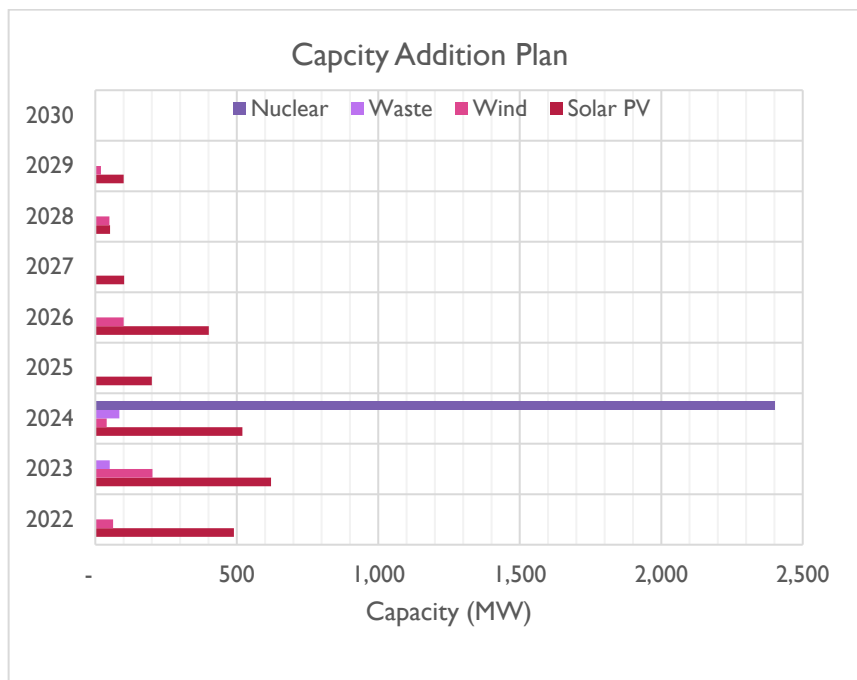


Figure 5: Clean Energy-based Capacity Addition in Power Development Plan from 2022 to 2030

Source: Bangladesh Power Development Board

GREENHOUSE GAS (GHG) EMISSION ANALYSIS

In the updated Nationally Determined Contributions (NDC) of Bangladesh, the country proposed reducing 43.74 Mt CO₂e in the power sub-sector by 2030 which is about 48.9 percent of the total emission reduction targets. 2012 was taken as the base year for emission calculation in the NDC. In the year 2012, the total emissions were 169.05 Mt CO₂e. The emissions in the power sub-sector were 20.98 Mt CO₂e and it was 12.41 percent of the total emissions in the base year. From 12.41 percent share in 2012 to 48.9 percent share in 2030 is a big leap in emission reductions that will require drastic measures.

Emissions in the Fiscal Year 2020-21

In the fiscal year 2020-21, Bangladesh generated 72,319 GWh¹ of electrical energy within the country. Associated emissions for those generated electricity was about 31.07 Million tonnes (Mt) CO₂e (estimated). The average emissions were about 430 t CO₂e per GWh electrical power generation. The average emissions for fossil fuel-based generation were 435 t CO₂e/GWh whereas for non-fossil fuel-based generations were only 34 t CO₂e/GWh. Through these non-fossil fuel-based generations (Solar PV and Hydro), the country avoided 0.33 Mt CO₂e of GHG emissions in that fiscal year.

Emission Reduction Potential

Bangladesh avoided about 0.33 Mt CO₂e emissions by producing 813 GWh of electrical energy in 2020-21. Based on the current power development plan of BPDB, Bangladesh will likely produce 24,744 GWh of electrical energy from clean energy sources in 2030. The emission reduction potential for those clean generations is about 9.10 Mt CO₂e on that year. This was estimated by comparing with the current average emissions from fossil fuel-based generation of Bangladesh. This is the highest possible emissions reduction potential as it was assumed that renewable/clean energy sources will get the priority in the merit order of the power plants.

Table 5: Emission Reductions Projection

	20 21	20 22	20 23	20 24	20 25	20 26	20 27	20 28	20 29	20 30
Emission Reduction Potential (Mt CO₂e)	0.33	0.63	0.95	8.58	8.66	8.93	8.97	9.04	9.10	9.10

Assumptions

¹ BPDB Annual Report 2020-21

The assumptions that have been taken in this paper are as follows:

- The emissions calculation for the fossil fuel-based generation has been conducted based on the average fossil fuel-based emissions of the fiscal year 2020-21.
- All the emissions calculation has been conducted with the mean emissions data for each technology based on literature.
- The merit order for generations from clean energy sources has been considered as the priority.

GAP ANALYSIS

Clean Energy Development

Unconditional Scenario :The BPDB plan complies with the conditional scenario of NDC in terms of total clean energy-based capacity addition by 2030. Although, some attention is required in biomass, biogas, and hydro-based power development.

Combined Scenario: Bangladesh proposed developing 2,972 MW Solar PV-based power plants in the combined scenario of NDC wherein the BPDB's plan 2,715 MW can be accounted for. There are about a 256 MW gap exists now. For wind power plants, the gap is now about 271 MW. While there are plans of installing new power plants based on Biomass, Biogas, and Hydro in the NDC, there are no plans for those technologies that can be found in BPDB's. A total of 5,026 MW renewable-based power plants are proposed in the combined scenario of the Nationally Determined Contribution (NDC) of Bangladesh. But only 3,326 MW can be found in BPDB's plan. The country still lacks about 1,700 MW to meet the global commitment it made in the updated NDC of Bangladesh.

Table 6: Gap Analysis of Clean Energy Development in the Unconditional Scenario

Technology	NDC_Unconditional (MW)	BPDB (MW)	Difference (MW)
Solar PV	637.8	2715.2	2077.4
Wind	149.0	475.0	326.0
Biomass	20.0		-20.0
Biogas	5.0		-5.0
Hydro	100.0		-100.0
Waste-to-energy		136.0	136.0
Total	911.8	3326.2	2414.4

Source: Ministry of Environment, Forests and Climate Change & Bangladesh Power Development Board

Table 7: Gap Analysis of Clean Energy Development in the Combined Scenario

Technology	NDC_Combined (MW)	BPDB (MW)	Difference (MW)
Solar PV	2,972	2,715	-256
Wind	746	475	-271
Biomass	70		-70
Biogas	10		-10
Hydro	1,100		-1,100
Waste	129	136	8
Total	5,026	3,326	-1,700

Source: Ministry of Environment, Forests and Climate Change & Bangladesh Power Development Board

EMISSIONS REDUCTION

If we consider the estimated highest possible emission reductions (9.10 Mt CO₂e) that will take place in 2030, Bangladesh will still fall short of about 34.64 Mt CO₂e emissions from the target proposed in the updated NDC in the combined scenario. Although in the unconditional scenario it appears that Bangladesh is on track.

Table 8: Emissions Reduction Gap

	Uncondi- tional Scenario	Combined Scenario
Emissions Reduction Proposed in NDC (Mt CO2e)	8.01	43.74
Emissions Reduction Potential (Mt CO2e)	9.10	9.10
Difference (Mt CO2e)	1.09	-34.64

Source: Ministry of Environment, Forests and Climate Change

CONCLUSION AND RECOMMENDATION

Lack of correlation among the policies has been a key problem in terms of policy implementation in Bangladesh. This is also evident if we consider these two policies (NDC and PDP). For the effective implementation of the NDC, the Power Development Plan must comply with that. We only have 9 years to implement our NDC targets, hence we have to start taking action now.

Three actions can be taken for the effective implementation of the NDC’s mitigation action targets for the power sector. Firstly, NDC targets have to be adopted in the national policies. For the power sector, it should be adopted in the currently formulating power master plan. Secondly, monitoring of these plans every year. The global stocktakes of the parties to the Paris Agreements will happen once every 5 years. If Bangladesh keeps relying on this only, the country is most likely to fall short of its targets. A yearly basis stocktake can be very effective here. The process for the first-ever global stocktake (2023) of the parties to the agreement is already started. The country's capacity development activities for conducting this stocktake started a few years back and UN Climate Change is taking care of that. We can take this first global stocktake as a learning opportunity and continue keeping a tab on our targets every year so that we are even better prepared for the next stocktake. Finally, a coordinated approach of all stakeholders in the

power sector. It has become a norm that our generation plants and grid infrastructures do not keep the same deadline. If we finish one a year ahead of the schedule and others don't, it doesn't make any sense. If we build a clean energy-based power plant in the future but cannot supply it to the national grid, it will not help in reaching the emission reduction targets.

As a Climate Vulnerable Forum (CVF) presidency, the revised Nationally Determined Contributions (NDC) of Bangladesh is somehow symbolic to all CVF countries. Implementation of the mitigation actions stated in the NDC is a matter of country image now. As one of the most climate-vulnerable countries of the world, Bangladesh needs to show the rest of the world that it is now or never!

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INTEGRATING TRADITIONAL AND MODERN SMART ADAPTATION PRACTICES FOR PRODUCING CROPS IN CLIMATE CHANGE HOTSPOTS OF BANGLADESH

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Abstract

Agricultural enterprises in Bangladesh are highly vulnerable to extreme and aberrant weather conditions. To face such threats of climate change farmers utilize their own knowledge or practices that varies for different geographies. To boost production several scientific innovations are evolved and disseminated by the service providers in recent times. However, literatures suggest that traditional local technologies offer solutions to numerous climate change impacts. The importance of such local technologies has not been assessed holistically from the perspective of climate-smart agriculture (CSA). Therefore, the aim of the study is to explore the prospects for promoting indigenous technologies along with the dissemination of recent innovations by extension agencies for sustainable food production as well as CSA. The study was based on the qualitative data collected from primary and secondary sources from climate hotspots of Bangladesh. Literature review, field visits, focus group discussions, stakeholder consultation etc are the major tools employed for collection of information. With emerging innovations or technologies by research institutions and universities and those were disseminated by extension workers, farmers are gradually benefitting with those technologies for their local production. Historically used age-old indigenous technologies for various climate-stressed hotspots of Bangladesh are also valuable for designing future direction of research. However, overuse of so-

called hybrid crop varieties marginalized the traditional varieties those have potential to combat weather adversities. Research institutions may take the proper research items from the farmers' traditional practices those observed at local level. However, negligible research, policy and extension supports are available for farmers to scale-up those local technologies. The study reports valuable findings of such traditional adaptations those practiced at local level in extremely climate-stressed areas of the country. The study, which has implications for researchers, practitioners and extension agencies promoting CSA, argues that although recent scientific innovations are available more areas should also be brought under local technologies if we want to combat the present and future climate change threats efficiently. The paper emphasizes best practices along with suitable genetic resources as well as modern innovations to enhance the application of indigenous and traditional ecological knowledge and technologies for achieving CSA.

Key words: Climate shocks and stresses, Climate-smart agriculture, Extension activities, Indigenous technology, Innovation, Local adaptation, Traditional practices

INTRODUCTION

Due to spatial geo-morphological setting, climate change intercepts all of the development sectors of Bangladesh. Among those, agriculture sector is under greatest risk as majority of workforce of Bangladesh is associated with it. About 47 percent of the total labour force employs in agriculture and the sector contributes 16 percent of GDP of the country (World Factbook, 2016). Agriculture in Bangladesh faces a variety of risks associated with climate change, such as erratic rains, flood, drought, tropical cyclones, sea-level rising, water logging, salinity, increased evaporation rates, higher temperatures (heat shocks), increased pests and diseases and changes in diseases and pest distribution ranges, and spatial shift in optimum growing regions, resulting in substantial yield losses (Hossain and Majumder, 2018). Additionally, the projected changes in climate will more

adversely affect the agricultural production in Bangladesh. The extreme weather events, including cyclone, floods etc are expected to induce food vulnerability to the already food insecure 60 million people (which includes 38% of total population) of Bangladesh (WFP, 2016) and this increases the cost of coping dramatically.

Weather aberration poses enormous threats throughout Bangladesh. Entire southern belt of the country is severely affected by tropical cyclone and salinity. In the south-western part salinity intrusion and water logging, monsoon flood in the central part, early or flash flood in the north-east and drought in the north-west are gradually increasing. These are causing increased vulnerability for agricultural production. The emergence of such risks calls for urgent, ambitious actions are to be implemented to ensure the resilience of Bangladesh agricultural sector for ensuring optimum production through climate-smart agriculture (CSA). There are numerous traditional technologies available in local level throughout Bangladesh and these have the potential to cope with adversities of climatic threats. Considering the climate change impacts, these technologies are valuable for present and future sustainability of agricultural production. Therefore, such indigenous measures need proper assessment to further escalate the scale of these practices for achieving CSA.

Climate change adaptation (CCA) is a context-specific action and the associated practices should be based on science, and incorporate knowledge of indigenous peoples and traditional innovations (FAO, 2017). CCA does not occur in isolation and it is an incremental process that can build upon a long history of previous adaptation (Burton, 2000). Evidence suggests that activity to combat climate change threat can be improved if CCA programmes integrate indigenous knowledge (Agrwal, 2010; Ajibade and Eche, 2017). With integrating mitigation avenue to CCA, the CSA is an approach that can transform and reorient agricultural systems for better management of climate change to ensure food security (Lipper et al., 2014). Nevertheless, the great challenge to expand agriculture production on shrinking land, as in Bangladesh, the CSA could address the food, fiber and fuel

issues which are prime needs for the growing population. Thus, the CSA can contribute to poverty reduction and economic development of the country. It also focuses to enhance the productivity and resilience of ecosystem functions for conserving natural resources through minimizing the trade-offs therein. CSA offers befitted and context or location-specific solutions for managing climate change through implementing state-of-the-art policies and financing measures. The concept of CSA is still evolving and there is no 'one-size-fits-all blueprint' for how it might be pursued.

To feed huge and over increasing population, agricultural sector of Bangladesh has adapted to modern technologies and high yielding cultivars as paradigm with green revolution. Consequently, the country has reached to a mark for agricultural production since decades against the gradually reducing agricultural land @ 0.45 per cent per annum (FPMU, 2013), but at cost of huge climate change, environmental pollution, degradation of soil health and microbial biodiversity. Additionally, such chase mostly ignored the immemorially tuned locally used traditional technologies (Zaman, 2017). Though discover of many modern technologies during recent times, many climate change hotspots of the country did not get proper attention. Farmers of Bangladesh are struggling with climate change since year after year; therefore they have some own inventions or traditional technologies although the production per unit of area is not so satisfactory. Uses of such technologies are also declining rapidly since the pressure or introduction of modern technologies including so called hybrid crop varieties. The modern varieties are more susceptible to weather extremes such as flood, drought, high temperature, cold, fog, and pests. Thus, the modern crop varieties may not be properly adapted to the changing climatic conditions in many instances as substantiated by the production failure of some crops in recent times.

Mean temperature of the world is predicted to elevate from 0.5 °F to 8.6 °F by the end of the twenty-first century (IPCC, 2013). That means climate systems are continually changing and a suitable cultivar which disseminated once may not be suitable

over the wide range of time for future climate. Thus many modern crop varieties could not keep pace to continually changing climate especially increasing temperature. It requires fast release and dissemination of new cultivars by rapid breeding cycles along with seed systems that deliver new varieties to farmers quickly, and then just as quickly replace obsolete ones, keeping pace with the changing climate (Atlin et al., 2017). Farmers in many temperate regions have this access, due to competitive seed sectors that encourage varietal turnover, however it is hardly possible for most smallholder farmers in climate-vulnerable areas of the developing world like Bangladesh where cultivars selected thirty or more years ago, in a different climate (Atlin et al., 2017). Against this backdrop, utilization of traditional crop cultivars with indigenous technology may be a good alternative, where possible. Because traditional varieties proven as candidates to less sensitive to changing climate.

Traditional agriculture with indigenous knowledge's has potential in CCA and mitigation process, low CO₂ gas emission, pest management, low energy inputs, biodiversity conservation and sustainable production (FAO, 2010; Srivastava et al., 2016; Patel et al., 2019; Upadhaya et al., 2020). Thus, traditional agricultural practices have regained the increased attention worldwide as climate-smart approach (Singh and Singh, 2017). Indigenous farmers and local people perceive climate change in their own ways and prepare for it through various adaptation practices (Tripathi and Singh, 2013). Thus uses of traditional or indigenous knowledge and local genetic resources may play key role to adapt to climate change as the approach support CSA for sustainable food production (Singh and Singh, 2017). For designing befitted technologies to achieve CSA, the traditional or indigenous ones used by the local people should be scaled-up where climate shocks are more severe. However, practice of traditional agriculture in full spectrum could not provide sufficient agricultural products from continually decreasing cultivable land to over increasing population in Bangladesh.

Therefore, the study was carried out to explore the traditional or indigenous adaptations practiced at local level by the farmers

as well as recent advancement of agricultural innovations towards the CSA in Bangladesh. The output of the study will help researchers, policy planners and extension workers to redesign proper technologies befitted for agricultural practices in worst hit climate shock's areas of the country.

MATERIALS AND METHODS

The study was conducted in the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh during the period from 2012 to 2016. Qualitative method has been employed to collect the data from grass root level or local level. Focus group Discussion (FGD) meetings with victimized farmers or villagers from climate change hotspots throughout the country have been conducted (Awal, 2015a) to assess the indigenous and traditional knowledge of local people as well as use of modern technologies to combat or minimize the worst effect of climatic threats. The traditional knowledge can be defined as the knowledge and belief of dynamic practice, know-how or skill of local or indigenous people which socially and spiritually developed from their empirical observations and on interaction with ecological systems to use or manage the natural resources, and sustained and gained as a cumulative form of perception through cultural transmission over generations (Berkes, 2012; Nakashima et al., 2012). Indigenous people act as custodians or guardians or owners of traditional knowledge or traditional ecological knowledge. Indigenous knowledge is essential for climate change adaptation process as it focuses on elements of significance for local livelihoods, security and well-being (Nakashima et al., 2012). Whereas the technology in agricultural point of view means the application of techniques to control the growth and harvesting of plant and animal products. It is also regarded to be a contributing factor to changes in the "structure" and organization of agriculture in developed countries like Bangladesh. Direct field visit to observe the promising or best agricultural practices against the climate shocks and stresses was conducted. The term 'best practices' may be referred to a practice that, upon

evaluation, has demonstrated success in contributing to the goal that it was set out to achieve, and that can be replicated providing that a certain set of predetermined conditions are fulfilled (FCCC, 2013).

Stakeholder consultation meetings were conducted with the experts working at Ministry of Agriculture, Ministry of Disaster Management and Relief, Ministry of Water resources, and Ministry of Environment and Forestry (Awal, 2014; Awal and Islam, 2020). Review of literatures and document analysis from hard copies and online sources, and personal communication to resource persons whenever necessary were carried out. In order to filling-up the gaps or scaling-up the indigenous knowledge towards the CSA, examples of available modern scientific innovations including stressed-tolerant modern crop varieties which have promising characteristics to fit and link with the local adaptation practices were explored. It can be mentioned that, CSA has three pillars or objectives: (1) sustainably increase productivity (production), (2) enhance resilience (adaptation), and (3) reduce/remove greenhouse gases (mitigation). The practices are considered CSA if they enhance food security (production) as well as satisfy one of the other pillars, either adaptation or mitigation, of CSA (CIAT World Bank, 2017).

Invention can be defined as a discovery of new thought, method, idea or imagination that has never been discovered before. In contrast, innovation is the utilization of an invention in to a solution or new goods or service meeting the market demands. There are some other meanings of innovation like 'introducing something new' or 'as change that creates a new dimension of performance' etc. More likely, innovation may be defined as a mechanism by which society adapts to changing resource endowments, and which is in turn driven by social and cultural values (Chhetri et al., 2011). This study considered two major types of climate-induced technological innovation: (i) innovation of location-specific crop varieties in diverse growing seasons and regions of Bangladesh, and (ii) development of climatically appropriate location-based production techniques or practices.

RESULTS AND DISCUSSION

Adaptation of agricultural practices to climate change stresses

Due to the worst experience from recurrent and multiple climatic stresses the farmers of Bangladesh are resilient enough who practice some local adaptations in agricultural production which vary from location to locations. Most of those adaptive strategies are addressed to reduce the negative impacts of slow onset disaster like water logging, salinity, drought etc. Some of those adaptation practices are mentioned.

Adaptation to water logging

Historically, some places like Barisal, Gopalganj, Jalokathi, Pirojpur etc in southern region of Bangladesh are waterlogged or swampy. However, from beginning of the twenty first century, many low elevated pockets (locally called *Beel*) of south-western districts like Khulna, Jessore and Satkhira became waterlogged due to a variety of reasons like natural changes in river flow, increased sediment in riverbeds due to reduced sediment deposition on floodplains protected by embankments, etc (Awal, 2014; Awal and Islam, 2020). Local people are being utilized such water congested land for production purposes using following techniques:

Floating agriculture/garden/farm or natural hydroponics: A floating bed is constructed with the help of water hyacinth and bamboo where different types of leafy vegetables, lady's finger, tomato etc they produce (Plates 1-2) (Haq et al., 2004; CDMP, 2009; Awal, 2014). It is revealed that floating bed farming for vegetable production has huge potentials to mitigate problems against flood or water congestion where land remain submerged for most of the time in a year. Such types of *soil-less* agriculture (locally known as *Baira*) are also common in similar types of landscape exist in many regions like Lake Inle in south-eastern Myanmar, the Tonle Sap in Cambodia, but in different, traditional ways (Huu et al., 2013; Ferguson, 2014; Htwe et al., 2015).

Although decomposed plant debris's supply nutrients to the growing crop plants, few specific nutrients as required for some crops can be applied. Therefore, it warrants experimental work whether the nutrients supplied from floating bed is enough for the crops grown.



Plates 1-2: Floating farms for vegetable production in submerged areas of Bangladesh. Photo Credit: Dr. Abu Wali Raghieb Hassan (personal communication).

Kandi or sorjan method of crop production: Crops like potato, cabbage, sugarcane, arum, banana etc can be grown on alternatively raised beds and deep sinks (Plate 3) (CDMP, 2009; Awal, 2014). HYV's of crops can be incorporated into the system along with trapping fishes with maximum economic profitability. Better nutrient management should also be considered, if any



Plate 3: Kandi or sorjan method of crop production in submerged areas of Bangladesh. Photo Credit: Dr. Abu Wali Raghieb Hassan

Cultivation of tall statured crops: Farmers utilize some local rice cultivars like Sadamota, Motabalam, Muthamota, Lalmota etc characterized with tall cum especially at seedling stage. They transplant the field with high density of old-age seedlings (45 to 60 days). Recently, Bangladesh Rice Research Institute (BRRI) has recommended two submergence tolerant rice varieties like BRRI dhan76 and BRRI dhan77 having taller seedling and plant height for southern tidal flooding ecosystem of Bangladesh (Barua et al., 2017). Some other crops or crop cultivars having submergence tolerance features like sesame (cv. BARI til3), kenaf (cvs. HC2, HC3 and HC95), jute (cvs. BJRI deshipat5 and BJRI deshipat8), sugarcane (cvs. Isd39 and Isd40), dhaincha (*Sesbania*) etc can be cultivated in waterlogged areas provided that the sowing or planting time as well as initial establishment period of those crop remains water free.

Dewatering for crop establishment: Water is drained out for rice cultivation in dry or *Boro* season (Plate 4). It is an expensive strategy for rice production and may fail on heavy downpour. Therefore, windmills can be used to pump water from congested areas (Wikipedia, 2019). Another strategy for downing water table is groundwater recharge (Singh, 2011). Both strategies require government intervention.



Plate 4: Draining out of congested water of a polder to cultivate *Boro* rice in Tala upazila of Satkhira district. Photo Credit: Author.

Dyke farming/gher farming: Farmers elevate and widen the border of waterlogged land or low-lying areas making the shape as a *gher* (like a pond or lake) for fish culture and boundary is utilized for horticultural crop production like banana, country bean etc (Plate 5). The venture intends to utilize the waterlogged lands with maximum economic profitability and to reduce vulnerability by using *sifting agriculture*. Duck rearing can be incorporated into the dyke farming.



Plate 5: Some year-round water logged lands of Keshabpur upazila of Jessore district are converted to fish culture by elevating and widening the periphery with soil brought from same land. The periphery is commercially used for bean cultivation. Photo Credit: Author.

Alternative sources of food: Many people or households altered livelihood from existing rice cultivation to catching fishes together with many other floras like water lily and faunas grown or propagated in the waterlogged areas (CDMP, 2009).

The acceptance of above mentioned practices within the local people in the coastal areas of Bangladesh has proved their success. The practices are continually scaling-up to a great extent with emerging of recent innovations and extension activities from GO and NGO bodies. However, maximum economic profits can be achieved by incorporating the crops with HYV's along with better nutrient management into the systems.

Adaptation to salinity

Southern coastal areas of Bangladesh constitute about 2.5 million hectares equivalent to 25 percent of the total cropland of the country. More than a million hectare of land from that coastal area is affected by salinity with various magnitudes, resulted very poor utilization of land (Karim et al., 1990). 'Local transplanting *Aman* rice–Fallow–Fallow' is the major cropping pattern used by the farmers in coastal area. The people of those areas have been cultivating saline tolerant (low to moderate levels) local rice varieties like Jotabalam, Ashfall, Ghunshi, Benapol, Sadamota, Lalmota, Muthamota, Tekshoil, Kutepatnai, Tikepatnai, Birlpala, Nuneshwer, Nonakhochhi, Raenda, Burimonteshwer, Dudkalam etc for more than hundred years. Beside rice cultivation, local people have adopted some coping strategies like sheep and duck rearing, shrimp cultivation, shrimp-rice-cultivation, reed cultivation, cultivation of prawn *renu*, golpata and salt production etc since ages. However, recent scientific innovations and extension works have suggested following practices in the areas:

Varietal intervention or cultivation of salinity tolerant crop varieties: Main crop in the coastal salinity intrusion areas of Bangladesh is *Aman* rice which entirely depends on monsoon rain when salinity concentration gets minimum level. Some moderately salinity tolerant HYV rice like BR23, BRRI dhan40, BRRI dhan41, BRRI dhan53, BRRI dhan54, BRRI dhan78 etc are recommended for *Aman* season (Table 1). In contrast, when salinity level or concentration getting higher in *Boro* season onward from December/January where recommended rice varieties are BRRI dhan47, BRRI dhan53, BRRI dhan55, BRRI dhan61, BRRI dhan67, BINA dhan8, BINA dhan10 etc. Salinity tolerant wheat cultivars like BINA wheat1, BARI gom25 etc are also recommended for those areas. Among the fruit trees guava, hog plum (*Spondias mombin*; cvs. BARI amra1 and BARI amra2), Indian jujube (*Ziziphus mauritiana* Lam.) etc can survive in saline and waterlogged areas.

Cultivation of sunflower, sesame, mungbean, grass pea, watermelon (hybrid), groundnut etc is also common and getting

popularity as cash crops during dry season in the areas (Plate 6) as these crops withstand salinity effects to some extent. However, local people don't care to select the cultivars of those crops. By cultivating salt-tolerant varieties with high yielding characters (Table 1), CSA can be achieved.



Plate 6: Cultivation of sunflower in salinity affected Soronkhola upazila of Bagerhat district during dry season from December to April. Photo Credit: Author

Table 1: Some salinity- and drought-tolerant crop varieties suitable for special geographies of Bangladesh (BINA, 2013; Gurung and Azad, 2013; Hassan and Shaw, 2015; BRKB, 2020; Digital Herbarium: <http://dhcrop.bsmrau.net/>)

SL No.	Crops/ Crop groups	Crop varieties	
		Salinity-tolerant	Drought-tolerant
1.	^a Rice		
	Local varieties	Jotabalam, Ashfall, Ghunshi, Benapol, Sadamota, Lalmota, Muthamota, Tekshoil, Kutepatnai, Tikepatnai, Birpala, Nuneshwer, Nonakhochhi, Raenda, Burimonteshwer, Dudkalam	Sonashail, Batraj, Jhingashail, Malshara, Subondari, Hansraj, Biyanophul, Magurshahil, Randhunipagol, Chiniatab
	<i>Aman</i> season	BR23, ^b BRRI dhan40, 41, 53, 54, 73 & 78	BRRI dhan55, 56, 57, 66 & 71
	<i>Boro</i> season	BRRI dhan47, 53, 55, 61, 67, BINA dhan8, 10	BRRI dhan55
	<i>Aus</i> season	BRRI dhan55	BRRI dhan42, 43, 55 & 65

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2.	Other cereals		
	Wheat	BINA wheat1, BARI gom25	BARI gom26, 28, 30, 32 & 33
	Maize	Khoi buhtta and BARI hybrid maize5 & 9	BARI hybrid bhutta11, 12 & 13
	Barley	BARI barley4, BSH32 & 142	BARI barley5, 6
	Sorghum	Genotypes IS3158 & IS9745	Pahat (Indonesia)
	Foxtail millet	Genotypes BD881 & 897	
3.	Pulse		
	Mung bean	BINA mug6 & 8	BARI mug6
	Lentil	BARI masur5	BINA masur10
	Chick pea	BARI chola9	BARI chola5
	Grass pea	BARI khesari1 & 2	BARI khesari1 & 2
	Cow pea	BARI falon1	BARI falon1
	Groundnut	BINA chinabadam1, 2 & 6, Dhaka 1, BARI chinabadam8	ICGV93269 & 3232, BINA chinabadam4
4.	Oil crops		
	Mustard	M-27-E2-1-5, BARI sarisha9, 11, 12, 16 & 17, BINA sarisha5 & 6	BARI sharisa16, 17
	Soybean	n-b0-1, BARI soyabean6	BARI soybean5 and Sohag
	Sesame	BARI til3	BARI til4
	Sunflower	Hysun33 & 36	
	Safflower		BARI saf1
	Linseed		Nila
5.	Other crops		
	Jute	BJRI deshapat5 & 8, BJRI tossapat5	
	Sugarcane	Isd38, 39 & 40	Isd20
	Potato	Saikat, CIP102 & 139, BARI potato72 & 73	
	Sweet potato	BARI mistialo6, 7, 8 & 9	BARI mistialo8 & 9

^a*Aman, Boro* and *Aus* seasons designate the time where rice varieties which are planted in mid July, November-December and March-April, and harvested in mid November-December, March-April and mid June-July, respectively.

^bBRRI dhan40, 41, 53, 54, 73 & 78 refer to BRRI dhan40, BRRI dhan41, BRRI dhan53, BRRI dhan54, BRRI dhan73 & BRRI dhan78. The same concept is applicable for other varieties.

Agronomic practices: Mulching controls salinity by preserving soil moisture in soil profile by restricting capillary rise. Discontinuing soil capillary pores by ploughing top soil is also an acceptable exercise to control soil salinity (Gurung and Azad, 2013). Similarly, growing of cover crops (using dhaincha or *Sesbania*, for example) is also beneficial which is practiced in India. Transplantation of aged seedling is also an agronomic practice to minimize salinity effect as older seedling can tolerate salinity as compared to the younger ones especially for rice. More seedlings should be planted per hill to keep the plant density as normal under saline conditions allowing some plants to death. Continuous maintenance of 2-3 cm water level in paddy fields until milking is necessary when salt accumulated paddy fields are used for cultivation (Gurung and Azad, 2013).



Plate 7: Growing *Boro* rice in Khulna division using harvested rain water (in adjacent pond) during last monsoon. Nearby a vast land remains fallow due to lack of water and higher degree of soil salinity. The rice varieties are also saline tolerant: BRRI dhan47 (nearest), BINA dhan8 (middle), and then BRRI dhan28. Photo Credit: Author.

Rain water harvest for crop production: In few instances some farmers those have ponds in the locality harvest rain water during

monsoon rain which is utilized to cultivate crops in dry season when the degree of salinity goes higher (Plate 7). It requires special attention for replicating the practice to the wider number of farmers in the areas as most of the land remained fallow in the dry season.

Early sowing/planting of crops: Early established crops can utilize the residual soil water (non-saline) of previous monsoon. While the late sown crops miss this opportunity expose to higher salinity. Thus the profile water can be utilized for winter crop production if the crop seed are sown early of the winter season. Short duration or early maturing varieties are also beneficial to this system (Kabir and Sarker, 2019).

Cultivation of economic halophytes: Some selected halophytes those who survive in strong saline habitat can be grown. A facultative medicinal halophyte like *Salvadora persica* L. (Meswak), is identified for growing in highly saline habitats (up to 50 dSm⁻¹) in coastal and inland black soils of India (Rao et al., 2004). An alkaloid named 'Salvadoricine' and some resins are found in the bark of this halophyte. The seeds are good source of non-edible oil rich in C-12 and C-14 fatty acids having immense applications in soap and detergent industries. The growing plants also provide a niche for eco-restoration through environmental greening. Cultivation of salt tolerant forage grasses like *Dichanthium annulatum* and *Leptochloa fusca* are also practiced in some saline affected areas of India (Gurung and Azad, 2013 and references therein). Accordingly, Bangladesh can seek these opportunities, and the intervention needs special attention.

Crab aquaculture: Crab culture is a common adaptation in the areas where salinity concentration is so higher that's why crops could not cultivate (Plate 8). Crab marketing channel should be improved so that the associated people can ensure maximum profit. Advanced researches are also essential to promote/scale up the crab culture.

Adaptation to drought

The north-west Bangladesh especially the high Barind Tract that comprised Chapainwabganj, Naogaon, and Rajshahi districts has been experiencing extreme hot weather and frequent droughts due to erratic rain. Historically, the farmers of that area have been cultivating rice in three consecutive seasons with some drought-tolerant rice varieties like Sonashail, Batraj, Jhingashail, Malshara, Subondari, Hansraj, Biyanophul, Magurshahil, Randhunipagol, Chiniatab etc. Local people plant trees and shrubs to reduce accelerated evaporation (Zuberi, 1998). Digging ponds also facilitates to storage water for domestic and agricultural purposes (CDMP, 2009). Some drought-tolerant HYV rice like BRRI dhan42, BRRI dhan43, BRRI dhan55 and BRRI dhan65 for *Aus* season, and BRRI dhan55, BRRI dhan56, BRRI dhan57, BRRI dhan66 and BRRI dhan71 for *Aman* season are also available for cultivation. However, scientific innovations along with recent extension activities have modified the agriculture of those areas with the following practices:



Plate 8: Crab culture with a crab farmer in extremely saline prone place of southern Shyamnagar upazila of Satkhira district. Photo Credit: Author.

Digging mini-pond for rain water harvest: The community people have adapted to harvest or trap rainwater in mini-pond

that digging at the agricultural site to be used in time of necessity for watering to the crops (Plate 9) (Awal et al., 2013). Farmers use the water from mini-pond for rice cultivation too. It also facilitates to cultivate fishes as well. In dry season when mini-pond becomes dry some farmers pour that with water from deep tube well. If the deep tube is far away from mini-pond they use a long flexible pipe for bringing water to their ponds over the uneven topography.



Plate 9: A mini-pond in drought prone Nachole upazila of Chapai Nawabganj district. The stored water in this pond is utilized for crop production purposes in nearby land. Photo Credit: Author.

Adjustment in cropping pattern: Due to scarcity of water farmers are recommended to cultivate wheat, pulses, oil crops, millet, pearl millet etc instead of *Boro* rice in dry season. Some drought-tolerant crop varieties suitable in that dry area are available (Table 1). It is mentioned that wheat's crop growth especially at reproductive stage of this crop is badly affected by high temperature leading to poor grain yield (Hossain et al., 2011, 2013; Hakim et al., 2012). Due to short winter in Bangladesh, wheat's grain filling mostly occurs at warmer weather in early spring thus grain production becomes lower. To overcome such climatic constraint some drought plus temperature or heat tolerant wheat cultivars like BARI gom26 and BARI gom28 can be cultivated in the dry areas which also produce higher grain yield even with late planting (Table 1).

Alternate wetting and drying (AWD) technology: It is a method of controlled and intermittent irrigation, practiced to cultivate lowland rice with much less water than the usual system of maintaining continuous standing water. Rice field experiences periodic drying period for a few days followed by a flooding by irrigation in such a way that could not impose any stress to growing crops. It reduces water demand for irrigation and greenhouse gas emissions without reducing crop yields. In conventional system, *Boro* cultivation is completely irrigation dependent while *Aman* needs it partly. To produce one kilogram of rice, a huge amount of water like 3000 to 5000 litre is essential, of which about 15-30 percent can be saved using AWD technology without hampering in grain yield as proved by IRRI (Bouman, 2009). Starting from about 15 days after transplanting, the land is irrigated until the water table goes 15 cm below the ground level when first small soil cracks are visible. A perforated plastic pipe with 7-10 cm diameter is inserted to a depth of 20 cm of soil to monitor the water level (Fig. 1). The practice is continued to heading and thereafter the rice field is kept submerged with 2-4 cm water until dough stage. It follows the principle of mitigation, a pillar of CSA, as it uses comparatively less amount of ground water thus needs less energy to lift that. Ground water is the main source of arsenic contamination in rice, therefore, absorption of less amount of ground water by this crop is a basic reason to decrease arsenic content in grain as well as in straw.

With growing water stress, the practice helps rice farmers become more resilient and reduces emissions (i.e. mitigation effort). The rice varieties suitable for AWD practice in Bangladesh are BRRI dhan28, BRRI dhan67, BRRI dhan69 etc in *Boro* season, and BRRI dhan71, BRRI dhan75 etc in *Aman* season. Heavy rainfall can impede the application of AWD. It can be used in any season throughout Bangladesh except in the southern coastal areas where the soil is affected by salinity.

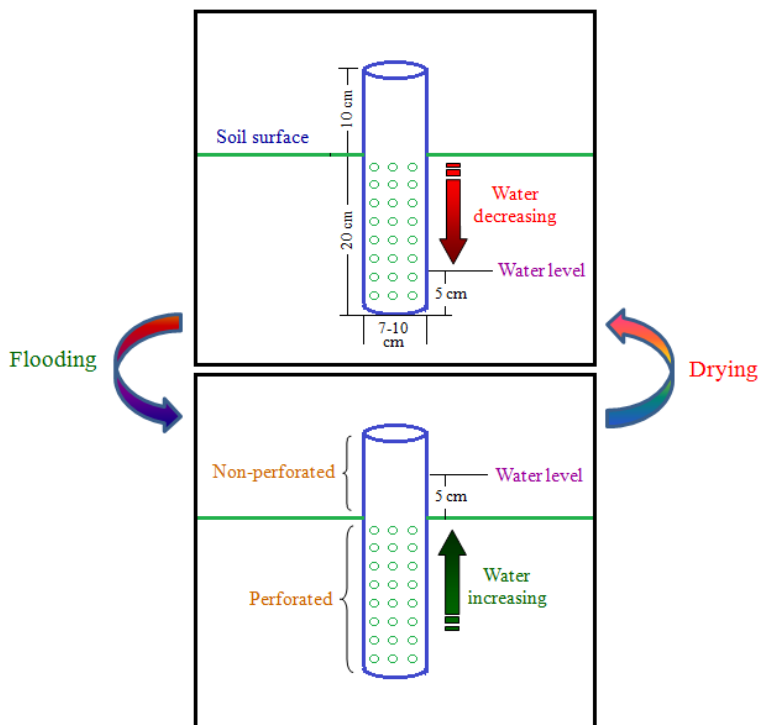


Figure 2: Operation technique of alternate wetting and drying method in rice field. Sketch Credit: Author

Adaptation of agricultural practices to climate shocks or extreme weathers

Bangladesh agriculture experiences two major extreme weathers like flood and cyclone. The adaptation measures to those climate shocks are hardly found.

Adaptation to flood

Bangladesh faces various types of floods like early/flash flood, river/monsoon flood, tidal flood etc. Flood sometimes heavily devastate the growing crops in the field. Duck rearing is the most common alternative economic activities of local people living in the flood prone areas of Bangladesh.

Early flood or flash flood or hilly flood: This flood destroys agriculture field and crops like *Boro* rice most severely within a short period of time. Farmers are recommended to cultivate short duration *Boro* rice like BRRI dhan28 especially for north-eastern *Haor* region (saucer or bowl shaped depressed lands remained marshy or submerged from May/June to November/December) of Bangladesh to avoid early flood that often strikes during the month of April when growing paddies are at matured or semi-matured stages (Plate 10). In order to get higher yield however, some famers utilized the variety BRRI dhan29 that often falls to early flood due to its longer life span of about 20 days as compared to BRRI dhan28. With scientific cooperation from the International Rice Research Institute (IRRI), the Bangladesh Rice Research Institute (BRRI) and the Bangladesh Institute of Nuclear Agriculture (BINA), have developed and promoted some submergence-tolerant (Sub1) rice varieties like BRRI dhan51, BRRI dhan52, BRRI dhan78, BRRI dhan79, BINA dhan11 and BINA dhan12 for cultivation in *Aman* season in northwest Bangladesh where flash flood hits frequently. Depending on the varieties, they can tolerate minimum period of 7-14 days to a maximum up to 20-25 days of submergence and revive on recede water (Mackill et al., 2012; Rahman and Zhang, 2016).



Plate 10: Growing short duration *Boro* rice at Dingapota *Haor* of Mohonganj upazila of Netrokona district. Photo Credit: Author.

Monsoon flood: It persists long time in the field from July to September/October. Many places of Bangladesh are experienced to this type of flood with deep water. Farmers usually cultivate local deep water broadcast *Aman* rice where culm elongation is occurred with flood level. It is very long duration rice sown in March/April and harvested in November/December. Rice varieties like Hijoldigha, Molladigha, Kaika, Vasa dhan, Dhepodhan, Chamara, Digha, Dhepa, Gabura, Lakkhi and many other local cultivars are still in practice for *Aman* season in low-lying flood prone areas of Bangladesh. The rice requires a special habitat of prolonged flooding. Some local varieties of rice like Chamara, Dhepa, Boron etc grow with rising water and the plants grow 3-15 feet (Zaman, 2017). These varieties have a matching affinity with water levels, while the life cycle of these varieties is so fine tuned with water regimes. These varieties can grow both in floods and with less water. Most local varieties are strongly sensitive to photoperiod and low filtering, producing a very high amount of biomass for culm elongation but with the least harvest index. However, the most important constraints of this rice are lack of varieties with high yield potential. Some late varieties of *Aman* rice like BR22, BR23, BRRI dhan46, Binasail etc can be transplanted after recede flood water. The varieties are important if early planted rice destroyed by flood. Flood tolerant sugarcane variety like Isd 34 can also be cultivated in flood prone areas (Hassan and Shaw, 2015).

Adaptation to cyclone

Tropical cyclone mostly hits Bangladesh coast during pre-monsoon (throughout May) and post monsoon periods (from mid October to mid November) (Awal, 2015b) largely corresponding to the harvesting time of *Boro* rice and *Aman* rice crops, respectively. Tidal surges accompanied by cyclonic storm make the areas saline as well as waterlogged. Farmers adjust the planting time to avert the cyclonic time (Khan and Awal, 2009) with short duration rice varieties like BINA dhan8 and BINA dhan10 in the *Boro* season and BINA dhan7, BINA dhan11, BRRI

dhan62 etc in the *Aman* season which are also salt tolerant characteristics to some extent. Previously, farmers used some low yielding local rice especially in *Aman* season as described earlier.

CONCLUSION

The traditional system or practices are implemented using basic and locally available inputs. The practices often integrate careful management of natural resources with intimate local or indigenous knowledge of environment and spiritual beliefs. It is usually passed on from generation to generation with improvements and adaptations taking place according to changes in local conditions. Thus the traditional practices may act as powerful devices to manage natural and cultivated ecosystems for meeting the societal needs. Although the productivity of the system is generally low, considerable potential exists to improve the productivity and efficiency using appropriate recent technology and innovation. Integrating indigenous or traditional knowledge with scientific innovations to planning, designing and implementation may strengthen the approaches of CSA.

Appropriate technologies can help farmers and other producers to overcome the physical and environmental constraints in fragile or exposed areas, improve productivity and incomes, and help them to adapt to changes in the climate. These are those which can be managed and maintained by the growers over the long term, and which integrate environmental, economic and social sustainability principles. The innovations have enabled farmers to cope with various climatic challenges and have been fundamental to the promotion of CSA throughout the country.

Drawing on examples from diverse climate-stressed hotspots of Bangladesh, this paper highlights the promising or best practices and available tools and modern innovations for, identifies gaps and link in, as well as recommends possible actions to enhance, the application of indigenous and traditional knowledge and practices for achieving CSA. The research workers may be benefitted by observing the interface between the

traditional technologies and recent scientific innovations in Bangladesh agriculture which appeared in this study.

Immemorially tuned indigenous technologies and genetic resources used by the farmers at local level have outstanding features to withstand the negative impact of climate change threats. Such indigenous ones should be prioritized for promoting/adopting recent innovations for combating over increasing threats of climate changes in agricultural production. That means, befitted scientific innovations should be devised by the local communities through their indigenous knowledge. Proper management and maintenance of indigenous technologies, coordination among practitioners, policy planners and service providers, and good governance are essential to achieve the CSA in Bangladesh. Donors and funders may be benefitted by learning from best-practices and local knowledge as well as recent innovations when investing in adaptation works. Key messages may reach to policy makers, researchers, practitioners and extension service providers to promote CSA in Bangladesh.

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SDGS AND AGRICULTURAL DEVELOPMENT IN BANGLADESH: ACHIEVEMENTS, GAPS AND CHALLENGES

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Abstract

Recent economic performance indicates the emergence of Bangladesh from backwardness. Despite that, our society is beset with multiple socio-economic problems while the pressure of climate change is addition. United Nations has tailored these wider issues under the Sustainable Development Goals and indicators so that they could be globally tackled by 2030. Various strategies and options could be used to meet the SDGs but agriculture stands as a single area where multiple United Nations Sustainable Development Goals intersect. Additionally, Bangladesh has to depend on this sector for food and employment for millions. So, using sustainable agricultural development principles referred in SDGs can also prepare Bangladesh agriculture to meet diverse socio-economic and environmental challenges. This qualitative exploratory study shows the existing challenges Bangladesh agriculture currently facing and what is the status of sustainable development principles in developing Bangladesh agriculture. This study concludes that developing agricultural sector with the guidelines of sustainable agricultural norms has manifold positive outcomes ranging from ensuring food security to reducing social inequality. Mechanizing and commercializing farms were regarded crucial to develop the agricultural sector of Bangladesh for better productivity and greater goods.

Key Words: SDG, Climate Change, Agriculture, Modernization, Ecology, Consumption.

INTRODUCTION

Background of the Study

After the expiration of the Millennium Development Goals (MDGs), United Nations has set the Sustainable Development Goals (SDGs) targeting to attain them by 2030 in 2015. These goals and indicators are a simple sketch of current socio-economic and environmental realities and needs (Nhemachena, et al. 2018). Nationwide sectoral effective planning and policy implementation with the line of SDGs are likely to bring manifold positive impact in our society. Evidently the state of Bangladesh is already facing various societal problems and environmental threats. Being an agricultural country (Jannat, et al. 2019), widespread poverty, food scarcity (Bishwajit, Barmon and Ghosh 2014), gender and rich-poor inequality, unemployment and frequent natural calamities have become a common feature of Bangladesh. Bringing agricultural development through promoting agriculture related indicators in SDGs can prove an effective mechanism to battle the above-mentioned problems and issues in the context of Bangladesh. At the same time, guiding Bangladesh agriculture sustainably can also help to achieve SDGs as well. Evidently, agricultural development is a crying need to transform the existing agrarian agricultural economy which produces only subsistence output. Taking SD as a guiding principle to transform existing agricultural sector may likely to eradicate poverty level of the rural farmers community, making more foods available for consumption for all classes (Bishwajit, Barmon and Ghosh 2014; Wahid 2015), inclusion of women in economic activities (Dawson, Martin and Camfield 2019), changing the living and livelihood standard of the poorer section of the society (Wahid 2015), and making farming sector resilient to natural calamities which is vital for maintaining food supply chain in overpopulated Bangladesh on the eve of climate change (Sarker, 2016; Bishwajit, et al., 2014). Successful accomplishment of agricultural development has potentiality of future industrialization (Sarkar, 2005; Miah, et al., 2020). This paper will investigate the current state of Bangladesh agriculture and the presence of sustainability from policy level to practice level

among farmers. We will also look into the reasons behind the backwardness of existing agricultural sector of Bangladesh. Special focus will be given to understand the impact of climate change on Bangladesh agriculture and the potentiality of mechanizing farms to transform Bangladesh agriculture for greater benefits.

Importance of the Study

Agriculture sector forms the largest employment generating source in Bangladesh. Two-third of the total population is directly and indirectly involved in this sector (Mistry 2021). Specially the involvement of huge number poor people in this sector compels studying on the agricultural development of Bangladesh as majority of the population dwell in villages. Moreover, Bangladesh is having an excessive number of populations with scarce land. Many people have chosen overseas migration and city-centric mobility for employment. Bangladesh economy is trying to industrialize its economy but the agricultural sector is still performing quite marginally. Despite some remarkable performance in readymade garments, Bangladesh needs to prioritize agriculture equally due to the maintenance of food security for millions of people. Still agriculture provides jobs and foods for a vast number of rural poor people. This paper addresses the challenges Bangladesh agriculture is facing and how SDGs can help to develop Bangladesh agriculture. Developing agriculture can provide further economic growth and social positiveness.

LITERATURE REVIEW

Scholarship in the agricultural sector of Bangladesh is abundant. But recent publications relating to sustainable development are very limited both in quality and quantity. This study is an attempt to fill part of this gap. However, this section would try to draw some notable literatures in the field of agricultural development in Bangladesh and the next section would try to draw overseas experiences related to our central objective of this study.

Major Findings on the Agriculture of Bangladesh

Islam (2009) provides a comprehensive study of Bangladesh agriculture sector. He rightly finds out land fragmentation, poor busying capacity of framers, lack of quality machines and knowledge of operation and excessive tariffs on spare parts keep this sector backward. He urges prioritizing agricultural development as to fill the food demand of wider population by pushing this sector in competitive manner. What Islam (2009) misses out is to relate agricultural development with the practice of sustainability and ignores the division among farmers in buying capacity rather exclusively focuses on mechanization of farms.

Despite the increment in total agricultural productivity at macro level, access to sufficient food at every household level has not been achieved in Bangladesh (Faroque, Asaduzamman and Hossain 2013). Massive population with disasterous climate change is putting utmost pressure on agriculture sector to increase its prouductivty level to match demand items. Faroque, Asaduzamman and Hossain (2013) suggest applying variety seeds, extending cultivating areas and deploying modern technologies to make Bangladesh agriculture resilient to climate change otherwise food security would be hampered in upcoming days. But what they forget to warn is the unintendeded consequences the unplanned modernization which may exacerbate environmental situatioion for worse as Li, Wang and Chen (2019) note in their analysis.

Hossain (1984) takes the development of agricultural sector of Bangladesh from a historical perspective dating back from 1949 to 1984. His rich historical study accounts that the agricultural growth was not influenced by land and labour due to limited geographical area of Bangladesh and abundance of labour in this sector. He argued that modern irrigation system, High Yielding Variety (HYV) seeds and using fertilizers were responsible for the expansion of agricultural production in Bangladesh. He did not give much credit to price incentive for this expansion rather the diffusion of technology as a crucial enabler.

Mustafi and Islam (2008) aspire using agricultural sector for all-encompassing development from women's empowerment to rural poverty reduction. Mechanizing agricultural sector is obvious to harness its fullest potentiality. They emphasize on creating new cultivating methods, technologies suitable to farmers and environment largely. Tayyeb(1978) explores the post-independence scenario of Bangladesh society. He finds agricultural sector facing multidimensional mismanagement crisis. Consequently, output of Bangladeshi agricultural sector is lesser compared to fellow countries. He recommends balancing population and introducing modern technology replacing traditional ways of cultivation can boost production scale. Astonishing description of Bangladesh agriculture sector by the author is still relevant to critically observe the backward reality of this sector.

Ashraf, et al. (2019) find achieving SDGs challenging for Bangladesh. Agricultural production is growing but this sector is diminishing. They argue that modernizing agriculture is obvious to meet the growing needs of vast population. But they warn unhealthy cultivating practices hoping to increase agricultural production would jeopardize the aim of sustainable development. Murshed-E-Jahan & Pems (2011) examine the probable outcome of introducing integrated aquaculture-agriculture (IAA) technologies in Bangladesh. They believe that this combined cultivating method would help to reduce poverty and make sure food security in Bangladesh where fish is an important source of diet. Intensive use of technology is supposed to reduce the cost of production and extend the output rate. So, we can hope the possibility of using alternative cultivating methods over traditional approaches. Rahman and Islam (2013) also find that the farmers have already started to use floating mats technique in lower southernwestern part of Bangladesh to cultivate vegetables. They also witnessed lower lands are further dug for cultivating fishes in rainy season and cultivate rice in monsoon. These new techniques remind us how adaptation strategy is taken to exploit the fuller potentials of land. Extensive study is needed to achieve further success from these indigenous techniques in Bangladesh so that we

can be better prepared for upcoming challenges in agriculture sector in Bangladesh and meet SDGs effectively by 2030.

Faroque, et al. (2011) find an increasing production in agricultural sector of Bangladesh in recent years. But this increment was followed by massive land and water degradation. They propose sustainable cultivation for ensuring increased productivity, environmental sustainability, economic profitability and social and economic equity. Transforming agriculture into sustainable methods leaves Bangladesh with many challenges.

Major Findings on the Cross-country Agricultural Experiences

Nhemachena, et al. (2018) argues that the development of agriculture is crucial for poverty and hunger reduction. SDGs will not be meaningful unless eliminating these two aspects existing in most of the developing societies. They also suggest to employ sustainable agricultural practices and indigenous knowledges to grow more agricultural output by dedicating lesser resources and beware of environmental cost due to agricultural development. Combination of science and local knowledge can really provide a good solution indeed. Authors of this paper find that there is a lack of legal framework to address the SD indicators related to agriculture. This also true in the case Bangladesh where there is absence of legal instrument to address SD and agricultural development in a meaningful manner.

Marafa, May and Tenebe (2020) think that the availability and accessibility to food will be crucial challenge to meet in upcoming decades. Authors draw Chinese experience of agricultural development to pull out of millions of rural farmers which eventually paved the way for massive industrialization. That is why they urge authorities to prioritize agricultural development in the strategy of economic development. Taking the market realities in consideration could be worthy despite authors' successful linkage of agricultural development with SDGs pursuit.

Makate, Makate and Mango (2017) find climate dependent traditional agriculture is highly vulnerable in the face of climate change. They recommend sustainable agricultural practices to be

widely persuaded to tackle changing realities. Their study also affirms positive impact of education in accepting technologies among farmers. So extending educational programme among farmers can be pushed forward to encourage agricultural development maintaining sustainability and higher productivity.

Li, Wang and Chen (2019) claim that despite the growing influence of non-agricultural sectors, agricultural sector still remains central to poverty reduction, economic development and sustainable development in this era. They urge international cooperation in agricultural sector for the better realization of SDGs since this sector has the potentiality to influence many SD indicators. It is true indeed that the effective implementation of SDGs is likely to bring positive outcome in the other areas of a society.

Dawson, Martin and Camfield (2019) take Rwanda and Laos to examine the intensification of agricultural production to achieve sustainable development. They basically focus on poverty reduction via modernizing agriculture with government provided subsidy. Their study also finds this market-based intensification is failing due to local property tenure and marginalization of the poorest in dynamic market force in those respective countries. Kumar, et al. (2016) provide a rich strategic framework to achieve SDGs in South Asia. Given higher growth and higher inequality in consideration, they ask for social protection and financial inclusion for solving this odd. Unfortunately, they do not mention agricultural development as a viable strategy to meet SDGs in South Asia where agricultural sector is large but peculiarly food shortage is common.

Greeley (1980) explores the application of technological means in rice processing in Bangladesh. He finds that agricultural technology producers have always tended to downplay traditionally used techniques in agriculture as unscientific and inefficient. So, Bangladesh hurriedly purchased their technology without paying attention to their local compatibility in Bangladesh's environment. His study also finds that introduction of modern technology has caused labour displacement in rural societies who are mainly poor female workers. That is why author

suggests policy planners to intervene in this issue so that the poor women can have partnership and invest as a group to minimize burden to acquire agricultural technologies. So, we can say that unplanned modernization can bring huge inequality.

THEORETICAL FRAMEWORK

Conceptual Understanding

We are passing through a time when there are a lot of socio-economic problems with additional burden of climate change is on our shoulder. Sustainable Development Goals have emerged as a sketch of these socio-economic and environmental vulnerabilities. Relationship between sustainable development and agriculture sector has been reflected widely in its indicators. SDGs provide a guideline to agricultural development whereas agricultural development is a necessity to meet the SDGs in return as this sector encompasses a wider group of marginalized poor people. Especially agricultural development is inevitable to reduce poverty (SDG-1) around the world as at least 2.5 billion people directly rely on this sector for their livelihood (Rockstroöm, et al. 2016). Sustained agricultural sector is also very necessary to ensure the food security (SDG-2) of billions of people. Subsections of SDG-2 provides a handful amount of suggestions regarding improvement, diversification and enhancement through investment in agriculture against the climate change. SDG 6 and 7 are also vital for agricultural development as natural resources and energy are key to agricultural functioning. So proper use of them has been suggested as well. Preserving natural resources was the prime focus of SDG 14 and 15 where SDG-13 takes the issue of climate change. Additionally, agriculture has relations with employment generation (SDG-8), inequality reduction (SDG-10) and ensuring sustainable way of production and consumption (SDG-12) for better human health. So, the interlinkage between agriculture and SDGs are diverse and complex. Their reciprocal nature makes it compelling to focus on agricultural development.

Sustainable Intensification of Agriculture: Theoretical Framework

Green revolution in 1960s in agriculture sector was solely based on dramatic rise in productivity which extended food security, reduced poverty of farming communities and spread other positive social welfare. But now we are passing through a critical time where increasing productivity cannot be the sole purpose rather managing agriculture in a sustained way to cope with stress and shocks caused by climate change. Humanity faces a burning question as how to transform our existing agriculture in such a which would meet the demands of billions, ensure poverty reduction through increasing productivity while making the planet ecologically stable for future generation (Rockstroˆm, et al. 2016). Blind application of ecological modernization would not be a sustainable way of ensuring future food security as it has further negative impacts on environment. But we cannot neglect the immense demand for growing population around the world. Sustainable Intensification of Agriculture (SIA) can be a good strategic framework to guide Bangladesh agriculture in the face of multiple challenges. SIA posits itself in a context of global environmental change while making agriculture focused on poverty and hunger reduction and contribute human wellbeing in other social areas. These aims and objectives have also been widely accommodated in agriculture related SDGs. However, definitionally sustainable intensification refers, “how to enhance agricultural productivity while reducing its environmental impacts (Rockstroˆm, et al. 2016 pp. 01).” It not only focuses on producing more but also contribute positively in natural and social capital (Pretty and Bharucha 2014). SIA assures the highest level of resource utilization. Specially the efficient use of water and fertilizers are few of the core objectives of sustainable agriculture which were broadly noted in SDG 14 & 15. Additionally, food waste is a paramount problem in the current food processing and consumption system which should also be addressed in a sustainable way so that resources are not relinquished. However, unlike mainstream intensification programme, sustainable intensification exploits the benefits of natural eco-system rather

than putting external inputs in functioning (Rockstroöm, et al. 2016).

Few characteristics have emerged from the wider literature on sustainable agricultural intensification (Pretty, Toulmin and Williams 2011; Tiftonell 2014; Royal Society 2009). Those are briefly note down below-

- Using the available inputs existing in eco-system to function agricultural activities. SIA also highly discourage to use unnecessary external inputs.
- Developing ecosystem-based strategies to make agriculture sector resilient and productive farming system against climate change.
- Minimizing technological usage which have adverse impact on environment and human health.
- Making sure nutrition quality in agriculture through mixing organic and inorganic inputs in farming.
- Making the best use of traditional wisdom in innovating new strategies which would resolve wider systemic problems like water scarcity, soil infertility and pest management.

It is clearly evident that SIA a good strategic framework against the backdrop of climate change and diminishing natural resources. Speciality of sustainable agriculture is that it is not against productivity increment or wants to go back to primitive agricultural system but destined to address socio-environmental issues alongside. Despite the positive approach and successful results of SIA, there are some limitations in this approach as well. Notably question comes about the hypothesis regarding that sustainable intensification assumes other forms of agricultural practices are unsustainable. Even there is a potential debate around the definition of sustainability itself (J. N. Pretty 1997). Another criticism is raised against the inherent priority of sustainable intensification; is it 'sustainability' or 'productivity', which is important to SIA? Critics say that SIA is also a business as usual strategy to the agricultural development (J. N. Pretty 1997). Productivity has always been prioritized at the end of every

agricultural development policy as they are based on the weak ecological modernization (S. Rahman 2003).

METHODOLOGY

Qualitative approach

Examining the likelihood of agricultural development in Bangladesh through the implementation of UN prescribed SDGs in this paper is a qualitative approach. Rationality behind employing qualitative approach in this study is to find out the nuanced ground realities of agriculture sector in the societal context of Bangladesh. Emphasis would be given to interpret quantitative aspects in qualitative manner. Analysing statistical aspects is not adequate to understand the actual situation. For example, having food availability in market does not ensure the food security for all because there are other factors behind these complex issues. For this reason, qualitative approach has been chosen to conduct this study.

Objectives of the study

First and foremost, this paper is an exploratory research on the agricultural development of Bangladesh in the light of sustainable development principles. Evidently the author of this research paper has no pre-dispositions to any particular thoughts. However, this study has few objectives to accomplish from this research on the implementation of SDGs in the agricultural development of Bangladesh. Those objectives are-

- Understanding the sustainable development practices in the agricultural sector of Bangladesh.
- Tracing the major challenges Bangladesh agriculture facing currently.

Central questions

Agriculture possesses a wider area in the whole agenda of Sustainable Development Goals. This study focuses only a few portions of that area. Central questions of this study are-

- How sustainable agricultural development has been perceived and practiced in the agriculture sector of Bangladesh?
- What are the major challenges Bangladesh agriculture is facing and how SDGs can provide a viable pathway to elevate?

Limitations of the study

This study is having various strength while it cannot be denied that there are few limitations as well. Those limitations are basically related to time, space and resources at micro level while there are limitations at theoretical level. Impact of time constraints have also been reflected in the depth of the study area and scale. Author of this paper had to choose limited area and working with a limited number of samples which may put strains on the credibility of this study. Access to higher officials was also constrained due to the presence of Covid-19. This research has promised to bring the academic perspective in the study the agricultural development of Bangladesh. Unfortunately, several attempts went in vain when academicians were less interested to contribute in this academic project through online based data collection methods. Alongside, financial constraints have also impeded research activities otherwise things could be done in more standard format. Least not the last, this study had to use a single theoretical framework to explain the subjective social realities which is both bliss and constrain. But it would have been better if this study could respond to all grand theory or separately could help to build a theory.

FINDINGS OF THE STUDY

Section (A): Importance of Agriculture in the Face of Industrialization in Bangladesh

Bangladesh has stepped one step forward to graduate into a developing country from the Least Developed Country (LDC) status in 2021 and scheduled to become a developing country by 2026 (Byron and Mirdha 2021). So, it would not be arbitrary to claim that the development priority of Bangladesh will be surrounding the

flourishment of the industrialization. Evidently, the contribution of agriculture has seen a gradual decline in the national economy of Bangladesh. Therefore, there is a likelihood of shifting priority in national economic policy as Bangladesh is destined to become an economic powerhouse in Asia. But the experts and farmers of this paper do not see this shift materializing soon anymore rather they position agriculture as the vital sector in the agenda of Bangladesh development.

Experts have opined that the demographic character and overwhelming dependency of rural economy on agriculture make it a compulsion to give highest priority to this sector. Wealth generated in the industrial sector cannot feed the millions of people in Bangladesh (Mistry 2021). Expert has claimed that Bangladesh cannot fulfil several SDGs without prioritizing the agriculture sector (Akter 2021) and notably this sector has complemented the fulfilment of LDC graduation criteria (Mistry 2021) and success in achieving MDGs in Bangladesh. It is not false that agriculture sector is losing out the race with other industrial sectors in contributing national wealth generation as it used to be the prime source of national income previously. But experts suggest that Bangladesh needs to focus on agriculture sector more to cope with the national industrialization process. Commercialization and mechanization of farming are proposed to develop the agriculture sector as there is space for diversifying this sector for harnessing more output and greater benefit for a large number of populations. Value addition and export-oriented agribusiness strategy can help to advance this sector (Dash 2021). Experts have linked all of their pleas with the broader line of sustainable agricultural development in the context of Bangladesh.

Farmers have also toned in the same melody that the agriculture sector has always been and will be the central pillar in the development of Bangladesh. We have no other option to consume such a large amount of food items from the outside world to feed our large number of populations as they unanimously opined. One respondent believes that, "Industrialization is not enough to develop Bangladesh unless we achieve real self-sufficiency in food production" (Respondent-1 2021). Even another

firmer believes that it is imperative to have agriculture onboard if Bangladesh seriously wants to become a developed country and go ahead (Respondent-6 2021).

So, it is undeniable to say that both experts and farmers themselves believe that agriculture will remain the prime foundation of Bangladesh development. Engagement of nearly two-third of population in agriculture makes it impossible to surpass it in Bangladesh despite the dramatic rise of industrial sectors in Bangladesh economy within last couple of decades. Bangladesh agriculture is also taking off from its subsistence level output generation performance to a certain degree of commercial sector as both experts and farmers themselves observe. Interestingly both group of participants think that there is a space for renovating current agriculture to make this sector compatible with other industrial sectors as well.

Section (B): Sustainability in the Agricultural Policy and Practices of Bangladesh

A major portion of the Sustainable Development Goals (SDGs) talks about the agricultural development and best-practices of agriculture to be attained by 2030. It is an important issue area to ask whether the agricultural policies have addressed the issue of sustainable agricultural development principles appropriately in Bangladesh. Experts have unanimously expressed that the latest National Agriculture Policy 2018 has rightly accommodated sustainable development principles and goals in its agenda despite few drawbacks. One expert related that Bangladesh agriculture policy has previously maintained a close coordination with Millennium Development Goals (MDGs) to eradicate poverty and hunger from Bangladesh and now following SDGs to address the broader challenges Bangladesh agriculture is currently facing (Dash 2021). Government of Bangladesh is destined to make sure the highest level of land and resource efficiency in its food production which is also one of the desired indicators of SDGs as another expert relates. However, experts have also outlined that Bangladesh government wants to employ environment friendly

technologies in agriculture while destined to double the production output as SGD-02 promises (Yasmin 2021). One expert has also traced a major practical change in their field directive is that they are now advising farmers to produce foods maintaining health safety and nutrition rather than emphasising on boundless production (M. M. Rahman 2021). However, experts do not rule out the unsustainable practices in the agriculture sector of Bangladesh. One expert has accused farmers for not adhering to their guidelines (Dash 2021). Farmers have tended to use more chemicals and synthetic fertilizers instead of bio-fertilizers in land which is contrary to SDG 15. Farmers have lack in their knowledge of sustainability and good agricultural practices. Additionally, there is also problem of coordination among government agencies in implementing and addressing agriculture developmental needs in Bangladesh. One expert has exemplified that there are few government agencies which do not have environmental knowledge but work on agriculture related projects which cause environmental degradation and the collapse of balanced ecosystem (Mistry 2021).

On the other hand, farmers themselves have also found some unsustainable practices in their agricultural activities. Almost every farmer has identified the inappropriate use of chemicals and fertilizers has negative consequence on land and food they produce. One farmer has noted that he is aware of the harmful impact of chemicals but there is no other alternative option left to him to cultivate safely while maintaining food productivity (Respondent-5 2021). Another farmer has blamed farmers' inefficiency in applying medicine properly at proper time (Respondent-3 2020). Experts on the other hand have agreed that SDGs could be used to revamp the agricultural development of Bangladesh through adequate scrutiny in policy level and spreading sustainable knowledge among farmers.

Section (C): Climate Change, Food Security & Land Degradation: Challenges Ahead Agriculture

Bangladesh agriculture sector is currently facing with multiple challenges. Both experts and farmers have noted manifold

asymmetric challenges caused by human induced activities and natural changes which are putting the future of this sector in danger. Soil infertility, water scarcity, raising production cost, unfair price of agricultural goods and climate change broadly have been identified by them as the major challenges of Bangladesh agriculture facing at this moment. As this paper has presented that the inappropriate combination of fertilizers has made the arable lands barren. Consequently, farmers have to use more and more fertilizers to match production which is also unsustainable practice of agriculture (Mistry 2021). It also increases the overall production cost. Another major problem, farmers are currently facing, is unfair price they get in market against the amount of capital they invest in agricultural production (Dash 2021). Market structure is also against farmers as there is the presence of syndicate who controls the price rather than the demand supply matrix. Poor infrastructural condition and the lack of coalition among farmers are responsible for their backwardness according to an expert (Dash 2021).

Climate change has been seen as one of the mounting impediments Bangladesh agriculture currently faces. This sector has become highly vulnerable to environmental change due to its over reliance on nature (Akter 2021). Excessive droughts and sudden floods cause a notable amount of loss for farmers round the year by threatening food security as most of the farmers firmly believe. One respondent farmer has said that the seasonal variety of Bangladesh is disappearing while unpredictability of weather pattern is putting excessive strain on their timely farming activities which prevents timely action for better outcome (Respondent-2 2021). They have also reported that there is highly water shortage in dry season whereas excessive water in rainy season cause substantial amount of damage to their crops.

Various problems along with the pressure of climate change in agriculture sector is likely to jeopardize the smooth food production. Bangladesh is already a country with millions of poor having lower buying capacity. Food production fall means the breaking of food security in Bangladesh. Perceptions between

agricultural experts and farmers have been quite opposite in this regard. Experts acknowledge that there is challenge but food security will not be an issue in Bangladesh as historical experience shows that Bangladesh has overcome all odds and thrived towards the self-sufficiency in own food production. Whereas, farmers have unanimously expressed their concern that Bangladesh would face serious food security in near future if things are not improved. They have also concerned that the arable lands are in decline which would naturally put massive pressure on scarce lands to produce higher quantity output generation. Experts have dismissed such ideas and claimed that the vertical intensification of land with mechanization of farming can help to reduce this pressure (M. M. Rahman 2021). Experts have urged the multiple times use of land for harnessing the highest level of output from limited landmass. Climate adaptive crop varieties and farming methods can also be used to halt the pressure of climate change in the context of Bangladesh (Dash 2021; Akter 2021).

Section (D): Potentials of Technologies in the Agricultural Development of Bangladesh

There is a wider consensus on a point from both agricultural experts and farmers that they unanimously desire for the more use of technologies in agricultural activities. They see the farm mechanization as a viable solution to many existing problems in the agricultural sector including land scarcity and climatic shocks. One expert has argued that the land scarcity and labour crisis in peak season can be solved through the introduction of all-out technologies in cultivating activities (Mistry 2021). Even there is no alternative to modernizing farms in response to climate change through sustainable adaptation. Interestingly, sustainable agricultural development also sees technology inclusion as a part of mitigative measure to the challenges in agriculture. Scientifically developing variety seeds resilient to climate specific conditions and innovating new technologies which are affordable is a big task ahead of Bangladesh as several experts stressed (Yasmin 2021; M. M. Rahman 2021). Even the climatic pressure creates time crisis in cultivating activities. Farmers noted that often they have to prepare

their land in a very short period of time or collect grains early, where manual labour is insufficient to conduct the task within scarce timeframe. Farmers have also welcomed recent technological usage in their regular functioning as it reduces labour cost and time pressure (Respondent-4 2021). Experts believe that the agriculture sector of Bangladesh has not yet reached to its peak of potential. Still there are a lot of areas to improve which is likely to broaden the potential outcomes in this sector.

As carbon emission is a big enabler of climate change, this study was also determined to understand the environmental cost of farm mechanization. Despite the overwhelming incitation among agriculture experts and farmers, it cannot be denied that the mechanization of farms has environmental consequences. Experts have also agreed that there are negative environmental impacts of farm mechanization in agriculture. One expert has expressed her concern that the overuse of fertilizers and chemicals in agricultural production is highly likely to contaminate our open water sources and disrupt health security (Akter 2021). But the amount of environmental negativity agricultural sector omits is highly negligible compared to other industrial sectors (Mistry 2021). Even the machineries which are being used in agricultural sector is environmentally friendly in majority (Yasmin 2021). Despite the limitation of alternative energy powered machines, government is diffusing them through various projects as field study has revealed. It is true that these projects are now at experimental stage but experts are optimistic about their positive outcome in near future (M. M. Rahman 2021). Alongside, higher level of subsidy is given to encourage farmers in machinery purchasing. But field experience tells that the farmers are less aware of these government incentives at root level. Farmers are craving for technologies (though they are less aware about environmental consequence of technologies) as various problems are emerging but many of the farmers do not have adequate financial ability to acquire necessary technologies. They have demanded the supply of water in dry season which is very crucial in producing foods and making sure of their livelihood.

DISCUSSION

Despite the gradual decline in the contribution of agriculture in Gross Domestic Product (GDP), agriculture still remains the most employment generating source in Bangladesh (IUCN n.d.). Even the economy of rural societies largely evolves around this sector. Non-agricultural sectors are emerging in Bangladesh national economy rapidly but agriculture still provides with huge number of employments, food security for millions of people, raw materials for industrial production and export goods (M. T. Rahman 2017). However, a nationwide policy shift towards more industrialization is unlikely to surpass the traditional value of this sector soon anymore as both experts and farmers themselves believe.

There was a time when approximately 90% population depended on agriculture which formed the nearly total export value of Bangladesh (Tayyeb 1978). Now things are changing as Bangladesh is slowly moving towards industrialization. Today agriculture accounts for 14% of GDP and 40% national employment generating source by driving economic growth, ensuring rural development and providing food supply (Bangladesh-Planning-Comisison 2020). Current growth rate of agriculture is 3.5 which was increased from 2% during 1970s to 1990s. However, this figure is not negligible as well since still there is scope for further economic growth and employment from this sector through strategic development. It is economically established claim that growth in agricultural sector is more capable of pulling out poverty of many people while same growth in non-agriculture sector has lesser potentiality to reduce poverty. Eradication of poverty is the goal number one of SDGs and reducing poverty through agriculture would mean the accomplishment of other SDGs as well in Bangladesh. However, the current development trend indicates that there is higher correlation between industrialization and increasing inequality in Bangladesh as rich-poor gap is skyrocketing (Osmani 2015). So industrial policies should also give considerable focus on this particular issue. Making sure of sustainable agricultural development, it would help to form a balanced society.

Covid-19 pandemic has made us realize the cruciality of agriculture sector around the world. Centre for Policy Dialogue's recent nationwide survey shows that a large number of people who used to work in service and manufacturing sectors have turned into farmers in the wake Covid-19 to match their livelihood survival strategy (Prothom-Alo 2021). This single event shows how vaguely Bangladesh industrial sector has built its foundation over the years. At the same time, it reminds us that there is a potential scope to reorganize our agriculture sector by applying the agriculture related SDGs. However, Bangladesh did not have to go through any major food crisis during this pandemic as our agriculture sector has achieved relative self-sufficiency in food production in 2013 (Bangladesh-Planning-Comisison 2020). Despite this sufficiency, Bangladesh agriculture is also facing various challenges and vulnerabilities. Specially the dramatic decrease in farming lands annually at an alarming rate due to the pressure of industrialization and urbanization has remained unaddressed. But the Government of Bangladesh is giving utmost priority to the industrial sector to keep its economic growth 7-8% (Bangladesh-Planning-Comisison 2020). In contrast, developing agriculture sector has multiple visible benefits which would also strengthen the SDGs achievement in Bangladesh where other non-agriculture sector is ill-suited to meet these goals. Evidently the people involved in agriculture sector is predominantly come from landless rural and poor socio-economic background, that is why focusing on this particular sector will be strategically important to reduce national poverty level. Bangladesh is already having a large number of people with acute poverty which has also been increased recently due to Covid-19. There is an emerging class of 'new poor' in Bangladesh economy (Barkat, et al. 2020). So, it would be ineffective policy outcome in poverty reduction (SDG 1) unless we address the agricultural development where majority are poor and live in rural areas. To unbox the wider reality of rural society, rural economy of Bangladesh is sustaining on the both internal and external migration. Basically, a large number of potentially working-class people move to major cities mainly in Dhaka city for employment

in informal sectors (Abdullah 2016) with low wage while a large number of uneducated men and women choose international migration as a form of livelihood strategy. It is undeniable that the service and manufacturing sectors are expanding in Bangladesh by absorbing huge employment but the unequal treatment and unsafe working environment and rapid unhealthy urbanization they cause is also questionable from the perspective of sustainability. Neoliberal economic policy has also caused a slum culture in Dhaka city (Lata 2020) as exploitation has become the guiding principle in the development of Bangladesh. Besides, international migration from Bangladesh is also facing multiple challenges as it could not create any viable strategy of developing and sending skilful manpower abroad (ADB 2016). But here focusing on rural agriculture through sustainable agricultural development can be a bliss and pathway of durable national development.

Above all, it is clearly evident that the agriculture sector will not be as prime as it used to be in 1960s and 1970s due to the current development trend. But intentionally or unintentionally describing this sector unworthy and less important in glorifying non-agriculture sector in government policies has potential negative consequence for Bangladesh. In doing so, primarily we would miss the fuller potential of agriculture in the development of Bangladesh. As experts suggested that preparing Bangladesh agriculture with the capacity to generate raw materials for manufacturing sectors can also reduce the external dependency of Bangladesh for raw materials in functioning its major industrial sectors. So, agriculture would find its rightful place in mainstream national economic development by accelerating overall economic productivity and growth. One expert has proposed that there should be a command method in cultivation on the basis of demand and necessity of that particular agricultural goods as he found this method effective during his field visit of Vietnam (Mistry 2021). So efficient management of resources would have been possible. On the other hand, Bangladesh still needs to import food items from the external sources despite its self-propelled claim of self-sufficiency in food production. A critical overview of Bangladesh food production suggests that there have been years when

domestic food production was record breaking high while import of staple food rice has been dramatically raised in a large amount (Taslim 2018). Despite the impressive improvement in local production, a large segment of population is unable to afford foods (Dev and Kabir 2020) which indicates the hollow of food security in Bangladesh. This contradictory nature of Bangladesh food production depicts that still we have a lot to work on it. SDG-2 promises zero hunger which is yet to be accomplished in Bangladesh. It would not be a prudent decision to leave this sector directionless at this particular stage of development because Bangladesh needs to move stage by stage through gaining maturity. We cannot expect much progress in promoting inclusive economic growth, poverty reduction and expanding food security without harnessing the fullest human and productive potency of agriculture and its positive contribution in overall economic development and social upward mobility (FAO 2002). It has been widely regarded that modernized agriculture lays the foundation of further industrialization. As Bangladesh agriculture has not reached its fuller potential, it would be naïve to believe that Bangladesh would build strong industrial base overnight. Covid-19 pandemic has shown how ill-fitted Bangladesh industrial sector is during any crisis (Sakamoto, Begum and Ahmed 2020). What Bangladesh would be able to do is just assembling foreign imported goods instead of establishing local resource-based industries.

To talk about the developmental stage of Bangladesh agriculture, there are some lacks. Especially traditional operational methods and environment dependent functioning make this sector backward and subsistent performance (Mahmud, et al. 2014). Additionally, climate change is bringing multiple challenges for Bangladesh agriculture. Erratic rainfall specially drought and floods along with salinity and heat strokes are making it harder for farmers to cultivate food grains (Sikder and Xiaoying 2014). These problems are and will acutely jeopardize the overall performance of agriculture sector in Bangladesh. Availability of foods will be central issue. Even the poorer buying capacity of many farming

household will prevent to purchase food despite the availability of foods at market.

Bangladesh agriculture is still depending on human labour where countries adopted technologies in their farming activities have shown greater performance. Output growth has increased in Bangladesh agriculture but it could be further increased through efficient use of mechanization. United Nations has promised to double the food production in SDG 2.3. To meet this target, government is already running some subsidy-based technology diffusion schemes but in many cases these incentives are unknown among actual farmers as this study revealed in previous section. Interviewee of this study has expressed farmers' thirst to accommodate modern technologies in their farming activities so that they could reduce labour cost and time pressure. But existing machineries in Bangladesh are largely failing to attract farmer groups due to their poor buying capacity on the hand while the quality of machines is also questionable in ground reality. Government funded review of technological diffusion to create employment in Bangladesh has suggested that these government subsidized machinery have become broken or hardly usable after one or two seasons use (Mahmud, et al. 2014). Even the scattered land structure due to heredity law and diverse cultivation methods are also great impediments in the way of mechanizing agricultural sector of Bangladesh (Tayyeb 1978). Experts have suggested that cooperative based cultivation under the direction of agricultural officers can reduce field level incoordination and open the potentials of large-scale farming through uniting farmers. Additionally, government should focus on developing cheap but durable small-scale machinery with multifunctionality which would empower farmers for achieving other SDGs as well. As climate change (SDG 13) is becoming the most concerning single event in the way of agricultural development in Bangladesh. That is why technological developments should also be climate sensitive and climate resilient at the same time. Current efforts to develop renewable energy led technologies is appreciable. Indian experience shows that solar based water pumps have created wider attraction among farmers to solve water scarcity problem for

timely irrigation (Rockstroöm, et al. 2016). This would also strengthen the SDG 7. Strengthening SDG 2.5 will also be crucial for Bangladesh by diversifying food items and cultivation methods. It is undeniable to say that there is growing economic class in Bangladesh, so cultivating new types of foreign grown foods can also create local demand while reduce the pressure on foreign currency in importing them. However, studying the experiences of other countries would be necessary for Bangladesh to develop its agriculture sector with the effective inclusion of agriculture related SDGs.

CONCLUSION

It was a milestone for the history of Bangladesh as the United Nations Committee for Development Policy has decided to recommend Bangladesh for the status of developing country from the category of the Least Developed Country (Byron and Mirdha 2021). Despite this achievement, Bangladesh is still struggling with various socio-economic and ecological issues. United Nations proposed SDGs have captured these diverse issues to settle globally. Bangladesh is also attempting to meet them through national policy undertaking. Industrialization has been accelerated for the purpose of human development in the wake of declining role of agriculture in national economic development. But this study has stressed that the stage Bangladesh economy is going through needs giving utmost priority to agricultural development. Having a large poorer section in national economy makes it inevitable to focus on agriculture sector if overall human development is to be achieved. Even the prospects of industrialization are limited unless raw materials are domestically produced. This paper has proposed that market development and technological development of agricultural sector can complement the overall industrialization process in Bangladesh. Herein, SDGs have a greater role to play. By nature, SDGs are some target-oriented goals and pathways to meet those goals. This paper has examined the status of Bangladesh agriculture and the presence of agriculture related SDGs in current practices. Various gaps and

challenges have been identified in the field study stage and durable solutions to them have been proposed in this paper to develop Bangladesh agriculture in more sustainable manner. Addressing the issue of technological application with the aim of SDG 2.3 in Bangladesh agriculture has huge potentiality to drive further economic growth and human development. Above all, focusing on the agricultural development is very crucial for the wider population of Bangladesh who get employment, food security and social upward mobility through this sector.

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THE RAPID URBANIZATION IN DHAKA: A PICTURE OF SHACKLING OF SUSTAINABLE DEVELOPMENT

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Abstract

Nowadays, people are more concerned about their lifestyle where they are mainly focused on eco-centered and decidedly natural development except decision makers. Meanwhile, the earth is a roughcast multidimensional development dilemma where rapid urbanizations is one of the most. Therefore, there is a perceptual gap between general people and the decision makers. In the recent phenomenon, about 55 percent of the world population are residing in urban areas whereas in 1950 it was about 30 percent. These days, the urbanization trends are very significant by population for instance in North America 82%, Latin America, and the Caribbean 81%, in Europe 74% and Oceania 68%. While the picture of the urban growth in Asia on an average 50% and Africa its 43% ([UN, 2018](#)). In the last two decades, due to rapid urbanization in Bangladesh is destructive of natural growth, people are destroying ecological/natural environment, besmirched historical monuments and finally the cost is so high in a sense of money and sustainable development. Most particularly, if we look in Dhaka the capital city of Bangladesh is the most vulnerable city in the world because of population, internal migration, air pollution, water pollution and many more genuine reasons. Accordingly, this city is now totally unable to carry the load of this growing populations' weight which is horrible ([ADB, 1998](#)). Because of unexpected traffic and people are

wasting their productive time on the way that also affects to the GDP of Bangladesh.

Keywords: ecology; biodiversity; GAP; rapid urbanization, sustainable development

BACKGROUND

Compared with other developing countries, rapid urbanization in Bangladesh is a rising phenomenon but anxiously affects urban sustainability in the wake of deficiencies in good governance. Effectively the rural poverty and vulnerability problems have been transferred to urban areas, predominantly in Dhaka the capital city of Bangladesh ([Rahman, G. 2008](#)). Urban development is a very challenging and complex issue due to housing and infrastructure, industrialization, lack of land and land use policy, water supply and waste management, traffic control, multidimensional pollutions and so on. Whispered, Dhaka is the number one polluted city in the world ([TBS, 2019](#)) due to cases and effects are involve that's mostly relevant to urban development. Climate change and its impact is also a key issue of urban development most particularly in Bangladesh where multi-implications are inbuilt in the planning process that is executed by develop centered plan. Where, neither consider biodiversity nor people centered development but it is highly expected that this development must be considered more eco-centered development pedagogy. Before that *the planners and decision makers* should consider this most significant part of its development planning but mostly neglected or did not consider it in every five-year plan. On the other hand, political willingness is one of the significant shortcomings in this rapid urban development in Dhaka ([Hussain, Z., 2013](#)). Ultimate result is developing urban areas with several inconsistencies and destroying ecology and historical monuments ([Rahman, G., 2008, Shovon, A. R., 2008](#)). The ultimate result of urbanisation is to increase building and construction, parks, museums, amusement areas, and industries. Besides, develop some hopes among the lower part of the city's inhabitants but top layer people got maximum benefits to utilising the hard labor of the

bottom part of the community (so called poor or labor class people).

It is important for proper planning and maintenance of urban open spaces such as parks and green belts around large cities where areas in the fringes of the city are reserved for vegetation. Planning of the transport system, where an appropriate strategy of road pricing may be introduced for specific areas within the urban area to deal with traffic congestion ([Dewan, A.M., M.H. Kabir, K. Nahar, and M.Z. Rahman, 2012](#)). Ensure the better management of existing road networks and effective traffic management. It is absolutely important that people need to address green cities and countrywide image building, urban governance, resource efficiency and coordination among agencies, policy coalitions and change makers for disaster preparedness ([Dewan, A.M., M.H. Kabir, K. Nahar, and M.Z. Rahman, 2012](#)); conservation of common resources for sustainable and climate resilient urbanization in Bangladesh like megacity Dhaka.

OBJECTIVE OF THE STUDY

This study aims to identify recent challenges in urban development and consequences of rapid urbanization in the short term and long-term impact on the environment as well as how impacting it in sustainable development in the name of urbanization. Meanwhile, what are the urban development trends in Dhaka and overall scenario of Bangladesh. Most prominently it is highly emphasised in this study that what are the environmental impact of rapid urbanisation in Dhaka ([Islam, N., 2005](#)).

METHODOLOGY

The study focuses on recent phenomenon of urban development in Bangladesh where rapid urbanization is the most significant area of discussion considering the qualitative analysis under anthropological pedagogy. In the first part of the study we authors choose secondary data as the main sources of this research work, where authors tried to figure out a comparative study as well prejudiced areas that's playing a significant role in the rapid

urbanization in Bangladesh ([Quader, A. K.M. A., 2000](#)). They also exasperated the underlying elements that are harmful of this swift urbanization ([Shovon, A. R., 2008](#)).

DEVELOPMENT SPECTRUM AND CONTEMPORARY THEORY

The development spectrum and the contemporary theories of growth accentuate habitually on capital and technology ([Ahmed, S.S., and Ahmed, M., 2017](#)). There is also a missing fundamental factor-geography of a country. Geographic units in terms of location, place, climate, resource endowments and environment are the constituent's elements of the engine of growth forming vast bundles of trade, transport, innovation, and talent ([Ahsan, M. M. and Rahman, M.H., 2018](#)). Generally, urbanization leads to industrialization. These two issues are closely linked in many ways. With the increasing economic development, dominance of the agricultural sector gradually diminishes, and industrialization takes place at an accelerated rate ([Islam, N., 2005](#)). Urbanization is positively correlated with industrialization which is traditionally happening. The level of urbanization in Bangladesh to total population is 28% but contribution of 28% population to GDP is 65%, Dhaka city consists of 9% of total population of Bangladesh but its contribution to GDP is near about 40%. ([BSS, 2015, ADB 2016](#))

In the twenty-first century, it is the most significant demographic transformation in our century because it rearranges national economies and reforms the lives of billions of people. In the recent statistics about 55% of the population globally lives in urban areas and about 1.5 million people are being added to the global urban population every week ([ADB, 2016](#)). Every year, urban areas are growing by a typical of more than 75 million people bigger than the population of the globe's eighty-five smallest countries collectively ([UN, 2018](#)). It is estimated that the world's population will reach 8.6 billion in 2030 and 9.8 billion in 2050. In 2010 people living 7.0 billion in the earth and more than two-thirds of the population will be living in cities in 2050 compared to about half of the population in 2010 ([UN, 2017 and ADB, 2016](#)). It is projected that in the developing countries entire urban areas will

expand triple between 2000 and 2030 from 200,000 sq km to 600,000 sq km ([BSS 2019, ADB 2016](#)). The additional 400,000 sq. km of newly urban built-up area that will be constructed within only 30 years equal the total built-up urban area throughout the world as of 2000. The number of megacities is also projected to increase to between 60 to 100 in 2050 from 22 in 2010, and these will be mostly in developing countries of Asia, Africa, and Latin America ([ADB, 2016, UN 2017, 2018](#)). These cities will face high levels of social, economic and environmental challenges due to increased road traffic congestion for augmented demand of transport, alongside both economic progress and enhanced living standards.

THE TREND OF URBANISATION POPULATION IN BANGLADESH

The urban population growth in Bangladesh prior to the twentieth century cannot be labelled rapid urbanisation in the accurate sense because the transformation in rural life associated with urbanisation was not evident ([Centre for Urban Studies, 1974](#)). The urban population growth in Bangladesh since 1901 is represented through the following eras. Only 2.43% of Bangladesh's population lived in urban areas in 1901([BBS, 1977](#)) but later, the next two decades the urban population continued almost immobile. Between 1911 and 1921 there was only an 8.85% increase ([BBS, 2015](#)) in the urban population in Bangladesh. In the recent trend it seems to that some building and constructions have been developing considering to the lower middle or middle class community ([Islam, N., 2005](#)) and developers are being benefited by many ways, for instance the handover time and commitment time never match because developers are always invest these money in multi project but they took these money from these community people by providing or showing hope of assets where they could live forever ([Huq, M. E., 2003](#)).

COMPARATIVE STUDY ON URBAN POPULATION IN DHAKA

In recent phenomenon, about 55 % of the world population is in the urban whereas in 1950 it was about 30%. These days, the

urbanization trends are very significant by population for instance in North America 82%, Latin America and the Caribbean 81%, in Europe 74% and Oceania 68%. While the picture of the urban growth in Asia approximately 50% and in Africa its 43% (UN, 2018). In the last two decades, due to rapid urbanization in Bangladesh is destructive of natural growth, people are destroying ecological/natural environment, besmirched historical monuments and finally the cost is so high in a sense of money and sustainable development.

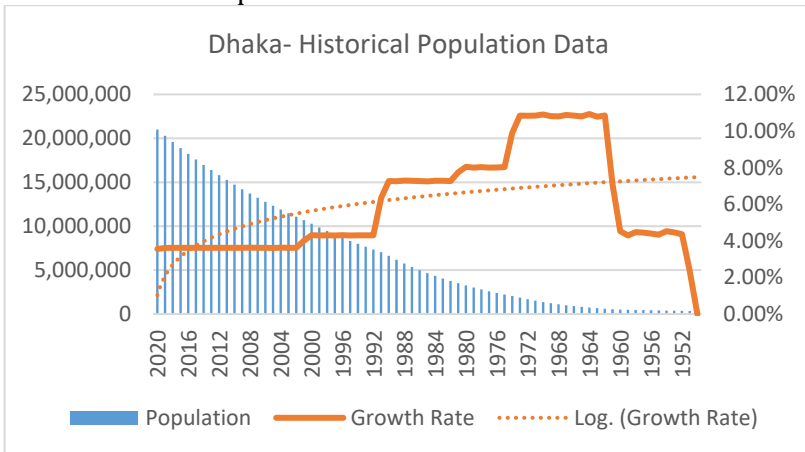


Figure-1: Historical Population Data, Dhaka

(Source: [Dhaka, Bangladesh Metro Area Population 1950-2020 | MacroTrends](#))

In the Figure 1, it has shown the population trends of Dhaka in last 70 years. In this historical population trends illustrates that in 1950 growth rate was about 0%, but 1962-73, 12 years growth rate was on an average 10.83% which was the highest growth rate average decade. Every decade the rate of population growth has been declined but the total population or cumulative figure is growing a lot. Through this analysis it is again illustrated that in 1950 the total population was 0.03 (0.0%) million, in 1960 it was 0.051 million (4.53%), in 1970 it was 1.37 million (10.90%), in 1980 it was 3.27 million (8.04%), in 1990 it was 6.62 million (7.27%), 2000 it was 10.29 million (4.31%), in 2010 it was 14.73 million (3.62%), 2020

it is 21.006 million (3.56% growth rate). In this figure 1 the Logarithmic line mention that over the period in 70 years population growth in Dhaka is in between on an average below 7% except in 1960 to 1991.

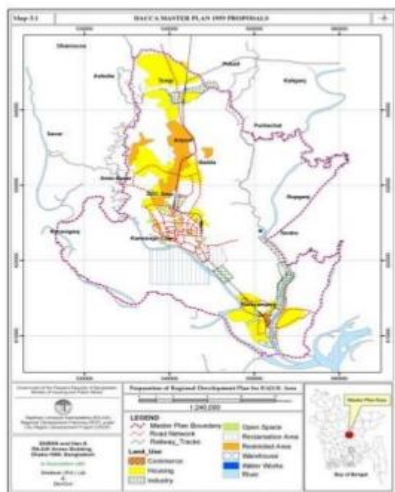


Figure-2: Dhaka City Master Plan 1961

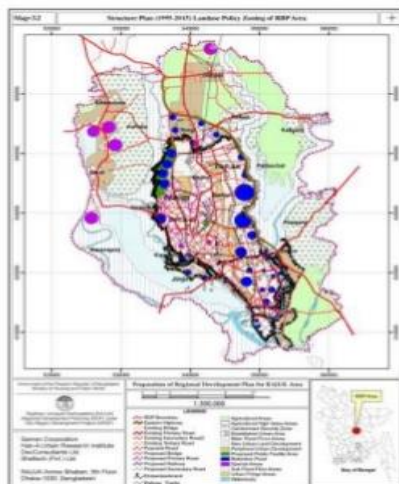


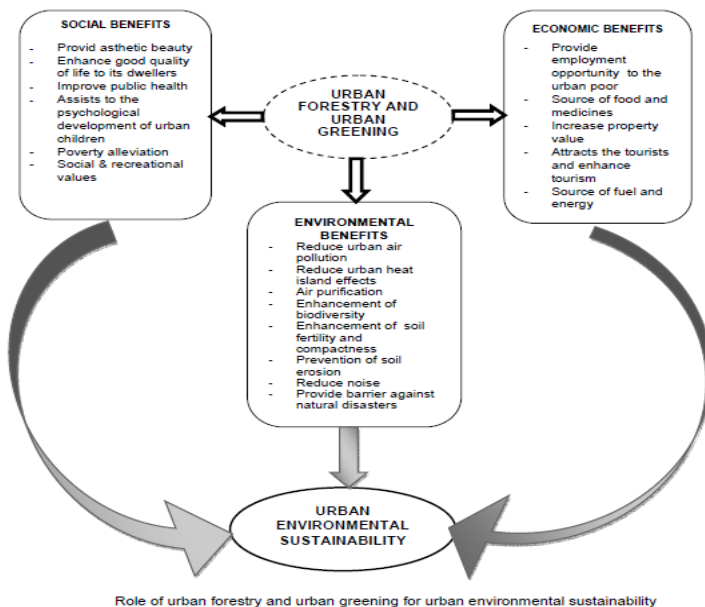
Figure-3: Dhaka Metropolitan Development Planning (DMDP)

There is an illustration through comparing the two maps of the Dhaka City Master Plan 1961 (Fig-2) and recent Dhaka Metropolitan Development Planning (Fig-3), ([Alam, M. J., 2018](#), [BBS, 2015](#)) where compared to 1961 plan and current plan in between there is a huge gap in planning over the time but a large number of population is living in this megacity in figure-1.

MAJOR CHALLENGES IN SUSTAINABLE URBAN DEVELOPMENT

In development, different countries have several challenges due to multi-environment and different culture and socio-economic conditions. In Bangladesh most significant challenges in the urban sector are housing and infrastructure, industrialization, lack of land, water supply and waste management, and multidimensional pollution. Government should address these

problems properly and need to take proper action to overcome these challenges ([Alam, M. J., 2018](#)). But what is happening in the urban development in Bangladesh. The Government is more focused on growth without developing a comprehensive development plan and how to executive this plan in a sustainable way including to consider SDGs achievement ([BBS, 2019, Ahsan, M. M, and Rahman, M.H., 2018](#)). The below figure has been addressing properly how *forestry and urban greening for urban environment sustainability*.



Role of urban forestry and urban greening for urban environmental sustainability

Figure-4: Role of urban forestry and urban greening for urban environment sustainability (Source: [S. Roy, S. Dutta and M. M. Hoque, 2016](#))

If we analysis the Figure 3 (*Role of urban forestry and urban greening for urban environment sustainability*) where we find if we try to establish a sustainable and green city, then we must consider forestation in the urban development plan and it must execute in the development process. This diagram also mentioned

that there is some social, economic, and environmental benefits and combined impact of these benefits are urban environmental sustainability. So, it has shown a clear picture of sustainable urban development.

URBAN DEVELOPMENT GAP IDENTIFICATION METHOD

In the developing world they are more consented as well as positively consider nature and their ecosystems in their urban development. If we look at their development works in the cities, they have a master plan including climate change, natural growth, balance of life as well as building and road construction are mostly eco-centered ([Alam, M. J., 2018](#)). But in Bangladesh the government and private sector have been investing a lot for achieving their return on investment for instant many Garments Industries and other multidimensional industries and factories are available in urban area and they are getting benefit more then they invested. In this regard, the cost of development is so high rather than other countries' urban development. In Bangladesh an overall challenge in livelihoods specially a large number of populations come to this megacity for ensuring their livelihoods and in most of the cases their hopes maximum reach into the slum dwellers as well as they have been passed year to year in these slum dwellers where life almost a prison. Meanwhile, they come to Dhaka with lot of hopes from their countryside due to several reasons like natural calamity- river erosion, flood, cyclone or manmade disaster ([Islam, N., 2005](#)), like local elite people captured their last piece of land in the name of debt (so called), fail to return of NGOs debt or other debt, even violence so called local elite or community people even though neighbors, even in many cases there is a Gender Based Violence ([Center of Urban Studies et al., 2006](#)).

Where are the main gaps in the way of urban development in Bangladesh? The authors have been figuring out the following gaps in the urban development in Dhaka, Bangladesh through the self-identified model.

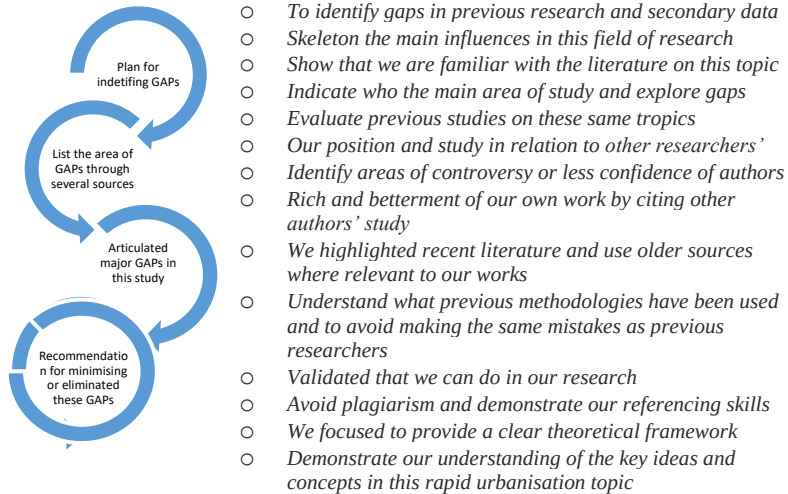


Figure-4: Framework of our study and urban Development GAP identification method

Identified major urban development GAPs are as shown as below for future consideration-

- *Planning gap is the main deficient among others because based on plan it must be executed*
- *Land use policy is not contemporary that is a massive gap for urban development*
- *Development plan is not considered biodiversity and eco-centered development*
- *Climate change is an important and significant issues, but it has considered very minimal*
- *General people's expectation does not consider which is highly important*
- *Water supply and waste management is much important for an urban, but it's observed that there is a gigantic planning shortfall in the Dhaka urban development*
- *Traffic management is very traditional that's less effective and people must spend on an average 30-40% productive time on the road*
- *Multidimensional pollutions have been observed in Dhaka and recently world number one in air pollution*

Throughout our study and analysis, urban development is a very challenging and complex issue due to housing and infrastructure, industrialization, lack of land and land use policy, water supply and waste management, traffic control, multidimensional pollution and so on. Whispered Dhaka is the number one polluted city ([ADB, 2016](#), [The business Standard, 2019](#)) in the world due to cases and effects are involve that's mostly relevant to urban development.

In Dhaka already over 13 million people are living and in 2025 it will reach 20 million or more population. But demand and supply of citizen essential services gaps are very high which is increasing day by day. According to the facts and figures of Farjana Islam¹ that the scale of gap that existed between supply and demand of basic urban services in the megacity Dhaka. Initially the supply of water in Dhaka is about 1700 million liters per day but demand is 2050 liters ([Alam, M. J., 2018](#)). That means, 30% people are under covered and the rest of 70% people are passing their daily life through alternative and different hazard sources of water and sanitation ([Ahmed, S.S., and Ahmed, M. \(2014\)](#)). It has shown how much uneven development or rapid urbanisation has been happening without considering its consequences. On the other hand, the people who live in this Megacity Dhaka, they know very well about waterlogging when rain falls a bit high and even when its fall as cats and dogs that's time suffering know no bounds. That's why its call the city is highly vulnerable to inundation when the rains come. According to [UN-Habitat's 2008](#) State of the World's Cities report, Dhaka is between 2 and 13 meters above sea level, so any rise in sea level poses a severe threat. It is the urban poor who live in water-logged and flood-prone areas, with 90% of slum dwellers sharing a single room with three or more people ([Dowall, David E., 1992](#)). In these high density, high-risk conditions, floods not only contaminate water supplies but mix with raw sewage and induce water-borne diseases.

¹ Farjana Islam is a young Bangladeshi planner. She graduated with a degree in Urban and Regional Planning from the [Bangladesh University of Engineering and Technology](#) in 2005, and then worked for three years as a planner in Savar Municipality in Dhaka

URBAN PLANNING AND ETHICAL VALUE

In Bangladesh ethical judgment in the urban planning process is lacking. The process of urbanization in Bangladesh is very rapid and with the rapid urbanization in Dhaka Megacity the natural environment has been seriously hampered. Water, air and soil have been polluted seriously ([Haque, J.M., 2004](#)). Due to excessive population and inadequate roads and lack of open space the city becomes unlivable. The rich enjoy all the modern immunities of life but most of the population are compelled to lead a miserable inhuman life. More than one third of the population lives in slums, the slums dwellers are deprived of basic human needs. Most of the citizens of Dhaka city have no access to pure drinking water which is very much essential for human existence. The roads and streets are under the control of the rich families, possessing private cars. Due to unplanned housing and roads, the general people have no right to use roads and streets and even they have no right to cross the roads safely. Even they are unable to walk in the footpath due to improper use of footpaths or sometimes these are occupied by hawkers or salespeople².

COMPETITIVENESS OF DHAKA MEGACITY

We author, other researchers, engineers, architects are very concerned about the **city competitiveness** is a dynamic and multi-dimensional concept and its importance and growth ([Ahmed, S.S. and Ahmed, M., 2014](#)). It describes a city's comparative advantage in attracting portable production features and its capability to leverage these returns to sustain growth in a fast-changing universal environment. The competitiveness of a city is depending on innovation, livability and connectivity in a global economy ([Ahmed, S.S. and Ahmed, M., 2014](#)). Empirical evidence suggest that cities with high innovation levels, a livable and high quality environment and internally and globally connected are more

² Authors experienced enough about the megacity Dhaka as he is living in this city last four decades.

economically successful, as they are attractive location for firms and workers Beautiful waterfronts, historical sites, echo park, sports facilities, good accommodation, comfortable transport system, industrial parks etc. are important for attracting foreign investment and economic growth ([Ahmed, S.S., and Ahmed, M.,2014](#)). Dhaka megacity alone shares more than half of the urban sector's contribution to GDP. This is important in examining the competitiveness of Dhaka.

The Dhaka city and its periphery are famous for garments and its relevant industries due to several reason for instance- law labor cost, low utility cost, low transportation cost. Considering all these Dhaka is the suitable place to the investor globally. Most of the garments industries in Bangladesh is mostly export oriented and where over 60% of factories are in Dhaka and its surroundings. The geographical concentration of factories in Dhaka and some districts gave them advantages in terms of access to skilled labor, lower transportation and other business transaction costs. This sector has gained comparative advantage due to the large pool of low-cost labor and low transportation costs due to co-location of industrial establishments and some supporting government policies. The government of Bangladesh has identified this sector as one of the 'thrust sectors' of growth of the economy and has provided significant support to its development. RMG is a highly competitive industry, driven by keeping labor, transportation, materials, and utility costs low. The profit of RMG is very low and factories engaged in manufacturing and retail of clothing, and apparel products are constantly seeking ways to keep costs down to maintain a competitive business edge ([Siddiqui, M.S., 2020](#)). Considering all these things a large number of populations are interested to come to Dhaka for ensuring their livelihood.

WORLD URBANIZATION PROSPECTS: THE 2018 REVISION

The world urbanization prospects 2018 ([UN, 2018](#)) and based on that document we found globally 55% of the world's population residing in urban areas in 2018 but in 1950 it was 30%. It has also projected that 68% would be the urban population in 2050 ([ADB, 2016](#)). Other significant regional scenarios are in North America

82% urban population, in Latin America and the Caribbean 81%, in Europe 74%, Oceania 68%, in Asia which is about 50% and in Africa 43% population live in urban areas, comparatively very low then the rest of the world. ([UN, 2018](#)).

SUSTAINABLE URBANIZATION AND CURRENT TRENDS

The world is continuing to urbanize, sustainable development depends increasingly on the successful management of urban growth, especially in low-income and lower-middle-income countries where the most rapid urbanization is expected between now and 2050 ([ADB, 2016](#)). Bangladesh is going ahead in the same way, but its planning and execution is not modern-day. Integrated policies to improve the lives of both urban and rural dwellers are needed, solidifying the linkages between urban and rural areas and edifice on their existing economic, social, and environmental bonds ([Center of Urban Studies et al., 2006, Dewan, A.M., M.H. Kabir, K. Nahar, and M.Z. Rahman, 2012](#)).

Transport is the life of a city and choices on public transit options are essential pronouncements about a city's future growth and development. It is a key infrastructure sector that acts as a stimulus to economic growth and development, and an important element of strategies for poverty reduction, regional integration and national development including the environmental objective of limiting GHG emissions ([Huq, M. E., 2003, Islam, N., 2005, ADB, 2016, UN, 2018](#)). As transport is one of the major contributors to global warming through burning fossil fuels, this sector could be one of the prime sectors where policies aiming to reduce GHG emissions will be most important ([The business Standard, 2019](#)). Sustainable transport that emphasizes the use of public transport, bicycles and walking, and discourages the use of individual motorized vehicles like cars and motorcycles is essential to achieve many of the proposed SDGs and the 2030 agenda for sustainable development and it is, therefore, mainstreamed across several SDGs and targets, especially those related to food security, health, energy, infrastructure, cities, and human settlements ([UN, 2018](#)).

CLOSING REMARKS

The paper focused more on to dig-out the gaps in planning and its execution in urban development especially in Dhaka, Bangladesh. They also acknowledge and take consideration to climate change and its impact which is also a key issue of urban development most particularly in Bangladesh due to multi consequences are inbuilt in the planning process. Before that the planner and decision makers should consider this most significant part of its planning but mostly neglected or did not considered highly expected sustainable development ([HUSSAIN, Z., 2013](#)), i.e. i) eco-centered development means minimal degradation of natural resources, and ii) less pollution based development or must be follow environmental assessment procedure and guideline during development planning and in an action ([Ministry of Environment and Forest. 1996](#)). That is also the lead focus in SDGs and the Bangladesh government has significant consideration but in planning we figure out a huge GAP in implementation. On the other hand, political willingness is one of the substantial deficiencies in this rapid urban development in Dhaka as well as in Bangladesh. In this study, the author also analyses the plan and the real-life scenario and identified that the institutes/organizations (BAPA, DoE, BELA) who are more concerned on about the environment are also failing to reduce the GAP. It is also very significant that the corporate social responsibility and public private partnership initiatives could add more value for ensuring sustainable urban development for the developing world like Dhaka.

RECOMMENDATION

- *For reducing planning gap all stakeholders and general people representatives (civil society representation or any other format) must be included in the planning and implementation process*
- *A comprehensive and modern **Land Use Policy** must be developed where government, civil society representatives, NGOs (expertise on this area), national and international experts can work. It is highly important to be established a*

contemporary land use policy for a sustainable urban development by reducing all massive gaps ([Dewan, A.M., Y. Yamaguchi, and M.Z. Rahman, 2010](#), [Dewan, A.M., M.H. Kabir, K. Nahar, and M.Z. Rahman, 2012](#));

- Every urban development plan must be considered biodiversity and eco-centered development by written and environmental assessment must be built-in in all development interventions
- Climate change is a vital issue due to multi-dimensional consequences and for this reason it has considered comprehensively
- For ensuring sustainable and eco-centered development general people's perception is must to consideration because ultimately, they would be the main beneficiary of all these developments
- Water supply and waste management is much important for rapid urbanization or today's cities or mega cities, like Dhaka but it's observed that a gigantic planning shortfall in the Dhaka urban development which must be reduced at tolerance level
- For improving and increasing productive time for the inhabitants of the Megacity Dhaka there is no alternative of a contemporary "Traffic Management System" in this city
- We may not consider the Mega City Dhaka as a world number one polluted city. So, all kinds of necessary initiatives must be taken for reducing pollution for instance- modern river, canal and drainage management system must be implemented, to apply a contemporary wastes management system and industries either must be under the green management system or shifted to other location that's why any remote environmental hazard may not impacted in this mega city

In the recent century it is notable that urban centers are the heart of economic growth and centre of all innovation and empowerment considering all development aspects ([Quader, A. K .M. A. 2000](#), [Rahman, G. 2008](#)). It contributes over eighty percent of the global

GDP, plays a critical role in people's normal life and is crucial to accomplish the sustainable development goals (SDGs). However, the speed and scale of urbanization brings challenges, including meeting accelerated demands for affordable housing, sustainable and inclusive transport systems and other infrastructure, basic services, and jobs, particularly for the nearly 1 billion urban poor who live in informal settlements to be near opportunities. Global climate change and its current and potential consequences for life, property and prosperity are now accepted as the major challenge for human society in the next 100 years ([The business Standard, 2019](#)). By 2030, without significant investment to improve the resilience of cities around the world, climate change may push up to 77 million urban residents into poverty ([UN, 2018](#), [ADB 2016](#)). So, developing a sustainable city along with its basic infrastructure is of utmost important to ensure future sustainability. Building cities that “work”—are inclusive, safe, resilient, and sustainable—requires intensive policy coordination and investment choices. Consequently, city-level actions will be a central part of sustainable development initiatives, where the world needs comprehensive and sustainable urbanization as a landmark in the path towards socio-economic development, as documented by SDG Goal 11: Sustainable Cities and Communities.

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STATUS OF NOISE POLLUTION IN RAJSHAHI CITY

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Abstract

Noise is an Environmental Pollutant, another outcome of the technological era. With this background, the present study has been carried out to assess the status of noise pollution based on different land use in Rajshahi city. This study was conducted in 38 locations of Rajshahi city, by using portable Noise Meter (Model: SD4023). The study has affirmed that the maximum noise mean was in 85.72 dBA and minimum noise mean 54.88 was found at silent area and residential area. Study also found that the higher ranges of sound was found in the industrial area (78.89 dBA). It further found that none of the values was within standard level of silent and residential area. The most polluted place found in the city was Hakim rice where the noise level was much higher than the standard level. It was also observed from this study that the noise level generally exceeded the National Standard Level in all the locations of the city.

Keywords: Noise level, Land Use, Rajshahi, Bangladesh

INTRODUCTION

The noise pollution is considered as a great problem like other environmental problem (Haq et al., 2012). “Loud and unpleasant” sound that exceeds the acceptable level and creates annoyance can be defined as a noise (Razzaque et., 2010); Extremely annoying,

mood swings, mutual relationship ruining, increasing the fluctuations, hearing impairment, high blood pressure, irregular heartbeat, headache, indigestion, peptic ulcers, and insomnia are caused by noise pollution, which is called a silent killer (*Chaudhary and Chaudhary, 2020*). To say a little bit more specifically, noise pollution refers to the possibility of hearing loss due to the over limit of hearing of humans or any animal (Jariwala et al., 2017).

Automobiles are an important source of air pollution and a significant proportion of noise pollution (Majumder and Bhochhibhoya, 2007). The level of noise pollution is very closely related with urbanization and motorization (Chowdhury et al., 2010). Unplanned urbanization, lack of regulation in industrialization (machine's machine noise, generator noise, heavy machinery noise), use of technology in home (blender, various types of machines), vehicles, increasing use of hydraulic horn in trains and vessels, VIP / emergency horn, airplane and rocket noise, And the change in the lifestyle of man (using the microphone, Use of mike in family or religious affairs, political assembly, open concert, mike playing campaign) are the main reason for noise pollution (Ismail and Ahmed., 2018). The World Health Organization (WHO) recognizes noise pollution as the main cause of the auditory reduction. In addition to noise pollution, due to inherited factors, birth defects, certain infectious diseases, chronic ear infections, side effects of medicine, excessive noise and senility, usually decreases the hearing or loss of hearing (Majumder et al., 2010, Majumder., 2018). People from all walks of life due to noise pollution are temporarily or permanently deaf. But students, children, hospital patients, traffic police, pedestrians, and drivers are most affected due to noise pollution. A study conducted by WBB trust in Dhaka found that 97% of students were disturbed by horns and among the general population; 78% experience aggravation, 71% experience headaches, 49% bad temper, 43% difficulty concentration and trouble sleeping, and 33% experience hearing problems from noise pollution. The reason behind choosing Rajshahi City is that it has gone through rapid and haphazard urbanization and experienced a massive increase in the number of vehicles and industries in recent years. Rajshahi City ambient noise

quality usually crosses international guidelines by 2/3 folds. This has potential adverse impacts on the environment and the health of people. The different Rajshahi **City sites** where the vehicular flows are high compared to other sites were of particular interest in this research.

METHODOLOGY

Study area is the selected area which is Rajshahi which locale is arranged between on 24.3733° N, 88.6049° E line. 40 areas were chosen on premise of the utilize of arrive. After that, all areas were isolated concurring to the utilize of arrive into seven sorts, which are sensitive, residential, mixed, commercial, road intersection, industrial, and village zone. There are a add up to of 6 delicate zones were chosen that counting healing centers and clinics, schools, colleges, mosques, madrasas, and authoritative Bhaban. On the other side, mixed areas contain bazaars, buildings, primary streets, etc. Rest 34 areas were categorized as; 5 locations, mixed areas; 5 locations, commercial areas; 7 locations, road intersection or busiest road junctions and bends; 6 locations, industrial area; 5 locations and village area; 6 locations.

GPS data was also collected by an android software name as GPS Location Camera, A noise level meter (REED SD-4023) was used for ambient sound pressure level monitoring in the concerned area. The survey was performed on working days. The measurement was carried out for major traffic intersection of the city. The sound pressure level of the traffic zone was measure by A-weighting. This SD series sound level meter has triple range measurement and features user selectable sampling rates from 1 to 3600 seconds. Using an SD card (up to 16 Gb) a user can select a desired sampling rate and quickly generate an Excel file with raw data, all without the use of software.

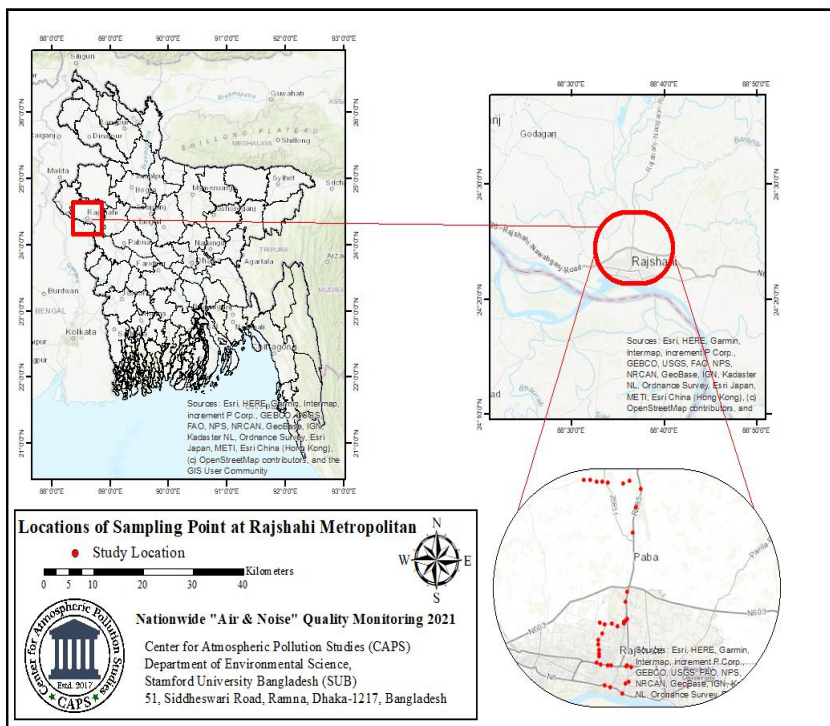
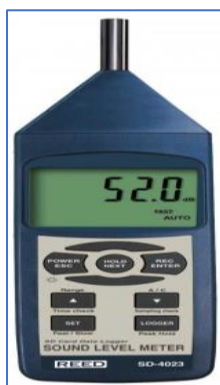


Figure 1: Study Area (Rajshahi Metropolitan Area)



Optional accessories include a tripod and AC adapter for continuous long-term monitoring and PC software that allows a user to tracking live measurements. Data was collected in numerous times in a day from morning to late evening at Rajshahi Metropolitan zone. Sharing the instrument detail within the underneath.

RESULT AND DISCUSSION

Analysis of data from six points of silent area of Rajshahi City shows that the highest noise recorded was 104.90 decibel in the main gate of Rajshahi Mohila Technical Training Center, which is more than twice the silent area's daytime standard (50 dBA). The lowest recorded in the Rajshahi Development Authorities area was 52.90 decibel, higher than the tolerable daytime standard level. The analysis also found that (table-1) the Leq (equivalent continuous sound level) all-inclusive silent area of Rajshahi Metropolitan was 82.09 dBA which is 1.6 times higher than silent area's daytime standard (50 dBA) determined by Department of Environment. This study also found traffic noise (L10) was noted 83.06 dBA. The background noise (L90) calculated values 61.3 dBA and Mid-level noise (L50) calculated value 70.9 dBA.

Study also analysis 5 residential areas of Metropolitan area, figure 3 Noise level in residential areas despite the maximum noise level found at the area Tanzimul Ummah Hifez Madrasa R/A which was 111 dbA, and minimum noise listed at 49.70 at Cristian Para. Table-1 shows the residential area's Leq (equivalent continuous sound level) found 92.81 dBA at Tanzimul Ummah Hifez Madrasa R/A. Daytime standard noise levels for mixed areas by Department of Environment 55 dBA. Where Leq (equivalent continuous sound level) in all-inclusive residential area of Rajshahi Metropolitan was 85.75 dBA which is 1.5 times higher than mixed area's daytime standard. This study also found traffic noise (L10) was 82.4 dBA, the background noise (L90) calculated values 59.3 dBA and Mid-level noise (L50) calculated value 68 dBA.

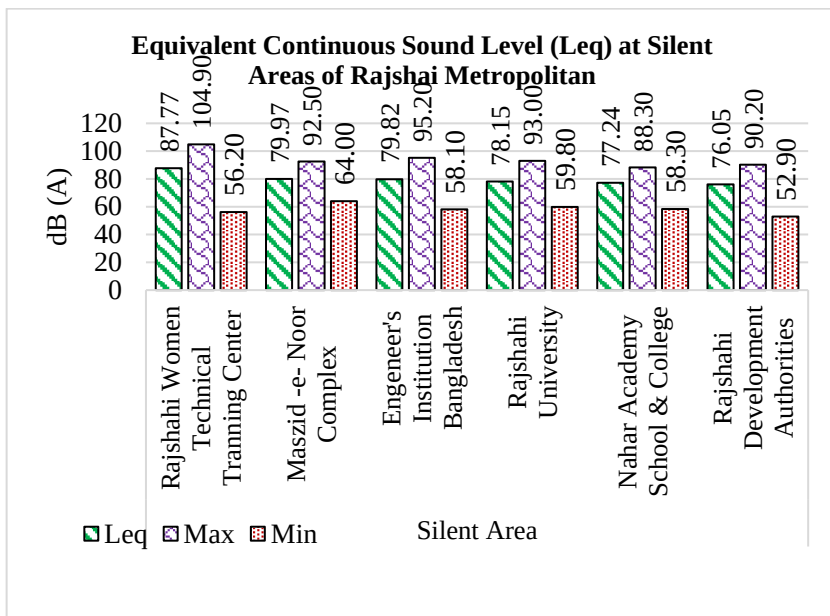


Figure 2: Average noise level in Silent areas

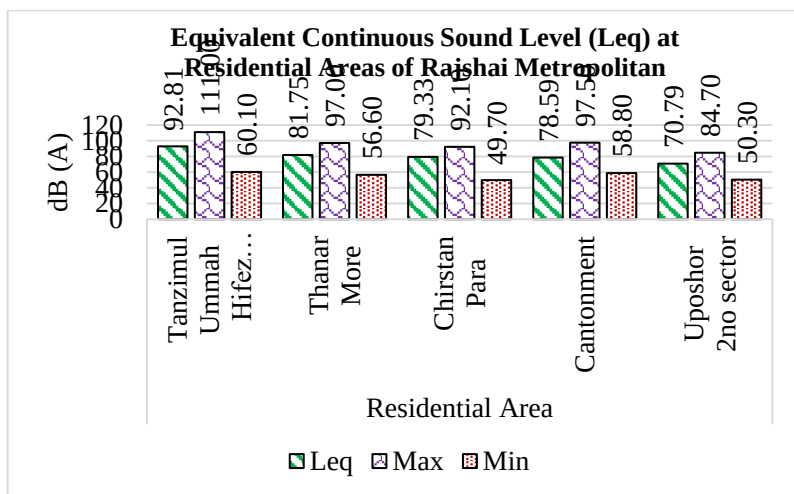
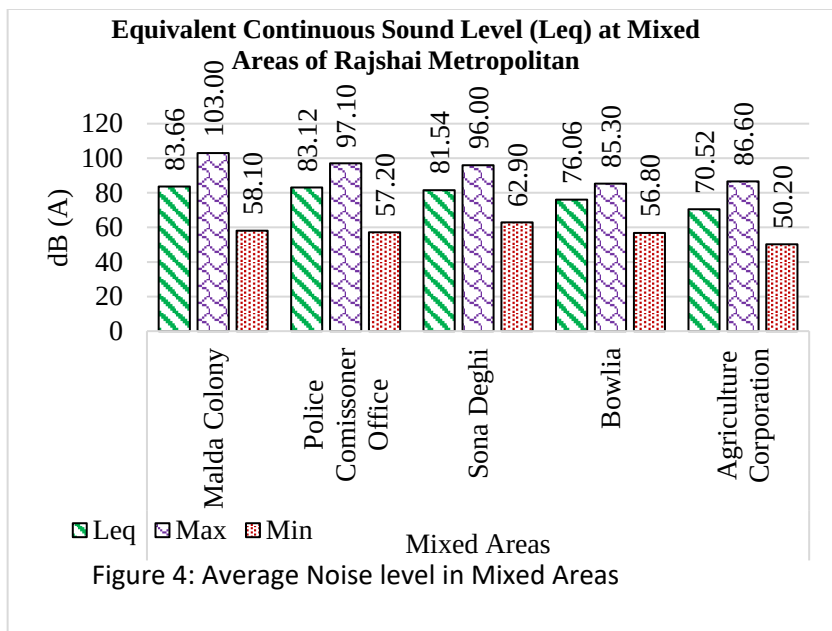


Figure 3: Average Noise level in Residential Areas

Figure 4 illustrates Equivalent Continuous Sound Level (Leq) at Mixed Areas of Rajshahi Metropolitan. Maximum 103 Decibel at Malda Colony and minimum 50.20 Decibel minimum at Agriculture Corporation. The maximum noise level is significantly high than the mixed area's daytime standard (60 dBA). Table-1 express Leq (equivalent continuous sound level) in all-inclusive mixed area of Rajshahi Metropolitan was 81.14 dBA which is 1.3 times higher than mixed area's daytime standard. This study also found traffic noise (L10) was 82.2 dBA, the background noise (L90) calculated values 59.5 dBA and Mid-level noise (L50) calculated value 70.2 dBA.



The Standard value for commercial area is 70 dBA in contrast figure-5 shows that commercial area of Rajshahi District shown the highest 104.50 dBA at the area of Raj Market. and lowest found 53.80 dBA at Bus Stand area. In table-1 there is all inclusive Leq (equivalent continuous sound level) for commercial area of

Rajshahi Metropolitan was 85.85 dBA which is 1.2 times higher than commercial area's daytime standard. This study also found traffic noise (L10) was 87.57 dBA, the background noise (L90) calculated values 63.13 dBA and Mid-level noise (L50) calculated value 75.5 dBA.

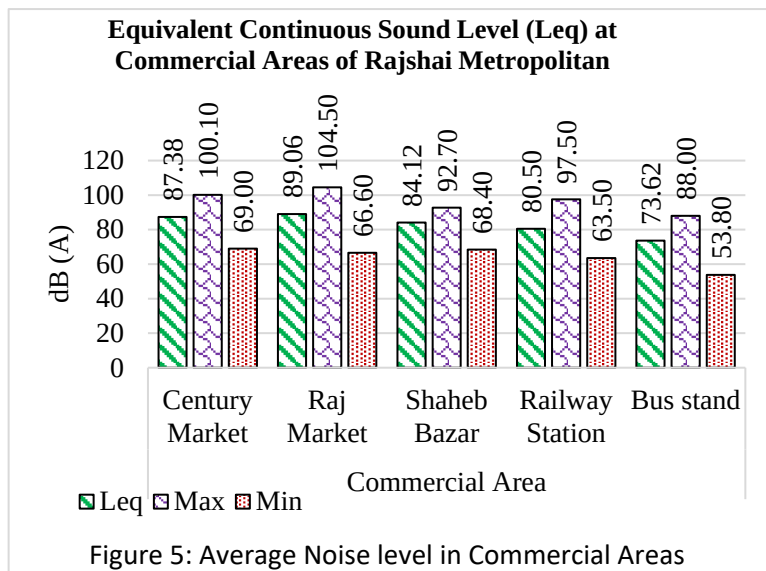


Figure 6 despite the highest maximum noise found at industrial area of Rajshahi metropolitan area is 129.60 dBA at MRF factory area and minimum reported at Hoque Rice Mill area which is 52.40 dbA. All-inclusive Leq (equivalent continuous sound level) for industrial area (table-1) of Rajshahi Metropolitan was 107.91 dBA which is 1.4 times higher than commercial area's daytime standard 75dBA. This study also found traffic noise (L10) was 92 dBA, the background noise (L90) calculated values 77.4 dBA and Mid-level noise (L50) calculated value 66.8 dBA.

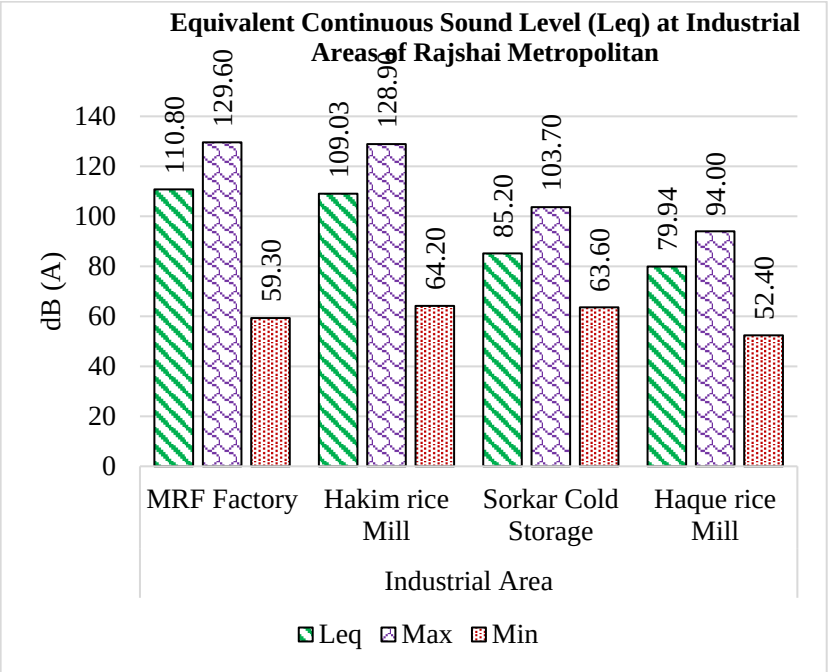


Figure 6: Average Noise level in Industrial areas

In the Road Intersection maximum and minimum noise level recorded at Talaimari mor which are respectively 114.20 dBA and 62.20 dBA (figure-7). Table-1 shows that, Leq (equivalent continuous sound level) for all-inclusive road intersections of Rajshahi Metropolitan was 87.08 dBA. This study also found traffic noise (L10) was 87.7 dBA, the background noise (L90) calculated values 68.9 dBA and Mid-level noise (L50) calculated value 76.95 dBA.

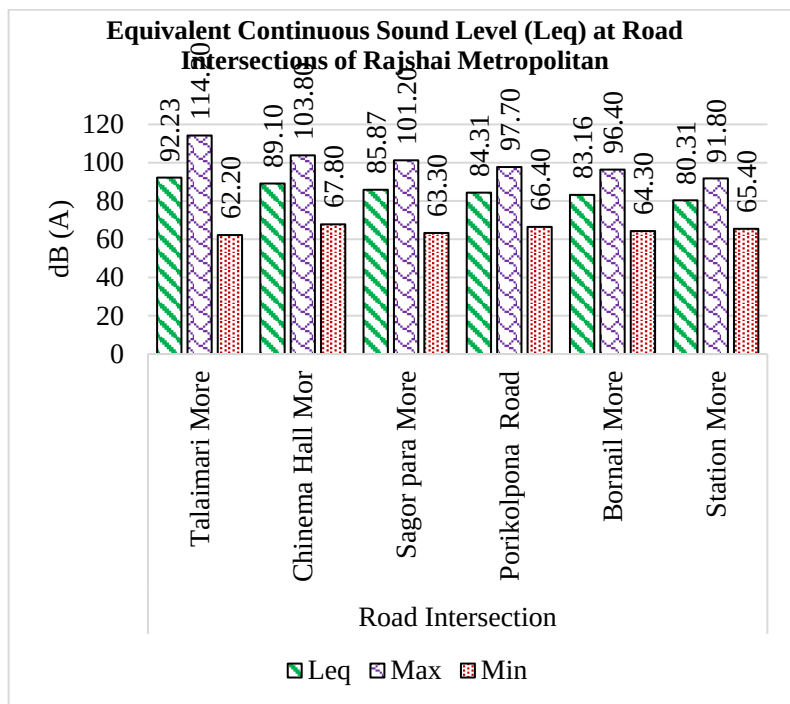


Figure 7: Average noise level in Road Intersections

The village area (Figure 8) showed significantly high at Mohanonda 116.10 dBA and lowest 45.50 dBA at Cowbaria. Table-1 shows that, Leq (equivalent continuous sound level) for all-inclusive village areas of Rajshahi Metropolitan reported 98.35dBA. This study also found traffic noise (L10) was 78.22 dBA, the background noise (L90) calculated values 53.9 dBA and Mid-level noise (L50) calculated value 63.6 dBA.

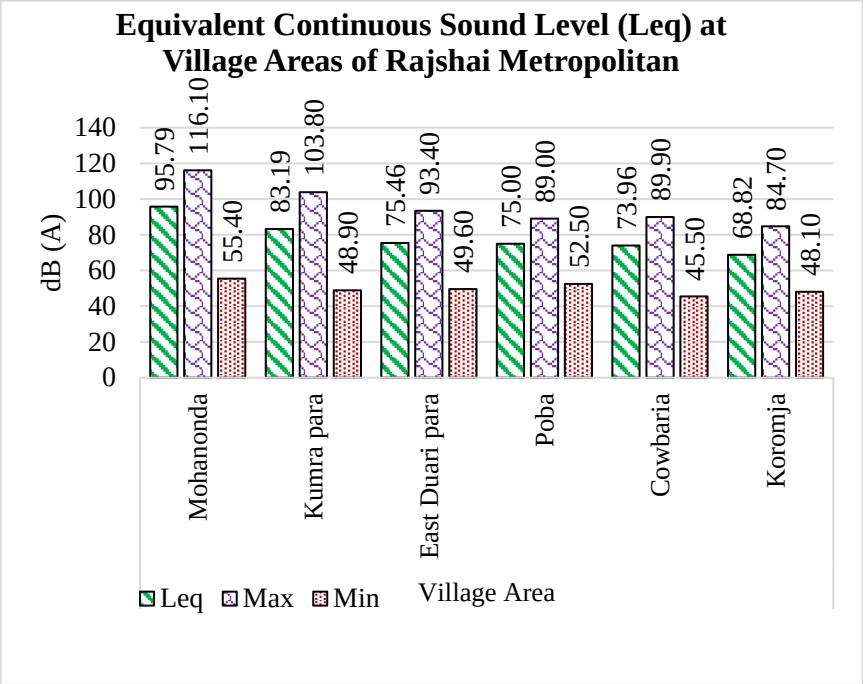


Figure 8: Average noise level in Village Areas

The subsequent Table 1 presents the descriptive statistics for the Noise quality of the study. Seven land uses. The higher equivalent noise level (Leq) found in the industrial area 107.91 dBA, and the area is almost the nearby to road intersection and commercial area, and lower equivalent noise level (Leq) found in the mixed area (65.27 dbA). Overall noise level at Rajshahi Metropolitan area’s is not satisfactory, equivalent noise level (Leq) found 98.35dBA which is 1.6 times higher than mixed areas standard (60 dBA) if whole Rajshahi consider as mixed area. This study also found traffic noise (L10) was 85.9 dBA, the background noise (L90) calculated values 59.9 dBA and Mid-level noise (L50) calculated value 72.5 dBA

From the comparison of mean, standard deviation, and coefficient of variation it observed that the highest variation in the residential area which means that future study for this zone. The

whisker box plot (Figure-9) shows average noise pollution in Rajshahi City. A horizontal black line marks the median. The lower boundary of the box indicates the 25th percentile. The upper boundary of the box indicates the 75th percentile. The whisker represents the maximum (upper *whisker*) and minimum value (lower *whisker*). Points above the whiskers indicate outliers.

Table 1: Equivalent noise level (Leq) and Ln value (statistical noise levels) at different land use of Rajshahi metropolitan.

S . N .	Land Use and Daytime Standard	Leq (dBA)	Max (dBA)	Min (dBA)	L10 (dBA)	L50 (dBA)	L90 (dBA)
1.	Industrial Area (75 dBA)	107.9 1	130.2	52.4	92	77.4	66.8
2.	Village Area	98.35	126.9	45.5	78.22	63.6	53.9
3.	Road Intersection	87.08	114.2	62.2	87.7	76.95	68.9
4.	Commercial Area (70 dBA)	85.85	109.4	53.8	87.57	75.5	63.13
5.	Residential Area (55 dBA)	85.75	111	49.7	82.4	68	59.3
6.	Silent Area (50 dBA)	82.09	104.9	52.9	83.06	70.9	61.3
7.	Mixed Areas (60 dBA)	81.14	103	50.2	82.2	70.2	59.5
	Total	98.89	130.2	45.5	85.9	72.5	59.9

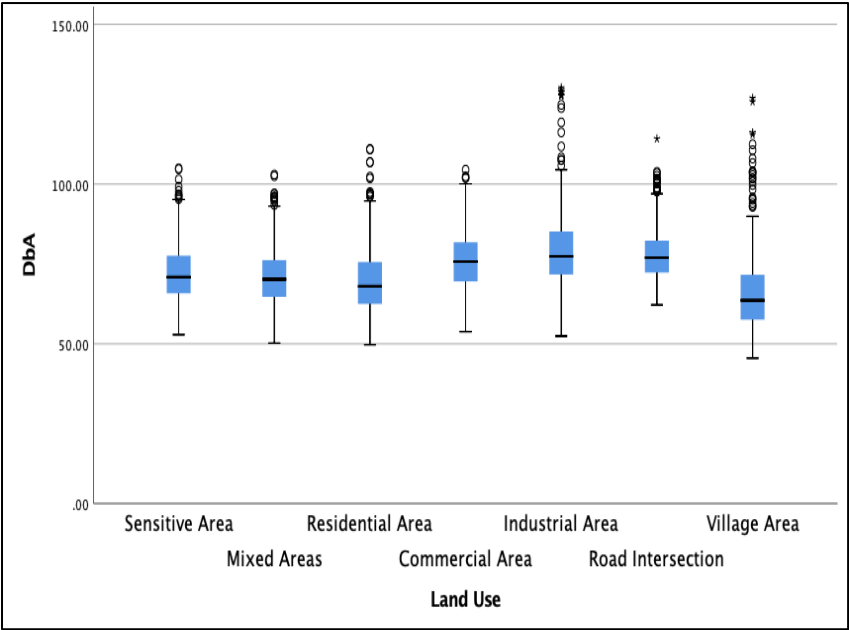


Figure 9 : Average Noise Pollution oh Rajshahi City

Figure 10 shows the Noise level at different places of Rajshahi City. Yellow areas have limited while rising higher levels shown in orange and red. The noise was found to higher (77-81 dbA Comply with Noise standard (2006) Table 2 shows, there are none of value shown with in standard level of Silent and Residential Area. But, 48.99% within the standard in Agriculture Corporation, which stands Mixed Area, on the other hand, 73.31% were found on Bus Stand Area at Commercial Zone. In the industrial area highest 66.22% with in standard level reported at Hoque Rice Mill Area.

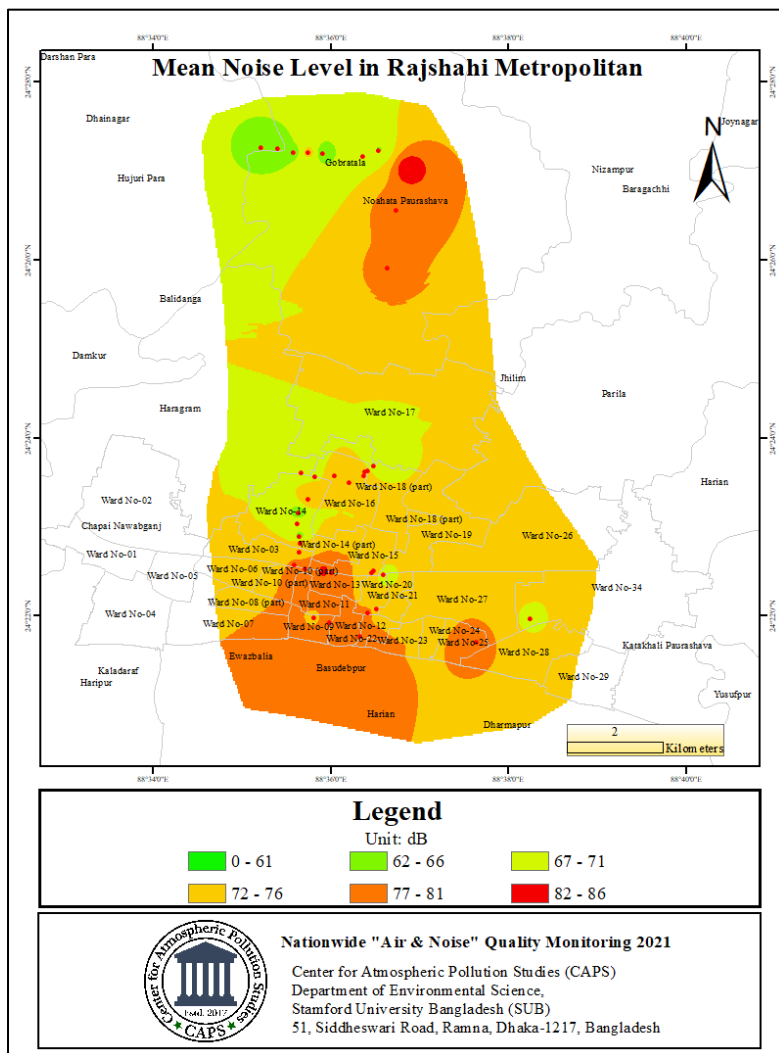


Figure 10: Spatial Map of average noise pollution

Table 2: Comply with Noise standard (2006)

Land Use	Location	Standard (day time)	Within Standard (%)
Silent Area	Engineer's Institution Bangladesh	50	0%
	Masjid -e- Noor Complex		0%
	Nahar Academy School & College		0%
	Rajshahi Development Authorities		0%
	Rajshahi University		0%
	Rajshahi Women Technical Tranning Center		0%
Residential Area	Cantonment	55	0%
	Chirstan Para		5%
	Tanzimul Ummah Hifez Madrassa		0%
	Thanar More		0%
	Uposhor 2no sector		4.73%
Mixed Areas	Agriculture Corporation	60	48.99%
	Bowlia		4.09
	Malda Colony		2.03%
	Police Comissoner Office		3.38%
	Sona Deghi		0.00%
Commertia l Area	Bus stand	70	73.31%
	Darusha Bazar		42.07%
	Railway Station		29.39%
	Raj Market		1.19%
	Century Market		2.53%
	Shaheb Bazar		2.03%
Industrial Area	Hakim rice Mill	75	18.51%
	Haque rice Mill		66.22%
	MRF Factory		33.21%
	Sorkar Cold Storage		41.25%
			100.00%

CONCLUSION

In Rajshahi City, the most source of clamor contamination is vehicles; it ought to be permitted to move as these were less pollutant emanating vehicles within the city zone. We have to be ensured not to utilize the weight horn. Activity administration in urban and semi-urban cities, counting Rajshahi City, ought to be logical so that less blares are made by vehicles. Activity stream and speed of vehicle activity are exceptionally crucial to clamor contamination. Subsequently, it is proposed that all sorts of vehicle ply maintaining a speed not less than 30-40 km per hour in urban regions. Vehicular commotion testing administrations ought to be trusted by private segments, such as vehicle repairing stations. But they got to be authorized by government organizations. A public mindfulness campaign ought to dispatch approximately the causes and source of commotion contamination through the start of both government and non-government segments. The foremost extremely contaminated zones are moreover required to organize transportation control measures; for illustration, measures to diminish automobiles with ruddy stickers are yelled close the school, healing center, and other open places.

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MANAGING COVID-RELATED PPE WASTE THROUGH ENERGY RECOVERY AND PROVIDING HEMP FACE MASK AS AN ALTERNATIVE: INNOVATION AND EMPLOYABILITY

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Abstract

Every year, around 300 million metric tons of plastics are manufactured for various consumptions (Singh & Sharma, 2016). Polyethylene (PE) and Polypropylene (PP), Polystyrene (PS) resins, Polyester, Polyamide, and Acrylic fibers (PP&A) are some of the most commonly produced materials (Hossain et al., 2020). The issue is that these components can take up to 1000 years to decompose, which has a direct impact on environmental pollution and consequent climate change (Browne et al., 2011; Laurance, 2019).

The current COVID-19 pandemic has resulted in widespread use of single-use plastics such as Personal Protective Equipment (PPE), commonly used in clinical settings. According to the World Health Organization (WHO), PPE materials will increase by 40% each month to effectively combat the pandemic (Markets and Markets, 2020). Bangladesh, a lower middle-income country with one of the

world's largest populations, has already suffered from poor biomedical waste management, but is now being seriously impacted by the sudden exposure to the massive COVID-19 plastic garbage. A recent survey showed that COVID-19 generated 890 tons of single-use masks and shopping bags as waste on March alone (European Environment Agency, 2021). Another study found that 13% Bangladeshis lost their jobs and another 45% had a reduced income due to this pandemic (BIDS, 2020; The Daily Star, 2020).

The objectives of this study are: a) better manage COVID-related single-use biomedical plastic waste by employing an energy recovery method, b) making face masks from hemp, which is easily biodegradable, so these masks will help to reduce plastic pollution and ensure environmental justice, c) focusing on local women's employment so that women can contribute to family maintenance-ending gender discrimination and ensuring equality. This study directly relates to Sustainable Development Goals (SDG) 2030 like SDG 8: Decent work and economic growth, and SDG 13: Climate action.

This study employed a narrative literature review. We searched Google and Google Scholar by using the key phrases "hemp as an alternative to plastic" and "waste management and energy recovery from single use face mask". We also solicited expert advice on hemp fiber extraction and its potential in the Bangladesh agricultural sector to replace single-use plastic masks, and how to create jobs. The outcomes have been used to propose a sustainable process to manage single-use mask waste and produce hemp-masks in Bangladesh that will also create employability.

The narrative review yielded 27 papers. Results suggest that for the energy recovery process, pyrolysis can be used to manage single-use mask and other PPE. This study also found that hemp mask is a viable alternative to single-use mask. We found three major steps were involved in hemp-mask production: a) cultivation, b) fiber extraction, c) fiber formation. By cultivating 750 plants on 5 katha lands, 100 kg fibers will be yielded. This fiber will be used to make 5000 reusable face masks and it will only cost BDT 269,200. If each mask is sold for BDT 75, there will be a profit of BDT 105,800. This project will employ 20 people as well. Hemp fiber has the potential to

be a viable alternative to plastics given it is considered the most sustainable crop in the world.

INTRODUCTION

Plastics were invented in the early 1900s and were originally employed to replace traditional materials like ivory, rubber, and shellac. Millions of extra plastic goods were produced after World War II. Plastics have changed medicinal products using life-saving apparatus, space-saving, light cars, planes and fuel and pollution-saving devices (Hosler et al., 1999). Plastics are mainly composed of synthetic or semi-synthetic organic elements. Europe produces some of the most popular materials worldwide, including polyethylene (PE) and polypropylene (PP), polystyrene (PS) resins, polyester, polyamide, and acrylic fibers (PP&A). Some of these products are also produced worldwide (Hossain et al., 2020). Every year, worldwide for different consumptions around 300 million metric tons of plastics are produced (Singh & Sharma, 2016). Nearly half of all plastic trash produced in the production process consists of single used plastics, notably plastic bags, straws, stirrers, and clam shells. 29.70% are burnt, 23.70% recycled and 46.60% are discharged straight into the environment (NRDC, 2021). The use and consumption of plastic by many sectors across the globe has been expanded. Packaging industry is the main user in plastics (consumers over 36% of worldwide plastics produced). This industry is also the world's largest producer (Tsakona and Rucevska, 2020). Plastic is a polymer type used in all areas, from the food packaging industry to the electrical sector. The chemical link of plastic molecules makes it resistant to the many natural processes of breakdown. Plastic garbage does not degrade, it accumulates on sites of waste and aquatic surroundings (Browne et al., 2011; Laurance, 2019).

Because of its astounding rapid spread, the coronavirus COVID-19 pandemic has become the most prominent problem since 2020. Recent research has classified the current coronavirus disease 2019 (COVID-19) pandemic as a syndemic because of its long-lasting susceptibility (Gravlee, 2020). The United Nations Framework for Urgent Economic and social Responding to the

COVID-19 Crisis has already generated concerns about the COVID-19 outbreak's impact on health, social, and economic systems (UNDP, 2021).

The modern-day COVID-19 pandemic imparted a gross use of single-use plastics in Personal Protective Equipment (PPE), typically utilized in clinical sectors like masks, face shields, goggles, gloves, aprons to shield the health professional staff from COVID-19 affected persons, pathogens, and contaminants. Recent research confirmed the worldwide marketplace for PPE raised from approximately \$40 Billion to \$58 Billion from 2016 to 2020 with a compound price of growth of 6.5% in step with year; in contrast, the World Health Organization projected that PPE materials need to grow through 40% month-to-month to deal the COVID-19 pandemic effectively. Since the COVID-19 outbreak, improved manufacturing and random makes use of plastic-primarily totally based PPE equipment, polyethene, single-use plastics like one-time-use plastic glasses, cups, plates for remoted sufferers and fitness caregivers were improved predominantly, that have led to a fast accumulation of probably infectious home stable waste streams (Markets and Markets, 2020).

Bangladesh, a low and middle-income economy and one of the most populous in the world, has already suffered from poor biomedical waste management, but is now severely affected by the sudden exposure to the huge COVID-19 plastic waste used by professionals by people in the General. The country's waste disposal facilities are insufficient to meet their needs (Rahman et al., 2020).

During this COVID-related pandemic, the unemployment rate has increased to 5.3% from 4.2% (Trading Economics, 2021), which is an 25.59% increase than the previous year (Knoema, 2021). Recently, Biosciences Innovation and Growth Team (BIGD), in collaboration with Australia's Monash University, carried out a study on the lightweight construction sector that showed that 42 % of male workers who were employed in February 2020 were unemployed during the shutdown and 15 % after the lockdown in contrast, the corresponding rates for women were 51% and 38 percent, respectively. These statistics show that women are more

likely to lose their jobs during lockdown and less likely to return to work after lockdown. As the study shows, the decline in earnings during and after the shutdown was greater for female employees than with pre-COVID (Narayan, 2020).

As a result, the primary goals of this research are as follows: a) better manage COVID-related single-use biomedical plastic waste by employing an energy recovery method, b) making face masks from hemp, which is easily biodegradable, so these masks will help to reduce plastic pollution and ensure environmental justice, c) focusing on local women's employment so that women can contribute to family maintenance- ending gender discrimination and ensuring equality. This study directly relates to sustainable development goal 2030 like SDG 8: Decent work and economic growth, and SDG 13: Climate action.

METHODOLOGY AND METHODS

In this narrative review we mainly focused on secondary empirical data from previous research related to hemp production and its effective use in replacing single-use face masks used during pandemic. We also investigated energy recovery options while managing the COVID-related plastic waste such as single-use masks, gloves, and aprons.

We collected data from Google and Google Scholar by searching key words like “waste management and energy recovery from single use face mask”, “industrial hemp harvesting”, “hemp cultivation agricultural activities”, “a sustainable and economical alternative to single-use mask”, “hemp mask”, “growing business of hemp”, “hemp as an alternate of plastics”, “hemp fiber as a raw material source for textile industry”, “rise of plastic pollution during COVID-19 crisis”, “hemp is the future of plastics”, “use of hemp fiber”, “retting of hemp”, “hemp cultivation, extraction and processing”, “how hemp seeds are created, obtained and stored”, “single use face mask to energy” “COVID-19 related waste management”.

We also collected data from various journals such as “Journal of applied microbiology”, “Industrial Crops and Products”, “Journal of Natural Fibers”. Furthermore, the research team investigated

relevant websites as per their existing knowledge-
www.textiletoday.com.bd, www.textileblog.com, nugistics.io.com,
news.un.org.

We also consulted experts to understand the potential of using hemp in replacing single-use masks in Bangladesh. We realize, in Bangladesh, hemp is a better solution for both unemployment problem and making biodegradable masks from hemp fiber. Data collection and analysis process is explained in the flow diagram below (Figure 1).

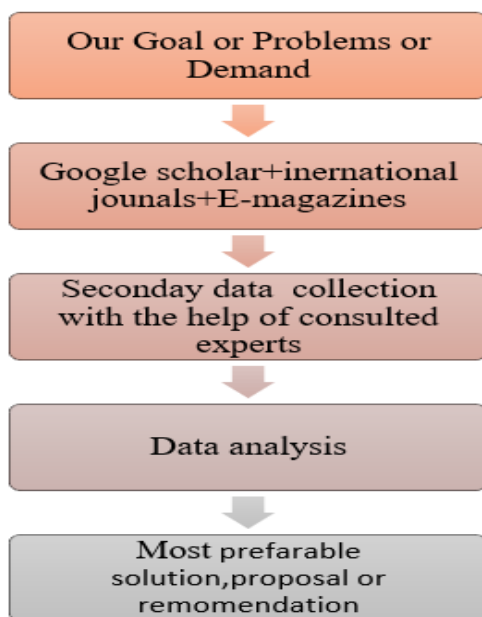


Figure 1. Research methodology flowchart

RESULTS

The process described above yielded 27 relevant papers that were included in this study. This paper investigated hemp production and its effective usage in replacing single-use face masks. We also explored energy recovery options to manage the COVID-related

plastic waste such as single-use masks, gloves, and aprons. Table 1 below describes the key findings of those selected papers.

Table 1. Key findings of the papers

The Authors et al. (Year), Country	Title	Key findings
Schumacher et al. (2020), USA	Industrial hemp fibre: A sustainable and economical alternative to cotton	Shown the cost, both properties and requirements to plant as well as growth of hemp.
Ivanovs et al. (2015), Latvia	Investigation of the technological spring harvesting variants of the industrial hemp stalk mass	The easy way to give stalk from hemp by using new technologies and machineries. It shows the cultivation of 11 cultivars of hemp.
Gusovius et al. (2016), Northern European (Germany)	Still special? Harvesting procedures for industrial hemp	The improvement of technologies in hemp fibre harvesting and conventional technology are development into modern.
Das et al. (2020) Global	Comparative evaluation of industrial hemp cultivars: Agronomical practices, feedstock characterization, and potential for biofuels and bioproducts	It shows the 11 different industrial hemp cultivars which combined agronomical, experimental, and economic analysis approaches related to biofuel and bioenergy.
Jankauskienė et al. (2015), Lithuania	Chemical composition and physical properties of dew-and water-retted hemp fibres.	Chemical properties and process of hemp fibre extraction are included into the paper.

Bleuze et al. (2018), Europe	Tracking the dynamics of hemp dew retting under controlled environmental conditions.	Knowing the dynamics of hemp retting under controlled air temperature and Humidity conditions and with simulated rain.
Bleuze et al. (2020), Global	Hemp harvest time impacts on the dynamics of microbial colonization and hemp stems degradation during dew retting.	Different crop harvest time significantly impacted microbial colonization, biofilm formation and eventually dew retting duration.
Yan et al. (2021), China	A natural yellow colorant from <i>Buddleja officinalis</i> for dyeing hemp fabric	Using of natural dye which collect from the nature and cost-effective process of yellow colouring of hemp.
Di Candilo et al. (2010), Italy	Effects of selected pectinolytic bacterial strains on water-retting of hemp and fibre properties	Bacterial inoculums increase the fibre quality than the traditionally retted fibre
Clarke et al. (2010), Netherlands	Traditional fibre Hemp (<i>Cannabis</i>) Production, Processing, Yarn Making, and Weaving Strategies—Functional Constraints and Regional Responses. Part 1	Total traditional fibre Hemp (<i>Cannabis</i>) Production in order to regional Responses
Amaducci & Gusovius et al. (2010), Italy	Hemp – Cultivation, Extraction and Processing	Hemp provides raw materials for various uses in industries

Manian et al. (2021), Austria	Extraction of cellulose fibres from flax and hemp: a review	Cellulosic fibres extraction processes from flax and hemp
Di Candilo et al. (2000), Italy	Preliminary results of tests facing with the controlled retting of hemp	Different factors like water type, the temperature of retting water and the bacterial inoculum all influenced the time of the process and the quality of the fibre.
Tamburini et al. (2004), Netherlands	Exploitation of bacterial pectinolytic strains for improvement of hemp water retting	Aerobic and anaerobic pectinolytic strains were isolated from hemp sources and characterised
Mahapatra et al. (2018), India	Extraction, processing, properties, and use of hemp fibre	Hemp processing in textiles
Nugistics, Global	Extraction, Processing, Properties and Use of Hemp Fibre	Hemp fibre harvesting and extraction, hemp fibre processing, fibre Properties, hemp fibre uses (clothing and textiles)
Giungato et al. (2021), Italy	Carbon Footprint of Surgical Masks Made in Taranto to Prevent SARS-CoV-2 Diffusion: A Preliminary Assessment	To reduce the carbon footprint smart shaping and reuse strategies result in the best options.
Prata et al. (2020), Portugal	COVID-19 pandemic repercussions on the use and management of plastics	During covid-19 pandemic reusable plastic may concern as a vector for SARS-CoV-2 virus, so that alternate of plastic product and proper disposal needed

Textileblog (2022), Global	Textile Manufacturing Processes for Students and Professionals	Textile Manufacturing Processes
ESDO (2020), Bangladesh	ESDO's Online Press Briefing on COVID-19 Pandemic Outbreak 14,500 Tons of Hazardous Plastic Waste in a Month	COVID-19 Pandemic Pushes Single Use Plastic Waste Outbreak: No Management, No Protection: High Health and Environmental Risk
Klemes et al. (2020), Global	Minimizing the present and future plastic waste, energy and environmental footprints related to COVID-19	Mitigate the potential impacts of the pandemic on waste management systems
Dharmaraj et al. (2021), India	Novel strategy in biohydrogen energy production from COVID-19 plastic waste: A critical review	Pyrolysis and gasification process, to produce highly efficient energy products from the wastes
Singh and Ruj (2016), India	Time and temperature depended on fuel gas generation from pyrolysis of real-world municipal plastic waste	The effect and formation of gaseous products was explained based on experimental investigation which shows an increase in H ₂ on increasing the temperature with decrease in low molecular weight hydrocarbons.
Dharmaraj et al. (2021), India	Pyrolysis: an effective technique for degradation of COVID-19 medical wastes	Conversion of plastic wastes into valuable energy products like oil, gas, and char through pyrolysis process.

Park et al. (2021), Korea	COVID-19 mask waste to energy via thermochemical pathway: Effect of Co-feeding food waste	Thermochemical management and utilization of the disposable face mask as a source of energy through pyrolysis process.
Harussani et al. (2021), Malaysia	Plastic Waste Conversion into Electrical, Thermal and Fuel Energy Via Incinerations and Pyrolysis Amidst COVID-19 Pandemic	Practiced PPE waste management during the COVID-19 pandemic and the applications of their end-products.
United Nations, 2020 Global	Five things you should know about disposable masks and plastic pollution	The fight against plastic pollution is being hit by the COVID-19 pandemic, as the use of disposable masks, gloves and other protective equipment soars.

PPE WASTE MANAGEMENT THROUGH ENERGY RECOVERY PROCESS

During the COVID-19 epidemic, the increased usage of single-use face masks has had both environmental and economic impacts. These are due to the extraction, production, transportation, waste treatment, and disposal of natural resources. CO₂ emission occurred in different stages to produce a mask. The carbon footprint of a surgical mask production is 32.7 g CO₂ eq. per mask (Giungato et al., 2021). In Bangladesh, minimum 2.65 billion masks are needed in every month for 160 million people (Prata et al., 2020). Near about 455 million surgical masks are use per month in Bangladesh reported by Environment and Social Development Organization (ESDO, 2020). So, the mask which will be produced from hemp fiber will reduce emissions of CO₂ in different stages of production.

One of the best methods for reducing carbon dioxide emissions and solid waste generation from single-use face masks is to use an environmentally friendly and sustainable hemp mask made from

hemp-based materials. According to ESDO, 36,987 MT waste is generated only from surgical masks each day (ESDO, 2020).

PPEs are primarily made of non-biodegradable polymers, with polyethylene terephthalate and high-density polyethylene being widely recycled and polystyrene and low-density polyethylene being seldom recycled (Kleme et al., 2020). Other PPE components, like polyvinyl chloride and polypropylene, are not recyclable. Used masks are frequently thrown incorrectly, mostly because the increased volume of waste overwhelms waste management systems (Prata et al., 2020). Previously, Incineration and landfilling processes are used for treating the COVID-19 plastic waste. The incineration and landfilling process may cause the release of harmful gases and defile the surrounding environment. These plastic wastes can be effectively managed using thermochemical processes such as pyrolysis or gasification, which help to degrade the trash and turn it into useful energy-producing products. The pyrolysis process produces liquid fuels and chemicals, whereas the gasification process produces syngas and hydrogen fuel. Pyrolysis is a thermochemical process in which solid and liquid organic components in plastic trash are disintegrated at high temperatures and anaerobic conditions (Singh et al., 2016; Dharmaraj et al., 2021). Pyrolysis takes place in an inert atmosphere within the chamber, and no additional chemicals are needed to get the process started. The pyrolysis process has the advantage of not releasing dangerous gases or compounds that are like fossil fuels. The pyrolysis process produces energy-yielding products, just like it does with any plastic waste. Similarly, for COVID-19 plastic waste, the same procedure can be used. Even though the pyrolysis approach for treating COVID-19 plastic waste is still new, it appears to be a better solution than other currently available technologies. Although pyrolysis units take up less space, they are more expensive than alternative technologies (Dharmaraj et al., 2021).

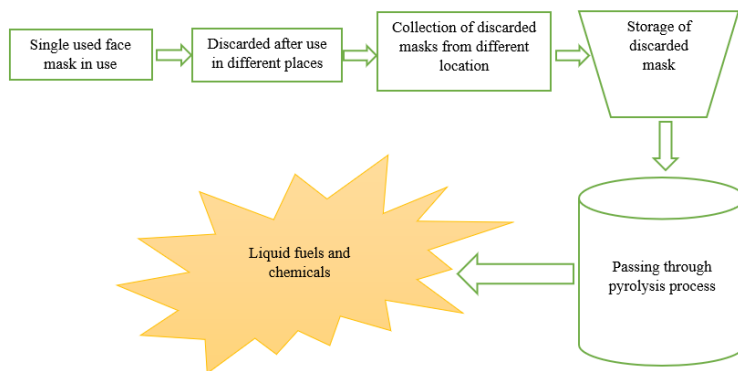


Figure 2: Recycle process of discarded face mask

HEMP-BASED FACE MASKS AS AN ALTERNATE TO SINGLE-USE MASKS

The findings suggest that Hemp is environmentally friendly and is a promising source of fiber that grows faster without the use of any artificial pesticides or fertilizers, which is suitable for a sustainable agricultural industry. Hemp has the potential to replace cotton, which uses a large quantity of chemicals that are detrimental to people and the environment. Currently, most of our textile need is satisfied through cotton and synthetic fibers, both of which have significant environmental impacts. Hemp fiber is a viable alternative to plastics and other fibers that have significant environmental impact. One thing to bear in mind is that while hemp fiber production does not harm the environment, chemical or other hazardous effects must be minimized throughout the fiber processing stage.

Following are the steps required for fiber extraction from Hemp (Agricultural activities to fiber formation):

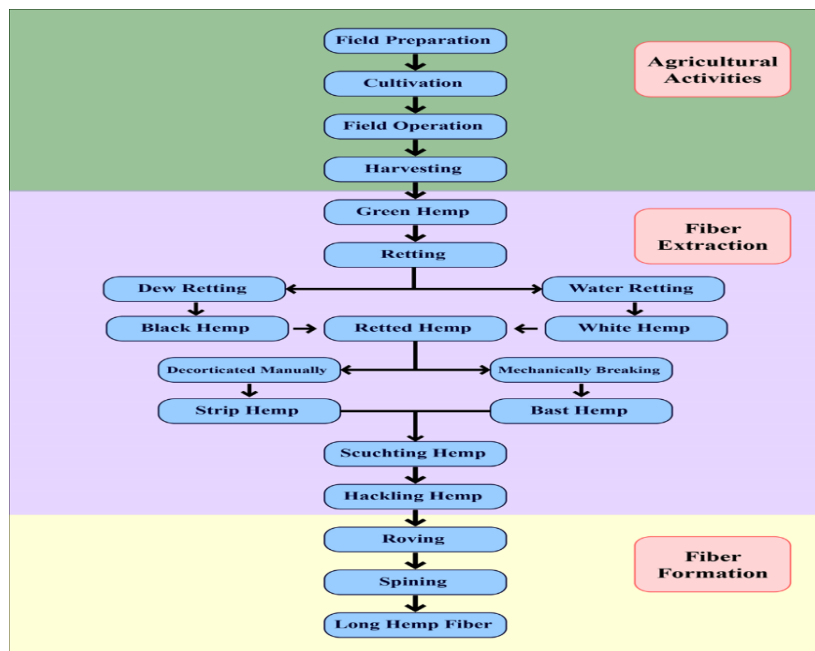


Figure 3: Fiber Formation from Hemp

Field Preparation

Soil preparation, fertilizer selection, and irrigation canal selection are the most important aspects of field preparation in hemp (*Cannabis sativa*) agricultural activities. Field preparation includes soil preparation prior to cultivation to ensure the hemp plant's optimal growth. To produce quality fibre, hemp requires a large amount of organic matter 3.5% (Ivanovs et al., 2015). It also needs high nitrogen fertilization, medium to high phosphorus levels (>40ppm), high sulphur levels (>5,000ppm), medium to high potassium levels (>250ppm), and low calcium levels (6,000ppm) (Ivanovs et al., 2015). Nitrogen, plant growth promoter microelement is helpful to produce fibre.

Cultivation

After the field preparation, the next and most important step is cultivation. Seed sowing, seed retting, weed management, irrigation, fertilization, and other aspects of hemp farming are considered part of this process of generating hemp fibre. Hemp seedlings then sprout up, seeds should be sown at a proper distance of around 2-3 cm apart, using traditional grain drill. Each seed should be sown at a depth of no more than 2.5 cm (Ivanovs et al., 2015). Hemp length is far more significant than width, thus they should be sown tightly together. This increased plant density will stimulate longer, thinner stalks, resulting in more fibre content and better fibre quality (Bengtsson, 2009).

Field Operations

The overall strategy includes field activities as well. The application technique in hemp growing is known as field operation. During the growing season, hemp requires the least amount of water, and beyond the first six weeks of growth, it is drought resistant. A lack of water, on the other hand, would hasten plant maturity and have an impact on the final stem mass. (Oliver, 1999). Water is required for hemp growing after the first six months (it could take less time), and Bangladesh has plentiful supplies of water for irrigation. The amount of water necessary to produce one kilogram of fibre starts with irrigation input during field operations for each plant, hence water costs will vary depending on location and precipitation. Water is plentiful in the Kustia region of Bangladesh, thanks to river water and other sources such as ponds and canals. Weed control is required for hemp farming, and weeding is part of the field activity.

Harvesting

Hemp is harvested by cutting the stem, which is the primary source of hemp fibre. To reduce extremely long stems to shorter pieces, the cutting method requires further cuts. This is the most crucial stage in ensuring that the hemp straw can be easily turned and swathed. Hemp harvesting is aided by several machine systems introduced in the mid-1990s. (Amaducci et al., 2010). Technology

has advanced, the combine harvester is another equipment that cut the hemp stem to remove the fibre. The machine needed to cut hemp at 3.0- or 4.5 meter widths was invented in the Netherlands in the 1990s, and it is now the most extensively used method for harvesting hemp and kenaf. Hemp harvesting requires enough dried soil so that machineries may pass through. Such stalks are not cut in the spring; instead, they are rolled down with rollers because the part of the stalks that meets the earth becomes brittle (it starts to degrade) and the stalks are easily broken.

Fiber Extraction and Preparation

The fibers extraction method of producing fibers bonded to one another in the form of strands. Through the retting process, fiber is extracted from green hemp.

(1) Retting: Retting is a plant-based technique that uses bacteria and moisture to dissolve or rot away most of the cellular tissues and sticky substances that surround bast fiber bundles, allowing the fiber to be separated more easily. To aid in their extraction, hemp stalks are retted to remove the green outer skin from the bark and to liberate the bark and fiber parts from the woody pith (boon or reed).

Retting provides for a "controlled reduction in the amount of pectin, lignin, and hemicellulose held by the stem, without the need for total destruction of these chemicals" (Castellini 1962). True retting, as opposed to steaming to remove the bark, is a microbial process, and the duration varies considerably depending on water or air temperature, with warmer conditions accelerating and cooler conditions slowing the retting process (Clarke 2007). Retting involves the removal of the substances that bind the fiber to other constituents of the hemp stalk. The most common method of hemp retting is: - a) Water retting and b) Dew retting

a) *Water retting:* Water retting involves soaking the dry hemp stems in bacteria-filled water tanks, ponds, or rivers. The water softens the outer layer of the stalks and promotes the growth of more bacteria to speed up the process. The fiber obtained is

evaluated considering color, softness, fineness. The results obtained indicated that the water type, the temperature of retting water, the bacterial inoculum all influenced the duration of the process and the quality of the fiber. Finishing of water retting process, duration distinctive with a geological location. In Europe, water temperatures range from 16°C to 21°C (60°F–70°F) and retting takes from 4 to 15 days. In Chile, retting takes 8–10 days in summer but 12–18 days in winter. In India and Bangladesh, retting takes 8 – 12 days in summer but 12 – 15 days in winter. Retting duration depends on the temperature of the water. When the temperature of water goes down from 24 to 28°C, it reduces the duration of the process from 6 to 4 days. Clearer, softer, and finer fiber is found when the water temperature is 20°C and the duration took 6 - 12 days (Amaducci et al., 2010).

b) Dew retting: Dew retting is the only type of retting that can be done on a field, while the other types require some sort of special facility. It is done by spreading the hemp stalks on the ground, so they are exposed to rain and dew. They should be cut as close to the ground as possible. It is a natural process that is triggered by dew that falls on the crop each morning. After cutting, the hemp stems were laid parallel in rows to dew ret. The plants are laid in the field for 4-6 weeks, during which the bacteria on the plant's surface will break down the outer layer. For even retting, they should be turned over when they start changing color from green to pale yellow and must be picked up at the right time to avoid over-retting. The retting is over when the color of the stem's changes to a slightly dark beige with small, dark spots. This type of retting is inexpensive but usually delivers poorer quality fiber compared to other types of retting. Retting is complete when the fiber bundles appear white, separate from the woody core, and divide easily into individual finer fibers for their full length. Once this process is complete (dry), the stalks are collected.

Retted Hemp: a) After the water retting process, hemp fiber also was not very homogenous, had white, grey color, look softer, and more decomposed.

b) After dew retting, the fiber was not very homogenous, had steel-grey and dark-grey color, contained some dark spots (the residues of dew retting fungi).

(2) Decorating: Decoration is the process of removing outer coverings such as bark from stems. Hemp decortication is the process that removes the tough, woody interior of the hemp plant and separates it from its soft exterior. Retted hemp can be decorticated through the process of (a)Decortication manually (b)Mechanically breaking.

a) Decortication Manually: This process is a less common, much quicker but more labor- intensive method. In this method, fiber has been separated by using hands. Strip hemp fiber was produced from this process.

b) Mechanically breaking: In this process, the retted hemp stems are then dried, conditioned, and freed from the wood kernel in a sequence of the squeeze, break, and scutching processes. In other words, it is described as breaking the stems by passing through a “breaker” or fluted rollers. Then the fiber is separated from the woody core by beating the broken stems with a beech stick or passing through rotary blades. Bast hemp fiber was produced from this process. Those fibers are used in the automotive industry, geotextiles, thermal blankets, fibrous insulating material, and composites, building boards, coarse yarn, coarse textiles, and reinforcement of several composites and structural parts.

(3) Scutching: After decortication, the fiber is scutched and hackled. Scutching refers to the dressing of the hemp in preparation for spinning. Scutching beats and scrapes the fiber bundles, separating more short fiber and the remaining hard material from the long fiber. The process separates the impurities from the raw material, such as seed particles and other matter. Scutching was once done by hand, but it is done by a machine called a scutcher. Scutching hemp results in long fibers called lines.

(4) Hackling: Finally, the material is passed through a hackling device to align and start separating the fiber bundles. Hackling removes the hard particles and any broken fibers and helps align the fibers in a continuous sliver. Hackling is when short and medium-sized fibers are combed out of the stalk. A special cutting machine is used to reduce the length of the fibers from 3 m to 650 mm. Any woody particles are removed and then aligned for spinning accordingly.

(5) Roving: Roving is the process of delivering materials via a roving machine. It's a process of twisting which keep fiber together. Roving frame Operation involved in three parts; these are: drafting, twisting, and winding. Drafting is about to reduce the weight and unit length of sliver. It makes it suitable for ring spinning system, twisting is to insert small amount of twist to give required strength of roving and winding is to wind the twisted roving on to bobbin (Textile Today 2018)

(6) Spinning of Hemp Fiber: The manufacture slivers are pre spun roving yarns. To meet the quality and the required finishing hemp yarn passes through the wet and dry spinning process. The rove is then boiled in caustic soda then the yarn is bleached with H_2O_2 (Hydrogen Peroxide). Hemp yarn is produced by both the wet and dry spinning process. Wet spinning involves passing the fibers through a trough of hot water before being spun. By using the above-mentioned process, 2 types of hemp yarn are produced namely long yarn and short yarn.

(7) Long Hemp fiber: After the raw materials have been transformed into yarns, the next step is to join these yarn threads to form the fabric. Hemp fibre has a dark tan or brown tint that is difficult to bleach, but it may be dyed in a variety of vivid and dark colors. Hemp fibre is a glossy fabric with the nodes and joints of linen, but a broader central canal. Cotton fiber is shorter, weaker, more absorbent, mildew resistant, and less insulative than hemp fiber.

Fabric Production and employment creation from Hemp

By cultivating 750 plants on 5 katha lands, 100 kg fibers will be yielded. If each mask is sold for BDT 75, there will be a profit of BDT 105,800 and this project will employ 10 people as well. The fabric will be used to make 5000 reusable face masks. Approximately 2,250,000 seeds equivalent to 10 kg (3000 seeds from each dried bud). Harvesting seeds and the seeds sale into online, 50,000 BDT can be earned by selling 10 Kg hemp seeds. This project will employ 10 people especially local women. These 10 people are eight farmers/laborers, one caretaker, and one traditional weaver. This project will indirectly help to create employability in many sectors such as people can income by marketing and selling of that product. This system aids local women to make money for their family maintenance, which will end gender discrimination and ensure equality.

DISCUSSION

Hemp fibers have several advantages: they have aseptic properties, good absorption, provides UV protection and reduce allergenic reaction (Kostic et al., 2008). Hemp material is antimicrobial, naturally resistant to different bacteria and mildew. Hemp fabric is biodegradable, quickly alters into compost. Single-use face masks are not biodegradable. On the other hand, hemp mask will biodegrade and not clog landfills. Currently more than 30 nations grow industrial hemp as an agricultural commodity. Hemp fabric is excellent for manufacturing face masks. Also, hemp can grow up to 0.31 m in a week, making it an ideal plant for commercial production due to its rapid growth and low maintenance (Oliver, 1999).

‘Hemp’ is a new (and often misunderstood) crop for Bangladesh. Therefore, it is a worry whether public will accept the products or not. Our social media campaigns will be helpful here to raise awareness in people. Since never cultivated in our country before, the farmers may experience unexpected challenges at every step-starting from cultivation to manufacture the final products. Hemp-based products could be expensive. Therefore, we must target our

initial clients carefully. And to start with, we should also keep a nominal profit margin- treating it as a social business.

STUDY LIMITATIONS

In this study, we did not have any primary data. In the context of Bangladesh, we did not have any secondary data too. Also, we did not employ a systematic search or synthesis process. As such, assessed the quality of the selected publications due to a lack of empirical investigations discovered throughout the literature review process.

CONCLUSION

Hemp is considered an eco-friendly crop because of its biodegradability and ability to store more carbon per year than any other tree. Hemp fiber has the potential to be a viable replacement for plastic surgical masks. Incineration and land filling can release harmful gases into the atmosphere, harming the ecosystem. Pyrolysis can reduce these side-effects and create energy. By replacing disposable surgical masks with hemp masks, we can produce energy and can create a pollution-free, healthy environment.

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**RESOLUTION ADOPTED AT THE SPECIAL
CONFERENCE ON "ENERGY, CLIMATE CHANGE, AND
SUSTAINABLE DEVELOPMENT" ORGANIZED BY
BAPA AND BEN ON FEBRUARY 11-12, 2022**

Preface

Following the tradition of Bangladesh Poribesh Andolon (BAPA) and Bangladesh Environment Network (BEN), a special conference on "Energy, Climate Change, and Sustainable Development" was held on 11-12 February, 2022 at the Siddheswari Campus of Stamford University in Dhaka. The conference was attended by a large number of delegates from different parts of the country and abroad. In addition, many delegates took part online. Among the participants in the conference, there were experts on various environmental issues, as well as leaders of various branches of BAPA and activists and well-wishers of the environment movement. The chief guest at the inaugural session of the conference was the Planning Minister M. A. Mannan, and the eminent economist Wahiduddin Mahmud was the special guest. The chief guest at the concluding session was a prominent intellectual of the country, Rehman Sobhan. Saber Hossain Chowdhury, the chairperson of the Parliamentary Standing Committee on Environment, Forest and Climate Change, Mohammad Alauddin, the Additional Secretary of the Power Department and the chairperson of the Sustainable and Renewable Energy Development Authority (SREDA), and other government officials were also present at the conference. In a special session at the conference, leaders of different political parties of the country expressed the position of their respective parties on energy issues. Many prominent members of the country's intelligentsia attended the conference.

About 60 articles were presented at the conference in various plenary and parallel expert sessions. These articles presented data and research findings on a wide range of issues related to energy, climate change, and sustainable development. In addition, in several plenary and parallel general sessions, BAPA leaders and activists from different parts of the country articulated their opinions on various issues of sustainable development in their respective localities.

This conference focused on the following issues as per the conference announcement and the call for papers. These were:

- (A) Matching between supply and demand of electricity;
- (B) Use of renewable energy sources and ensuring efficient and optimal fuel mix;
- (C) Combination of the roles of the public and private sectors;
- (D) Combination of domestic and foreign actors in the energy and power sector;
- (E) Size-distribution of power plants;
- (F) Geographical distribution of power generation, transmission, and distribution facilities;
- (G) Pricing and distribution of electricity and fuel;
- (H) Financial sustainability of the power and energy sector;
- (I) Environmental sustainability of the power and energy sector and maintaining the balance between energy, water, food/crops, and climate change;
- (J) Risk of energy use and power generation to acceptable levels;
- (K) Utilization of traditional fuels;
- (L) Environment-friendly use, waste management, and recycling of renewable energy sources;
- (M) External dependence and promoting national capability-based formulation of policies and plans regarding energy and other important sectors of the economy.

Apart from energy issues, the conference also discussed issues related to climate change and sustainable development. In particular, local experiences in different parts of the country

regarding the issues of rivers, the environment, and sustainable development were discussed and recommendations emerging from these experiences were presented. This resolution, therefore, has two parts. In first, observations and recommendations regarding energy and power are presented and grouped according to the above list of issues. The second part of the proposal covers observations, recommendations, and demands relating to other issues of sustainable development.

PART I

Various Recommendations Regarding Energy and Power

The Conference notes that in the recent past, especially since 2008, the power generation capacity of Bangladesh has increased rapidly. As a result, the country's power shortage crisis has been resolved. The Conference, for this achievement, commends the strong leadership in this regard of the present government, especially that of Prime Minister Sheikh Hasina.

The Conference believes that the energy sector of Bangladesh has entered a new phase by alleviating the shortage of electricity. In this new phase, new generation problems, issues, and challenges have emerged. In many cases, the policies that have been followed to increase power generation have themselves given rise to these problems, issues, and challenges.

The Government of Bangladesh announced an ambitious and updated "Nationally Determined Contribution" (NDC) toward the mitigation of climate change at the COP-26 conference held under the United Nations Framework Convention on Climate Change (UNFCCC). The Government of Bangladesh has announced the "Mujib Climate Prosperity Plan" (MCP) to fulfill the announced NDC. According to this plan, 30% of the energy will be extracted from the renewable energy sector by 2030 and 40% by 2040. It should be noted that at present this ratio is less than 3%. Achieving the goals of MCP will therefore be a considerable challenge.

The Conference believes that to meet the above challenges, it is necessary to discard the current fragmentation of policies and

instead adopt a comprehensive, integrated strategy for the energy and power sector, and develop the national capacity that is necessary for its implementation. With that goal in mind, the Conference is making the following observations and recommendations.

(A) Ensuring Proper Matching Between the Supply and Demand of Electricity

The Conference notes that the rapid increase in the power generation capacity has now created a surplus capacity in the country. According to researchers, about one-third or more of the country's power generation capacity remains unused. The government now has to spend a huge amount of money (about Tk 10,000 crore annually, which is about 1.75% of the proposed budget for 2020-2021) as the capacity charge to the owners of the electricity plants with unused capacity. Consequently, public money is wasted, causing undue pressure on the government's budget. The Conference also notes that, though the "Power Sector Master Plan" (PSMP) formulated and revised by the Tokyo Electric Company in 2016 suggests the "reserve margin" of a country to be limited to 10-20%, it itself planned for a reserve margin of 40-50% or more by 2030. It is not clear why PSMP (2016/2018) formulated a power development plan with such a huge reserve margin. Furthermore, the actual reserve margin proved to be much higher than what was projected even by the PSMP.

Considering the above, the Conference urges the Government to take immediate steps to reduce the reserve margin and to prevent the emergence of such abnormal reserve margins in the future. To this end, the Conference suggests the following measures:

- (a) diversifying industrial development;
- (b) increasing access to electricity;
- (c) exporting electricity to neighboring countries;
- (d) avoiding taking up or implementing projects to build needless power generation plants;

- (e) refraining from guaranteeing the purchase of power by the government when approving private sector power plants;
- (f) formulating a new power development plan in light of the new situation and ensuring better matching between future demand and supply and lowering the reserve margin.

(B) Increasing the Use of Renewable Energy and Ensuring Efficient and Fuel-mix

The Conference notes that in the past, Bangladesh was leaning towards coal in its fuel mixture. At one stage, it was even proposed to increase the role of coal in the fuel mixture to 70%. On the other hand, the use of renewable energy was neglected. Reflecting this neglect, the contribution of all renewable energy in power generation has been limited to 330 MW (which is less than 3% of the total generation) by 2017.

The conference also notes that BAPA and BEN opposed the inclination toward coal from the outset and called for more utilization of renewable energy. It is a pity that the government agencies did not listen to these recommendations of BAPA and BEN at that time.

However, the Conference notes that on the eve of the 26th UN COP-26 conference in 2021, the government announced a goal of moving away from coal. To that end, ten coal-based power projects were canceled, with five of them to be converted to gas. The government has also announced the goal of increasing the role of natural gas in power generation to 40% by 2041. In addition, the Government of Bangladesh has announced the goal of using state-of-the-art technology to produce environment-friendly hydrogen fuel and to generate energy from waste and biomass.

The Conference welcomes these announcements and decisions but notes that the government has neither completely scrapped the Rampal coal-fired power project nor did it offer to convert it from coal to gas. The Conference has expressed strong dissatisfaction

with the issue and reiterates its demand for the cancellation of the Rampal project.

The Conference calls for the proper implementation of the announced target of increasing the contribution of renewable energy to 40% by 2041. The Conference worries that in the absence of special efforts, this goal may not be achieved. If renewable energy is to play an active role in climate change mitigation and sustainable development, the Government of Bangladesh must ensure its use in agriculture, housing, and other sectors. The Bangladesh National Building Code, with appropriate modifications, may be used to promote the use of renewable energy in the housing sector. In evaluating the feasibility of large projects – such as MCPPP's "4GW Mujib Bangoposagar Independence Giga Array" -- aimed at using wind power and other renewable energy sources, it is important to conduct good environmental impact and sustainable life cycle assessments. The Conference notes that the issue of financial, social, and environmental sustainability is closely linked to the issue of the fuel mix. That is why this issue demands more in-depth attention.

Every effort should be made to include the maximum amount of renewable energy derived from diverse sources (such as rooftop solar panels, solar power, wind power, wave power, tidal power, small to medium-sized hydropower, ocean-thermal power, hydrogen, etc.) in the Integrated Energy and Power Master Plan.

Plans have to be made to store energy produced by renewable energy sources and use it during peak demand or to export it. The Conference also notes that, despite announcing the goal of generating 40% of electricity from renewable energy by 2040, Bangladesh has not signed COP-26's "Global Coal to Clean Power Transition Statement." The Conference believes that Bangladesh should sign this document.

Despite the various limitations and challenges noted above, the Conference welcomes the policy of decreasing the dependence on coal and increasing the use of renewable energy. It believes that, through the proper implementation of these policies, Bangladesh can set a positive example in the international arena and brighten the country's image in the world. In particular, by setting up a test

model for hydrogen production, using environment-friendly, state-of-the-art technology, Bangladesh can gain a worldwide reputation.

(C) Ensuring Proper Combination of the Roles of the Public and Private Sectors

The Conference notes that the role of the private sector in power generation has gradually increased in Bangladesh, bringing it closer to the role of the public sector in terms of its share in power generation. The relative shares of the public and the private sector in power generation vary by country. However, more important than this ratio is the regulatory framework under which the private sector is developing. If this development is achieved under a competitive, transparent, and proper risk-reward framework, it would be beneficial to the economy. However, if the development is driven by government favoritism rather than an appropriate risk-reward framework, it could be detrimental to the economy. The development of the private sector in power generation in Bangladesh so far seems to have been driven more by government favoritism than through the risk-reward mechanism. That is why the government is currently having to pay huge amounts of subsidies to the owners of private power plants for their unused production capacity. In light of this experience, before approving the installation of power plants by the private sector in the future, it is necessary to formulate the necessary policy framework so that these power plants do not rely on government subsidies and other concessions. Providing selected businesses or business groups licenses to set up power plants as a way of bestowing them favors would have serious consequences for the economy. In short, the politicization of the power sector must be resisted.

The Conference notes that the public sector usually assumes a larger role in power generation in the initial stage of development of a country. Power generation is a capital-intensive process, and at the initial stage of development, private entrepreneurs generally do not have the capacity to invest such a large amount of capital. Also, in the initial stage of development, the government generally

lacks the policy framework necessary for the promotion of power generation by the private sector, and it also generally lacks the institutional capacity required to enforce the framework, even if it was there. Over time, both the investment capacity of the private sector and the institutional capacity of the government to formulate and implement necessary policy framework increase. As a result, the proportion of power generation by the private sector can increase. However, the proposals put forward in PSMP (2016/2018) contradict the above generally observed pattern. According to this proposal, the role of the private sector in power generation in Bangladesh will first increase and will then decrease to a very low level. No suitable explanation is available in the PSMP (2016/2018) as to why such an opposite pattern regarding the evolution of the role of the private sector in power generation would apply to Bangladesh. The Conference thinks that it is necessary to review the role of the private sector in power generation in Bangladesh and to formulate the necessary policy framework for this purpose.

(D) Ensuring Proper Combination of Domestic and Foreign Actors

The Conference notes that the importance of foreign agencies and influencers has gradually increased in the energy sector of Bangladesh. The influence has spread in two areas: first, in the area of energy sources, and, second, in the area of power generation. Earlier, Bangladesh's power generation was almost fully dependent on domestic gas. But due to the insufficiency of domestic gas, as compared to the rising demand, Bangladesh is currently importing Liquefied Natural Gas (LNG) from abroad. Furthermore, the construction of large-scale coal-based power plants, such as at Rampal and Payra, has resulted in an increase in coal imports from abroad. As a result, the issues concerning the fair price and the right strategy for importing foreign energy resources have become important. For instance, the Rampal plant is importing relatively low-quality coal from India despite earlier commitments to import high-quality coal from Australia and Indonesia. On the other hand, there are allegations of importing LNG from the spot market at high

prices instead of importing at relatively low and stable prices under long-term contracts. The Conference believes that the government needs to be more consistent and transparent in these matters.

Experts have also expressed doubts about the need for importing gas from abroad. They believe that interested quarters have prodded the government towards importing LNG from abroad instead of exploring and extracting domestic gas. In this regard, they note that only twenty exploratory wells were dug in the last twenty years. Moreover, the extraction of gas from the already discovered gas fields is not moving ahead at an expected pace. For example, gas from two fields discovered in Bhola is not extracted because of the lack of pipelines necessary for transmission. Similarly, the exploration and extraction of gas and oil in the Bay of Bengal was expected to increase after the resolution of maritime border disputes with India and Myanmar. However, not much activity is observed in this regard. The Conference believes that more emphasis needs to be placed on domestic gas exploration and extraction so that Bangladesh does not have to depend on imported gas. The Conference calls on the government to take steps in that direction.

Second, the number of power sector joint ventures between both government and non-government organizations of domestic and foreign origin has increased in recent years. The Conference thinks a proper regulatory structure needs to be developed and enforced in this area as well. The participation of foreign companies should not be based on government favors and subsidies and should not involve risk-free profits. Instead, this participation must be market-based, non-subsidized, and adhere to the "reward for risk-taking" principle. The Conference urges the government to take necessary steps in this regard.

(E) Ensuring Proper Size Distribution of Power Plants

The Conference notes that the size of power plants can vary. Larger plants have some advantages. First, larger plants can benefit from, what is called by economists, the "economies of scale," which allow

having lower per unit cost of electricity produced. Second, large-scale plants make it easier to meet the electricity requirements of large-scale industrial enterprises. However, large-scale power plants have some disadvantages too. First, they are associated with long construction periods (gestation lag). Second, being generally away from many customers, they face higher transmission and distribution costs and system losses. Third, due to the large investments required, large-scale power plants are often built in the public sector where corruption and inefficiency are generally more prevalent. As a result, despite the economies of scale, per-unit production costs are often not lower than that of the average-sized plants. With their per unit costs exceeding the market price of electricity, the large-scale plants often turn into loss-making establishments (i.e., white elephants). However, because of the huge investments (a sunk cost) involved, they are difficult to get rid of and instead become a burden on the government budget.

The Conference notes that in the recent past, Bangladesh has been leaning toward the construction of large-scale power plants. In most cases, these are being built under the "purchase guarantee" offered by the government. However, the government is already paying a large amount of subsidy for the idle capacity of power plants. The amount of subsidy may increase further if the planned and under-construction large-scale power plants are implemented under the "purchase guarantee" arrangement.

The Conference, therefore, calls upon the government to encourage the construction of medium and small-scale power plants. In this regard, the Conference holds the view that the role of the private sector in power generation can better be limited to the establishment of small and medium-sized power plants. Private entrepreneurs can set up these plants on the basis of local power demand, using their own capital, under the "reward for risk-taking" policy, so as not to become a burden on the government's budget. These plants can be closer to the consumers and thus face less transmission and distribution costs and system losses.

The Conference notes that it is risky to set up large-scale nuclear power plants in a densely populated country like Bangladesh. Meanwhile, progress in nuclear technology has now

made it possible to install the fourth generation, safer, small and medium-sized modular reactors, instead of large ones. The Conference urges the government to consider these options if the expansion of nuclear power generation proves to be necessary.

On the basis of the above observations, the Conference urges the government to move away from the emphasis on building large-scale power plants, and instead to work towards an "optimal size distribution," including large, medium, and small-scale power plants.

(F) Ensuring the proper geographical distribution of power plants

Determining the geographical location of power plants is an important issue in the development of the power sector. In this regard, the Conference notes that the government, in recent decades, has emphasized the building of large-scale power plants in coastal areas. Since many of these plants rely on imported coal, there is a reason to locate them in coastal areas.

The Conference, however, notes that there are also many downsides to setting up power plants along the coast or in remote areas. As already noted, power plants located away from customers face higher transmission costs and system losses. Power plants, if built in remote locations, require accommodation and other facilities to be built for their workers, thus increasing the cost of production. Also, power plants built along the coast may cause irreparable damage to the coastal and marine environment. In the case of Bangladesh, the Rampal power plant poses a serious threat to the Sundarbans, the largest mangrove forest on the earth. The coast of Bangladesh is also often hit by cyclones and tidal surges, posing an additional threat to large-scale power plants along the coast.

Based on the above observations, the Conference calls upon the Government to work toward a more optimal geographical distribution of power plants by reducing their placement along the coast. The Conference notes that, in view of the government's

recent decision to reduce coal dependence, the rationale for setting up power plants along the coast has diminished. The imported gas can be more easily transported to the interior of the country through the network of pipelines. Hence, gas-based medium and small-scale power plants can be constructed all across the country and closer to the consumers. Similarly, renewable energy-based power generation can be spread all across the country. This will also help to save space required for power generation facilities. In general, the Conference calls for the spatial decentralization of power generation and transmission as much as possible.

(G) Ensuring Proper Transmission, Distribution, and Pricing of Electricity and Fuel

The Conference notes that in addition to power generation, policies regarding its transmission and distribution are of special importance. It is generally assumed that the power transmission capacity should be more than 50 percent and the power distribution capacity should be 100 percent higher than the power generation capacity. Hence, increasing power generation capacity needs to be accompanied by the adequate expansion of transmission and distribution capacity.

The Conference further notes that the responsibility for ensuring the necessary transmission and distribution system – which is generally used by many public and private power plants – rests largely with the public sector. It is therefore necessary for the government to pay special attention to fulfilling this responsibility properly. In doing so, the government can recoup the costs by charging the public and private power producers at appropriate rates for using the transmission and distribution facilities and thus avoid the additional burden of subsidies.

The Conference notes the need to ensure both efficiency and fairness in energy distribution. For example, the policy of supplying gas for household use through pipes -- instead of cylinders -- led to inequalities across regions, income groups, and rural and urban residences. Even today, Bangladesh has not been able to overcome these inequities in access to gas. Going forward, the government

needs to pay more attention to ensuring equity in access to fuel and electricity.

The Conference notes that, with the growing importance of imports, the purchase and sale price of fuels has become more important. The source, method, and price of imported coal and gas are of special interest to the country. It has recently been alleged that gas has been procured from spot markets at exorbitant prices instead of being purchased at relatively low prices under long-term contracts and that this has resulted in the government incurring extra costs and increasing the price of the blended (combining domestic and imported) gas in Bangladesh. The Conference calls on the government to prevent such activities that are harmful to national interests. Similarly, the Conference also calls on the government to ensure that national interests are upheld in procurement decisions regarding the import of coal.

The Conference further calls on the government to rationalize the prices of fuel and electricity within the country. According to the economic theory, efficient utilization of a domestic resource requires its valuation at, what is called the “border price,” which is the price this resource commands in the international market, with the cost of its transportation to Bangladesh’s border added to it. For a long time, domestic gas in Bangladesh was priced at an extremely low level. Hence, it would not be advisable to raise its price to the “border price” level in one go. However, this has to be declared to be the goal so that all consumers can start preparing themselves for the “border price” of domestic gas. The rationale behind the “border price” rule will have to be explained well to the public so that they can recognize its merit and accept it willingly.

The Conference emphasizes the necessity for avoiding subsidies in both supplying fuels to power producers and purchasing power from them. It notes that the failure to adopt this policy has resulted in the huge subsidies that are now provided to power producers, especially to private power producers. In general, the Conference calls for the rationalization of both input and output prices, based on the “border price” rule, in the long run.

(H) Ensuring financial sustainability of the energy and power sector

The Conference has the views that the energy sector needs to be financially sustainable. Accordingly, the Conference expresses concern over the policy of expansion of power generation capacity by providing subsidies. Instead of providing private sector power producers various government favors, subsidies, and "risk-free profits," it is necessary to encourage market-based and non-subsidized development of the private sector that adheres to the "reward for risk principle.

The Conference expresses the view that the public sector should also refrain from adopting projects that are questionable from the viewpoint of financial sustainability. The Conference thereby expresses concern over the construction of the Ruppor nuclear power plant with a capacity of only 2,400 MW at a cost of more than \$18 billion. The Conference notes that, according to knowledgeable observers, similar power plants have been built in other countries at much lower costs. The Conference calls on the government to explain to the people of the country why the cost of the Ruppor power plant is so high. The Conference laments that a project entailing such a large budget was accepted and went for implementation by the government without much, if any, public discussion. The Conference notes with concern that the government has already announced the goal of setting up a second nuclear power plant. The Conference urges the government to take the decision on this subject on the basis of adequate public discussion, transparency, and accountability. In view of the Conference, reducing corruption, waste, and mismanagement in the public sector will help Bangladesh to achieve financial sustainability in its energy and power sector.

The Conference notes that greater emphasis on domestic gas exploration and extraction will also help Bangladesh to ensure the financial sustainability of Bangladesh's energy sector.

The Conference emphasizes that those responsible for the growing losses incurred by the energy and power sector need to be

held accountable and this sector has to be freed from all kinds of corruption and put on the track of environment-friendly, economically responsible, and sustainable development.

(I) Ensuring Environmental Sustainability of the Energy and Power Sector and Maintaining the Balance Between Energy, Water, Food/Crop, and Climate Change.

The Conference notes that, though Bangladesh's contribution to the global volume of "Greenhouse Gas (GHG)" emissions is negligible, it can set an example to the world by playing an active role in reducing GHG. In this regard, the Conference positively notes the enhanced "Nationally Determined Contribution (NDC)" that Bangladesh has made at COP-26 in fulfillment of the Paris Agreement on climate change. At the same time, it observes a large gap between NDC announced and the actual steps and their limited outcomes. The Conference urges the Government to take immediate and appropriate measures to bridge this gap.

The Conference believes that measures to reduce GHG are necessary not only for meeting global goals. They can be beneficial for the local environment too. Rampal Power Station provides an important example. The scrapping of this plant—or at least its conversion into a gas from coal -- could play a role not only in reducing global warming but also in ensuring the protection of the Sundarbans. The same is true for other coal-fired power plants. While increasing the use of energy, it is necessary to maintain a balance between water, food/crops, and climate change. It would not be right to inflict unreasonable damage on one sector while trying to develop another.

(J) Keeping the risk of fuel strategies limited to acceptable levels

The Conference notes that there are three types of energy-related risks: environmental, financial, and life and health-related risks. The Conference expresses concern that the current energy policy

of Bangladesh is not paying due attention to these multifaceted risks. For example, Rampal and other coal-based power generation projects are increasing environmental risks. The National River Protection Commission (NPRC) has issued a written order to evict the Barisal Power Plant that is currently under construction at Taltoli in Barguna and occupies land at the mouths of the three rivers, namely Payra, Bishkhali, and Baleshwar. The draft Environmental Survey of Southwest Bangladesh, prepared by the Ministry of Environment, Forests and Climate Change, did not offer any discussion make any recommendations to the government regarding the potential damage that this power plant can do to the Sundarbans, a World Natural Heritage Site, even though the latter is within 20 km from the plant. The coal-fired power plants under construction in the Payra region will have a huge negative impact on the production of Hilsa fish that migrate through the above-mentioned rivers and also of watermelon that is grown in this area. Similarly, the power plants, under construction in the Matarbari-Moheshkhali region will have a significant negative impact on the country's salt production and tourism industries. The Conference seeks to warn the government of all of these possible consequences and expresses grave concern.

The Conference notes that the expansion of subsidy-dependent power generation and the construction of hugely expensive nuclear power plants are increasing the financial risk. The construction of nuclear power plants in densely populated areas within the country is increasing the risks to life and health. The Conference calls on the government to ensure that the power and energy policy of the country put emphasis on mitigating all three types of risks as mentioned above.

The Conference also calls upon the government to take necessary measures for the mitigation of the risk to public health, caused by the deterioration of the air quality index, resulting from the construction of fossil fuel-based power plants.

All the sources of air pollution and risk to public health (e.g., unscientifically built brick kilns, unfit cars, buses, motorcycles, trawlers, launches, steamers, air crafts, and various equipment

used for industrial and agricultural purposes, etc.) must be identified and gradually disallowed and removed from operation.

In the medium and long-term planning of energy and power generation, policies need to be adopted to meet SDG 7 (Clean and Affordable Energy for All) in such a way that ensures social inclusion and reflects social aspirations.

In deciding matters concerning power generation, supply, distribution, and choice of locations of power plants, the Life Cycle Sustainability Assessment of all projects has to be carried out to minimize the risk to public health, socio-economic damage, and impact on the environment.

(K) Ensuring Environment-friendly Use and Management of Waste Generated by the Use of Renewable Energy Sources

The Conference notes that no fuel is safe from all viewpoints. Thus, in using solar energy, it is necessary to ensure proper and safe disposal of solar panels after their expiration. In developing countries around the world, about 75 percent of electricity is expected to come from renewable energy by 2050, and this could result in 78 million metric tons of solar panel waste alone during 2020-2050 (wastes from wind power, battery storage units, and short-lived off-grid electricity production are not counted.). These facts point to the huge challenge that Bangladesh will have to face in managing the waste arising from the use of renewable energy. Bangladesh, therefore, has to focus on this challenge from the very beginning,

The Conference also notes that the use of renewable energy can expose people to many toxic wastes, as is the case with the use of many electronic goods. These toxic wastes include cadmium and copper-derived substances, lead, hexafluoroethane, polyvinyl fluoride, tin, lithium, and silicon tetrachloride, whose high levels can be harmful to humans and the environment. Similarly, the proper removal, transfer, and disposal of radioactive waste from nuclear power plants would be an important challenge. It is important to keep in mind that conventional hydropower (i.e.,

power generation through river dams) is not renewable in the long run because these dams have limited longevity and cannot be rebuilt due to changes in the river morphology and the surroundings. As Bangladesh aims to generate 30 percent of its energy from renewable sources by 2030 and 40 percent by 2040, it, like developed countries, needs to ensure proper management, recycling, and disposal of waste and hazardous materials used in the utilization of various renewable energy sources.

The Conference calls for all efforts to generate electricity from waste. This will require radical changes in the solid waste management systems in cities and villages. Sanitary landfills should be set up in each district at the initial stage and in each upazila in the subsequent stages. These enclosures should be surrounded with protective covers so that the surrounding land and air are not polluted and the contaminated wastewater does not reach the surrounding surface and groundwater tables.

(L) Ensuring Proper Use of Traditional Fuels

The Conference notes that traditional fuels still play an important role in the economy of Bangladesh, especially in the rural areas. The Conference notes that there are two possible goals in this regard. One is to try to replace traditional fuels with modern fuels as soon as possible. The second is to mitigate the negative aspects of traditional fuels and make use of their positive potential. For example, the introduction of improved cooking stoves can allow more efficient use of traditional fuels while not suffering from the smoke that traditional open stoves generate. The Conference hopes that the right goals and strategies regarding the use of traditional fuels will be adopted based on the necessary research on these alternatives.

(M) Reduction of foreign dependence in the formulation of policies and plans

The Conference notes that although Bangladesh is economically more self-sufficient than before, it is still very much dependent on foreign agencies for the formulation of policies and plans. For

example, Bangladesh Government turned to the financial assistance of JICA and technical assistance of the Tokyo Electric Company of Japan for the formulation of the Power Sector Master Plan (PSMS). Similarly, Bangladesh turned to the Dutch Government for financial help and the Dutch Consulting firms for formulating the country's "Delta Plan 2100." However, closer examinations show that the plans made by foreign experts and agencies cannot serve the best interests of the country. In fact, in many cases, they can lead to harmful outcomes. Thus, a review of PSMS 2016/2018, prepared by the Tokyo Electric Company, shows that it contains many erroneous and harmful proposals for the country. For example, it could not ensure a proper matching between demand and supply, resulting in huge excessive reserve margins. Second, the PSMS pushed Bangladesh towards coal, and Bangladesh now had to cancel ten coal-based power plants. Third, the PSMS proposes a questionable trajectory for the role of the private sector in the power generation of the country, without offering any explanation for it. Fourth, the PSMS has set Bangladesh on a course toward increasing the import of electricity from abroad. All in all, the PSMS, prepared by the Tokyo Electric Co., has not proved successful in protecting either the national interests or the environment.

In light of the above observations, the Conference urges the Bangladesh Government to stop depending on foreign agencies for policy-making and formulation of plans. Instead, it should formulate plans and policies on the basis of national capability. Similarly, all efforts should be made to increase the participation of national agencies and experts in the discovery of new gas fields within the country and its Exclusive Economic Zone in the Bay of Bengal. For this purpose, it should strengthen the capacity of the national agencies. An effective commission can be formed to look into ways of increasing efficiency and security in the energy sector. In particular, attention should be paid to raising the efficiency of machinery used in energy and power generation, industry, vehicles, agricultural, and household use.

The Conference calls upon the government to build the necessary institutional framework to enhance the national capacity for research and policy formulation in the power and energy sector in general. A state-of-the-art Center for Energy Excellence could be set up for this purpose. The Conference proposes that BAPA-BEN could provide the required assistance to the government in setting up the aforementioned center. The Conference hopes that the government will consider this proposal seriously.

Finally, the conference hopes that the government will pay attention to the analysis and recommendations presented above and take steps to make the country's energy and power policies and plans more people-oriented, economically sustainable, and environment-friendly.

PART II

Other recommendations for Sustainable Development

During the conference, other issues of climate change and sustainable development, in addition to the power and energy issues of Bangladesh, were discussed. Especially, leaders of BAPA local branches shared their experiences about facing such issues in different parts of the country. Based on these experiences and detailed discussion of them, the Conference reached the following observations and recommendations, grouped according to different regions of the country.

Coastal Environment of Bangladesh

The establishment of fossil fuel-based power plants along the coastal belts of Bangladesh led to environmental degradation. This environmental disaster along the coastal belts was not considered seriously and was not reflected in the government-led "Strategic Environmental Assessment" of the southern and western parts of Bangladesh. BAPA already submitted its clear recommendations on this issue to CEGIS, a government organization. BAPA strongly demands a new "strategic environmental assessment," based on its already proposed recommendations to CEGIS and reflecting the

opinion and participation of the general public and the people of the coastal region who are suffering due to the environmental degradation caused by fossil fuel-based power plants.

Climate change-induced impacts on different sectors of Bangladesh are very prominent and visible. The agriculture, irrigation, and industrial development sectors are severely affected, together with the natural process of delta formation, as well as the existence of coastal forests, including the Sundarbans. Additionally, scarcity of fresh drinking water, unpredictable flooding, frequent drought, constant water-logging, and aggravation of river and coastal erosion are impacting the livelihoods of the general public.

BAPA strongly demands the protection of the Sundarbans and other coastal forests of Bangladesh. Located in the coastal region, the Sundarbans has outstanding universal ecological value and must be protected from further environmental degradation. BAPA, therefore, demands the adoption of major policies and government actions to protect Bangladesh's coastal belt, which is well known for its fisheries sanctuaries.

Sundarbans is a UNESCO-recognized World Natural Heritage Site and it serves as a safety belt to protect coastal life and resources. Projects that affect the natural habitat and the health of the Sundarbans must not be adopted and implemented. Bangladesh must protect Sundarbans at any cost for its own existence.

The environment of greater Sylhet and Haor region

Effective policy and steps must be adopted immediately to stop environmental pollution by the uncontrolled and unregulated waste disposal by tourists in Sylhet and other regions of Bangladesh. The random practice of cutting down of trees and hills must be stopped in Sylhet and other regions. Effective actions must be taken to stop the illegal grabbing of marshland and wetlands in the Haor region. Furthermore, meaningful and visible action must be taken to stop the open and unregulated dumping of industrial

waste into different rivers and wetlands in the *Haor* region. Rampant corruption during the execution of different development projects in the *Haor* and other regions of Bangladesh must be stopped immediately. Furthermore, meaningful action must be taken to stop projects impacting the heritage of Habiganj and prevent further degradation of the environment and soil pollution of the district. It is important to note that, recently, Habiganj has been ranked fourth in the air pollution category in Bangladesh.

The environment of the Teesta Basin

It is demanded that an environmentally-friendly flyover must be constructed by demolishing the existing road from Teesta to Kurigram. BAPA demands a re-evaluation of the effectiveness of the Teesta Barrage project. The local people confirmed that the natural water flow in the river was normal until 1985, before the implementation of the Teesta Barrage project. The ecology and biodiversity of the river basin were rich and thriving until that year. The local population of the Teesta basin is convinced that the Teesta Barrage project negatively affected the legitimate demands of water flow in several international rivers of the Teesta basin, such as the Saniyajan, Lautara, Kunsai, and Buri Teesta. Realizing the importance of this situation, BAPA is demanding more results-driven, effective actions to bring back normal water flow in the Teesta River.

The Teesta road bridge, Sheikh Hasina bridge, and Teesta railway bridge impeded the natural flow of the river and narrowed the effective width of the river, leading to subsequent and frequent riverbank erosion. Immediate scientific investigation and evaluation are demanded to adopt effective action to deal with the problem of riverbank erosion. The legality of different projects along the bank of the Teesta River, including the project of the Sena Kalyan Sangstha, must be challenged and river encroachment of the Teesta river must be stopped.

On the environmental issues of the Chalan Beel area

Due to the environment-destroying activities and projects, only 180 species of fish are available in the Chalan Beel area, compared to the 260 species that were present in the past. Many of the bird, turtle, dolphin, and crocodile species are on the verge of extinction. The cropland in the Chalan Beel area is declining at alarming rates. Water availability has declined in the Chalan Beel area due to the Farakka Barrage. This is high time to take steps against this decline and to adopt the right set of policies.

Unplanned roads, culverts, and other infrastructures need to be removed, and waste disposal needs to be controlled. It is demanded that the boundaries of the rivers in the Chalan Beel area be determined and demarcated immediately. The Chalan Beel needs to be free from illegal land grabbers. Illegal pond-grabbing activities by individuals need to be stopped, and steps need to be taken to preserve the ponds.

The Chalan Beel needs to be declared an Ecologically Critical Area. This declaration should be followed by curtailment of industrial activities and an increase of the preservation of ponds and other water bodies. The development of the Chalan Beel area needs to be carried out in an integrated manner so that ecological integrity and environmental sustainability are ensured.

Groundwater exploitation in the Chalan Beel area needs to be controlled.

On other environmental issues

- Unplanned and illegal sand mining activities are responsible for riverbank erosion. Sand mining occurs with the help of corrupt politicians and certain members of the administration. The Conference denounces such illegal and immoral activities.
- Public transportation in megacities, including Dhaka City, needs to be improved. The use of private vehicles needs to be discouraged in order to reduce traffic congestion and air pollution.

- In general, the Conference calls to eliminate such “developmental” activities that are creating an imbalance in the environmental equilibrium of the country.

CONCLUSIONS

The 2022 BAPA-BEN conference on "Energy, Climate Change, and Sustainable Development" explored deeply and extensively all aspects of the theme of the conference and made specific recommendations that have been presented in the above sections. Now, it is important to place these recommendations before the nation, draw the attention of the policymakers to them, raise awareness among the citizens and organize a mass movement to ensure their implementation.

The Conference seeks cooperation from the electronic and print media, TV channels, newspapers, and other types of media. The media has been playing a crucial role in support of the environmental movement. This conference hopes that the media will continue to play this role in publicizing the people-oriented, patriotic, economically sensible, and environmentally sustainable energy policies and recommendations that are presented in this resolution. The media can play a huge part in ensuring the proper implementation of the recommendations by the government.

The conference calls on all BAPA-BEN members and other environmental organizations to play an active role in spreading the messages expressed in this Resolution and its recommendations to the people and the concerned authority.

Finally, the conference calls on the people to step forward to ensure implementation of the people-oriented, patriotic, economically sensible, and environmentally sustainable energy development in light of the recommendations presented in this Resolution adopted by the Conference.

“জ্বালানী, জলবায়ু পরিবর্তন, ও স্থায়িত্বশীল উন্নয়ন” বিষয়ক বিশেষ সম্মেলনে গৃহীত প্রস্তাব

মুখবন্ধ

বাপা এবং বেনের ঐতিহ্য অনুযায়ী ২০২২ সনের ১১-১২ ফেব্রুয়ারি ঢাকায় অবস্থিত স্ট্যামফোর্ড বিশ্ববিদ্যালয়ের সিদ্ধেশ্বরী ক্যাম্পাসে হাইব্রিড পদ্ধতিতে “জ্বালানী, জলবায়ু পরিবর্তন, ও স্থায়িত্বশীল উন্নয়ন” বিষয়ক বিশেষ সম্মেলন অনুষ্ঠিত হয়। এই সম্মেলনে দেশের বিভিন্ন স্থান এবং বিদেশ থেকে বহু সংখ্যক প্রতিনিধি সশরীরে অংশগ্রহণ করেন। এছাড়া বহুসংখ্যক প্রতিনিধি অনলাইনে অংশগ্রহণ করেন। সম্মেলনে অংশগ্রহণকারীদের মধ্যে একদিকে ছিলেন পরিবেশের বিভিন্ন বিষয়ে বিশেষজ্ঞ এবং অন্যদিকে ছিলেন বাপার বিভিন্ন শাখার নেতৃবৃন্দ এবং পরিবেশ আন্দোলনের কর্মী ও শুভানুধ্যায়ীগণ। সম্মেলনের উদ্বোধনী অধিবেশনে প্রধান অতিথি ছিলেন পরিকল্পনা মন্ত্রী এম এ মান্নান এবং বিশেষ অতিথি ছিলেন দেশের বিশিষ্ট অর্থনীতিবিদ ওয়াহিদউদ্দিন মাহমুদ। সমাপনী অধিবেশনে প্রধান অতিথি ছিলেন দেশের বিশিষ্ট বুদ্ধিজীবী রেহমান সোবহান। এছাড়া সম্মেলনে অংশগ্রহণ করেন পরিবেশ বিষয়ক সংসদীয় কমিটির সভাপতি সাবের হোসেন চৌধুরী, টেকসই ও নবায়নযোগ্য জ্বালানী উন্নয়ন কর্তৃপক্ষের (স্রেডা) চেয়ারম্যান বিদ্যুৎ বিভাগে সংযুক্ত অতিরিক্ত সচিব মোহাম্মদ আলাউদ্দিন এবং অন্যান্য সরকারী দায়িত্বপ্রাপ্ত কর্মকর্তাগণ। দেশের বিভিন্ন রাজনৈতিক দলের নেতৃবৃন্দ সম্মেলনের একটি বিশেষ অধিবেশনে জ্বালানী বিষয়ে নিজ নিজ দলের অবস্থান ব্যক্ত করেন। দেশের বুদ্ধিজীবী মহলের অনেক বিশিষ্ট সদস্য সম্মেলনে অংশগ্রহণ করেন।

এই সম্মেলনে প্রায় ৬০টির মতো প্রবন্ধ বিভিন্ন সম্মিলিত এবং সমান্তরাল বিশেষজ্ঞ অধিবেশনে উপস্থাপিত হয়। এসব প্রবন্ধে জ্বালানী, জলবায়ু পরিবর্তন, এবং স্থায়িত্বশীল উন্নয়নের বিভিন্ন বিষয় নিয়ে তথ্য-উপাত্ত এবং গবেষণা ভিত্তিক অনুসিদ্ধান্ত উপস্থিত করা হয়। এছাড়া এই সম্মেলনে একাধিক সম্মিলিত এবং সমান্তরাল সাধারণ অধিবেশনে দেশের বিভিন্ন স্থান থেকে আগত বাপার নেতা ও কর্মীগণ নিজ নিজ এলাকার স্থায়িত্বশীল উন্নয়নের বিভিন্ন ইস্যু নিয়ে বক্তব্য রাখেন।

সম্মেলনের ঘোষণা এবং প্রবন্ধ আমন্ত্রণ অনুযায়ী এই সম্মেলন নিম্নরূপ ইস্যুসমূহের উপর মনোযোগ নিবদ্ধ করে। এগুলো হলো:

- (ক) চাহিদার সাথে সরবরাহের সামঞ্জস্য বিধান;
- (খ) নবায়নযোগ্য জ্বালানীর ব্যবহার বাড়ানো ও উপযুক্ত, কার্যকর ও ফলপ্রসূ জ্বালানী মিশ্রণ নিশ্চিতকরণ;
- (গ) রাষ্ট্রীয় ও ব্যক্তিখাতের ভূমিকার সঠিক সমন্বয়;
- (ঘ) দেশীয় এবং বৈদেশিক সংস্থা এবং প্রভাবের সঠিক সমন্বয়;
- (ঙ) বিদ্যুৎ উৎপাদন প্রতিষ্ঠানসমূহের সর্বোত্তম আকার নিশ্চিতকরণ;
- (চ) বিদ্যুৎ উৎপাদন, বিতরণ ও সঞ্চালন স্থাপনার সঠিক ভৌগলিক অবস্থান নিশ্চিতকরণ;
- (ছ) বিদ্যুৎ ও জ্বালানীর উপযোগী বিতরণ এবং সঠিক মূল্য নিশ্চিতকরণ;
- (জ) জ্বালানী কৌশলের আর্থিক স্থিতিশীলতা নিশ্চিতকরণ;
- (ঝ) জ্বালানী কৌশলের পরিবেশগত স্থায়িত্বশীলতা এবং জ্বালানী, পানি, খাদ্য/ফসল ও জলবায়ু পরিবর্তনের এ মধ্যে ভারসাম্য রক্ষা
- (ঞ) জ্বালানী কৌশলের ঝুঁকি সহনশীল পর্যায়ে সীমাবদ্ধ রাখা;
- (ট) সনাতনী জ্বালানী বিষয়ে সঠিক কৌশল অবলম্বন;

- (ঠ) নবায়নযোগ্য জ্বালানীর পরিবেশ বান্ধব ব্যবহার, বর্জ্য ব্যবস্থাপনা এবং পুনর্ব্যবহার নিশ্চিতকরণ।
- (ড) জ্বালানী এবং দেশের অন্যান্য গুরুত্বপূর্ণ বিষয়ে নীতি নির্ধারণ এবং পরিকল্পনা প্রণয়নে বৈদেশিক নির্ভরতা পরিহার করে জাতীয় সক্ষমতার ভিত্তিতে প্রণয়নের লক্ষ্যে পদক্ষেপ গ্রহণ।

সম্মেলনে জ্বালানীর বিভিন্ন বিষয় ছাড়াও জলবায়ু পরিবর্তন এবং স্থায়িত্বশীল উন্নয়নের বিভিন্ন ইস্যু নিয়েও আলোচনা অনুষ্ঠিত হয়েছে। বিশেষত দেশের বিভিন্ন স্থানের নদনদী, পরিবেশ, এবং স্থায়িত্বশীল উন্নয়নের অভিজ্ঞতা আলোচিত এবং তাঁর ভিত্তিতে সুপারিশ উপস্থাপিত হয়। সেকারণে এই প্রস্তাব দুই অংশ বিভক্ত। প্রথম অংশে জ্বালানী বিষয়ক পর্যবেক্ষণ এবং সুপারিশসমূহ উপরে উল্লিখিত তালিকা অনুযায়ী পরিবেশিত হয়েছে। প্রস্তাবের দ্বিতীয় অংশে স্থায়িত্বশীল উন্নয়নের অন্যান্য ইস্যু সম্পর্কে পর্যবেক্ষণ, সুপারিশ, এবং দাবী পরিবেশিত হয়েছে।

প্রথম অংশ

জ্বালানী এবং বিদ্যুৎ বিষয়ক বিভিন্ন সুপারিশ

সম্মেলন লক্ষ করে যে, বিগত সময়কালে, বিশেষতঃ ২০০৮ সনের পর থেকে বাংলাদেশে বিদ্যুৎ উৎপাদন ক্ষমতা দ্রুতগতিতে বৃদ্ধি পেয়েছে। এর ফলে দেশের বিদ্যুৎ ঘাটতিজনিত সংকট দূরীভূত হয়েছে। এই সাফল্যের জন্য সম্মেলন এসময়কালের সরকার, বিশেষত প্রধানমন্ত্রী শেখ হাসিনার বলিষ্ঠ নেতৃত্বের প্রশংসা করছে।

সম্মেলন মনে করে যে, বিদ্যুতের অভাব মোচনের মাধ্যমে বাংলাদেশের জ্বালানী খাত এক নতুন পর্বে উপনীত হয়েছে। এই নতুন পর্বে আবার উদ্ভূত

হয়েছে নতুন প্রজন্মের সমস্যা, ইস্যু, এবং চ্যালেঞ্জ। অনেক ক্ষেত্রে, বিদ্যুৎ উৎপাদন বৃদ্ধির লক্ষ্যে যেসব নীতি অনুসরণ করা হয়েছে, সেগুলিই এসব সমস্যা, ইস্যু, এবং চ্যালেঞ্জের জন্ম দিয়েছে।

তদুপরি বাংলাদেশ সরকার সম্মেলনে জলবায়ু পরিবর্তন সংক্রান্ত জাতিসংঘের কাঠামোগত (ফ্রেমওয়ার্ক) কনভেনশনের [United Nations Framework Convention on Climate Change (UNFCCC)]-র আওতায় অনুষ্ঠিত কপ-২৬ (COP-26) সম্মেলনে একটি উচ্চাকাঙ্ক্ষী এবং হালনাগাদ করা “জাতীয়ভাবে নির্ধারিত অবদান” [Nationally Determined Contributions (NDC)] জমা দিয়েছে। বাংলাদেশ সরকার “মুজিব জলবায়ু সমৃদ্ধি পরিকল্পনা” (Mujib Climate Prosperity Plan (MCP))-র মাধ্যমে এই অবদান নিশ্চিত করার ঘোষণা দিয়েছে। “মুজিব জলবায়ু সমৃদ্ধি পরিকল্পনা” অনুযায়ী ২০৩০ সালের ভিতরে ৩০% এবং ২০৪০ সনের মধ্যে ৪০% জ্বালানী নবায়নযোগ্য জ্বালানী খাত থেকে আহরণের লক্ষ্য ঘোষণা করেছে। লক্ষ্যণীয় যে, বর্তমানে এই অনুপাত ৩% এর চেয়েও কম। নবায়নযোগ্য জ্বালানী সংক্রান্ত এই লক্ষ্য অর্জন বর্তমানে বাংলাদেশকে এক নতুন চ্যালেঞ্জের মুখোমুখি করেছে।

সম্মেলন মনে করে যে, উপর্যুক্ত চ্যালেঞ্জ মোকাবেলা করার জন্য জ্বালানী ও বিদ্যুৎ খাতের বর্তমানের খণ্ডিত অবস্থার পরিবর্তে সার্বিক সমন্বিত কৌশল গ্রহণ ও ব্যবস্থাপনা নিশ্চিত করা প্রয়োজন এবং সে উদ্দেশ্যে বাঞ্ছিত জাতীয় সক্ষমতা গড়ে তোলা আবশ্যিক। এই উপলব্ধি থেকে সম্মেলন নিম্নরূপ পরিলক্ষণ এবং সুপারিশসমূহ উত্থাপন করেছে।

(ক) চাহিদার সাথে সরবরাহের সামঞ্জস্য বিধান

সম্মেলন লক্ষ করে যে, বিদ্যুৎ উৎপাদন ক্ষমতার দ্রুত বৃদ্ধির ফলে এখন প্রয়োজনের অতিরিক্ত বিদ্যুৎ উৎপাদন ক্ষমতার সৃষ্টি হয়েছে। গবেষকদের

মতে দেশের বিদ্যুৎ উৎপাদন ক্ষমতার প্রায় এক তৃতীয়াংশ কিংবা তার বেশী অব্যবহৃত থেকে যাচ্ছে। এই অব্যবহৃত উৎপাদন ক্ষমতার ক্যাপাসিটি চার্জ হিসেবে সরকারকে এখন বিপুল পরিমাণ অর্থ (বাৎসরিক প্রায় ১০ হাজার কোটি টাকা, যা ২০২০-২০২১ সালের প্রস্তাবিত বাজেট এর প্রায় ১.৭৫%) ব্যয় করতে হচ্ছে যা সরকারের অন্যান্য উন্নয়নশীল খাতে ব্যবহার করা যেত। এর ফলে জনগনের টাকার অপচয় হচ্ছে এবং তা সরকারের বাজেটের উপর অনভিপ্রেত চাপের সৃষ্টি করেছে। সম্মেলন আরও লক্ষ করে যে, যদিও বাংলাদেশের জন্য টোকিও ইলেকট্রিক কোম্পানি কর্তৃক ২০১৬ সনে প্রণীত এবং ২০১৮ সনে পরিনিরীক্ষিত “পাওয়ার সেক্টর মাস্টার প্ল্যান” (PSMP) অনুযায়ী একটি দেশের “রিজার্ভ মার্জিন” ১০-২০ শতাংশে সীমাবদ্ধ থাকা প্রয়োজন, কিন্তু এই পরিকল্পনাই আবার বাংলাদেশের জন্য বিদ্যুৎ সরবরাহ এবং চাহিদার এমন প্রক্ষেপণ প্রস্তাব করে যে, তাতে ২০৩০ সাল পর্যন্ত রিজার্ভ মার্জিন ৪০ থেকে ৫০ শতাংশ কিংবা তার বেশী নির্ণীত হয়। কেন PSMP (2016/2018) এত বিপুল পরিমাণে রিজার্ভ মার্জিন সহকারে একটি বিদ্যুৎ উন্নয়ন পরিকল্পনা প্রণয়ন করেছিল, তা পরিষ্কার নয়। তবে এটা পরিষ্কার, যে এত বিপুল রিজার্ভ মার্জিন বাঞ্ছনীয় নয়।

উপর্যুক্ত পরিস্থিতির আলোকে সম্মেলন সরকারকে রিজার্ভ মার্জিন দ্রুত কমিয়ে আনার এবং ভবিষ্যতে যাতে এরূপ অস্বাভাবিক হারের রিজার্ভ মার্জিনের উদ্ভব না ঘটে সে লক্ষ্যে দ্রুত পদক্ষেপ গ্রহণের আহ্বান জানাচ্ছে। সম্মেলন মনে করে যে, সে লক্ষ্যে সেযব পদক্ষেপ সরকার বিবেচনা করতে পারে সেগুলো হলো:

- (ক) শিল্পায়নের চরিত্রকে আরও ব্যাপক করা;
- (খ) আরও বেশী মানুষের কাছে বিদ্যুতের সরবরাহ পৌঁছানো;
- (গ) প্রতিবেশী দেশসমূহের নিকট বিদ্যুৎ রপ্তানি;

- (ঘ) অপ্রয়োজনীয় বিদ্যুৎ উৎপাদন কেন্দ্র নির্মাণ প্রকল্প গ্রহণ ও বাস্তবায়ন থেকে বিরত থাকা;
- (ঙ) ব্যক্তি খাতে বিদ্যুৎ প্রকল্প অনুমোদনের ক্ষেত্রে সরকার কর্তৃক বিদ্যুৎ ক্রয়ের গ্যারান্টি প্রদান থেকে বিরত থাকা;
- (চ) নতুন পরিস্থিতির আলোকে এবং ভবিষ্যৎ চাহিদা এবং সরবরাহের মধ্যে নিরন্তর সামঞ্জস্য নিশ্চিত করে, রিজার্ভ মার্জিন ১৫ থেকে ২০ শতাংশে সীমাবদ্ধ রেখে বিদ্যুৎ বিকাশের নতুন পরিকল্পনা প্রণয়ন।

(খ) নবায়নযোগ্য জ্বালানীর ব্যবহার বাড়ানো ও উপযুক্ত, কার্যকর ও ফলপ্রসূ জ্বালানী মিশ্রণ নিশ্চিতকরণ

সম্মেলন লক্ষ্য করে যে, বিগত সময়কালে বাংলাদেশ জ্বালানী মিশ্রণের ক্ষেত্রে কয়লার দিকে ঝুঁকে পড়েছিল। এমনকি এক পর্যায়ে জ্বালানী মিশ্রণে কয়লার ভূমিকা ৭০ শতাংশে উন্নীত করার প্রস্তাব করা হয়েছিল। পাশাপাশি নবায়নযোগ্য জ্বালানী ব্যবহারের প্রতি অবহেলা প্রদর্শিত হয়েছিলো। তারই প্রতিফলন হিসেবে ২০১৭ সন নাগাদ বিদ্যুৎ উৎপাদনে সকল নবায়নযোগ্য জ্বালানীর ভূমিকা মাত্র ৩৩০ মেগাওয়াটে সীমাবদ্ধ থেকে গেছে (যা কিনা মোট উৎপাদনের মাত্র ২ শতাংশের চেয়েও কম)।

সম্মেলন আরও লক্ষ্য করে যে, বাপা ও বেন প্রথম থেকেই কয়লার প্রতি ঝুঁকে পড়ার বিরোধিতা করেছে এবং নবায়নযোগ্য জ্বালানীর প্রতি আরও মনোযোগ দেয়ার আহ্বান জানিয়েছে। পরিতাপের বিষয় যে, সরকারী সংস্থাসমূহ তখন বাপা-বেনের এসব সুপারিশের প্রতি কর্ণপাত করেনি।

তবে সম্মেলন লক্ষ্য করে যে, ২০২১ সনে জাতিসংঘের ২৬তম কপ (COP-26) সম্মেলনের প্রাক্কালে সরকার কয়লা থেকে কিছুটা সরে আসার লক্ষ্য ঘোষণা করেছে। সে উদ্দেশ্যে অনেকগুলো কয়লা-নির্ভর বিদ্যুৎ প্রকল্প পুরোপুরি বাতিল ঘোষণা করা হয়েছে এবং অনেকগুলি বিদ্যুৎ প্রকল্পকে কয়লার পরিবর্তে

গ্যাসে রূপান্তরিত করার সিদ্ধান্ত গ্রহণ করা হয়েছে। পাশাপাশি সরকার ২০৪১ সনের মধ্যে বিদ্যুৎ উৎপাদনে প্রাকৃতিক গ্যাসের ভূমিকা ৪০ শতাংশে বৃদ্ধি করার ঘোষণা দিয়েছে। এছাড়া, বাংলাদেশ সরকার অত্যাধুনিক প্রযুক্তিভিত্তিক ও পরিবেশ বান্ধব হাইড্রোজেন উৎপাদন এবং বর্জ্য ও বায়োমাস থেকে শক্তি উৎপাদনের লক্ষ্য ঘোষণা করেছে।

সম্মেলন এসব ঘোষণা এবং সিদ্ধান্তকে স্বাগত জানায়, তবে সম্মেলন লক্ষ্য করে যে, সরকার রামপাল কয়লাভিত্তিক বিদ্যুৎ প্রকল্প সম্পূর্ণরূপে বাতিল করে নাই; এবং এটাকে কয়লা থেকে গ্যাসে রূপান্তরের প্রস্তাবও করে নাই। সম্মেলন এ বিষয়ে জোরালো অসন্তুষ্টি প্রকাশ করেছে এবং রামপাল প্রকল্প বাতিল করার দাবী পুনর্ব্যক্ত করেছে।

পাশাপাশি সম্মেলন বিদ্যুৎ উৎপাদনে নবায়নযোগ্য জ্বালানীর ভূমিকা ২০৪১ সন নাগাদ ৪০ শতাংশে উন্নীত করার যে লক্ষ্যমাত্রা ঘোষিত হয়েছে, তার যথাযথ বাস্তবায়নে সচেষ্ট হওয়ার আহ্বান জানাচ্ছে। সম্মেলন আশংকা করে যে, বিশেষ প্রচেষ্টার অনুপস্থিতিতে এই লক্ষ্য অনার্জিত থেকে যেতে পারে। নবায়নযোগ্য জ্বালানীকে যদি জলবায়ু পরিবর্তন এবং স্থায়িত্বশীল উন্নয়নে সক্রিয় ভূমিকা রাখতে হয় তাহলে অবশ্যই বাংলাদেশ সরকারের উচিত কৃষি খাত, আবাসন খাত এবং আরো অন্যান্য খাতে নবায়নযোগ্য জ্বালানী ব্যবহার নিশ্চিত করা। সেক্ষেত্রে বাংলাদেশ ন্যাশনাল বিল্ডিং কোড (Bangladesh National Building Code)-এর মাধ্যমে আবাসন খাতে নবায়নযোগ্য জ্বালানী ব্যবহার নিশ্চিত করা যেতে পারে। MCP-এর “4GW মুজিব বঙ্গোপসাগর ইনডিপেনডেন্স গিগা এর্রে” (Mujib Bongoposagar Independence Giga Array)-র মত বায়ু শক্তি ও অন্যান্য নবায়নযোগ্য জ্বালানী সংক্রান্ত বড় প্রকল্পসমূহের সম্ভাব্যতা যাচাই করার সময় অবশ্যই ভালোভাবে পরিবেশগত প্রভাব মূল্যায়ন (Environmental Impact Assessment) এবং জীবনচক্রব্যাপী স্থায়িত্বশীলতা নিরূপন (Life Cycle

Sustainability Assessment) করা জরুরী। সম্মেলন লক্ষ্য করে যে, জ্বালানী মিশ্রণের সাথে আর্থিক, সামাজিক ও পরিবেশগত স্থায়িত্বশীলতার ইস্যু ঘনিষ্ঠভাবে জড়িত। সে কারণে এই ইস্যু আরও গভীর মনোযোগের দাবী করে।

বিভিন্ন ধরনের নবায়নযোগ্য জ্বালানীর (যেমন ছাদে ব্যবহৃত সৌরবিদ্যুত প্যানেল, সৌরতাপ বিদ্যুৎ, বায়ু বিদ্যুৎ, ঢেউ বিদ্যুৎ, জোয়ার-ভাটা বিদ্যুৎ, ছোট-মাঝারী আকারের জল-বিদ্যুৎ, সমুদ্র-তাপ বিদ্যুৎ, হাইড্রোজেন শক্তি, ইত্যাদি) ব্যবহার সমন্বিত জ্বালানী মহাপরিকল্পনায় (Integrated Energy and Power Master Plan) জ্বালানী মিশ্রণে সর্বোচ্চ পরিমাণে অন্তর্ভুক্ত করার লক্ষ্যে সব ধরনের প্রচেষ্টা করতে হবে।

এছাড়া নবায়নযোগ্য জ্বালানী দ্বারা উৎপাদিত শক্তি মজুদ করা এবং সর্বোচ্চ চাহিদার সময় তার ব্যবহার অথবা বিদেশে রপ্তানির পরিকল্পনা এখন থেকেই নিতে হবে। সম্মেলন আরও লক্ষ্য করে যে, ২০৪০ সালের ভিতরে ৪০% বিদ্যুৎ নবায়নযোগ্য জ্বালানী দ্বারা উৎপাদনের লক্ষ্য ঘোষিত হলেও বাংলাদেশ কপ-২৬-এর "বিশ্বব্যাপী কয়লা থেকে ক্লিন পাওয়ার ট্রানজিশন স্টেটমেন্ট"-এ স্বাক্ষর করেনি। সম্মেলন মনে করে যে, এই দলিলে বাংলাদেশের স্বাক্ষর করা উচিত।

উপর্যুক্ত বিভিন্ন সীমাবদ্ধতা ও চ্যালেঞ্জ সত্ত্বেও সম্মেলন কয়লা থেকে সরে আসা এবং নবায়নযোগ্য জ্বালানীর অধিক ব্যবহারের নীতিকে স্বাগত জানায় এবং মনে করে যে, এসব নীতির সঠিক বাস্তবায়নের মাধ্যমে বাংলাদেশ আন্তর্জাতিক অঙ্গনে একটি ইতিবাচক দৃষ্টান্ত স্থাপন করতে পারে এবং তা বিশ্বে বাংলাদেশের ভাবমূর্তি আরও উজ্জ্বল করতে পারে। বিশেষত, অত্যাধুনিক প্রযুক্তি ব্যবহারকারী ও পরিবেশ বান্ধব হাইড্রোজেন উৎপাদনের একটি টেস্ট মডেল স্থাপনের মাধ্যমে বাংলাদেশ সারা বিশ্বে সুনাম কুড়াতে পারে।

(গ) রাষ্ট্রীয় ও ব্যক্তিখাতের ভূমিকার সঠিক সমন্বয়

সম্মেলন লক্ষ করে যে, বাংলাদেশে বিদ্যুৎ উৎপাদনে ব্যক্তিখাতের ভূমিকা ক্রমশ বৃদ্ধি পেয়ে এখন তা রাষ্ট্রীয় খাতের ভূমিকার সমকক্ষ হয়ে দাঁড়িয়েছে। পৃথিবীর বিভিন্ন দেশে বিদ্যুৎ উৎপাদনে রাষ্ট্রীয় এবং ব্যক্তিখাতের ভূমিকার বিভিন্ন অনুপাত লক্ষ করা যায়। তবে অনুপাতের চেয়ে বেশী গুরুত্বপূর্ণ হলো কী নিয়ন্ত্রণ-কাঠামোর অধীনে ব্যক্তিখাতের বিকাশ সাধিত হচ্ছে। যদি এই বিকাশ একটি প্রতিযোগিতামূলক, স্বচ্ছতাসম্পন্ন, ঝুঁকিগ্রহণের সাথে মুনাফার সঠিক সম্পর্কের অধীনে অর্জিত হয়, তবে সেটা অর্থনীতির জন্য উপকারী হতে পারে। কিন্তু সেটা যদি কেবলই রাষ্ট্রীয় আনুকূল্য এবং মুনাফার সাথে ঝুঁকি গ্রহণের সাথে সম্পর্কহীনভাবে গড়ে ওঠে, তবে তা অর্থনীতির জন্য ক্ষতিকর হতে পারে। বাংলাদেশে এখন পর্যন্ত বিদ্যুৎ উৎপাদনে ব্যক্তিখাতের বিকাশে মূলত উপর্যুক্ত দ্বিতীয় ধারাতে গড়ে উঠেছে বলে প্রতীয়মান হয়। সে কারণেই সরকারকে বর্তমানে ব্যক্তি মালিকানার বিদ্যুৎ কেন্দ্রসমূহের অব্যবহৃত উৎপাদন ক্ষমতার জন্য বিপুল পরিমাণ ভর্তুকী দিতে হচ্ছে। এই অভিজ্ঞতার আলোকে ভবিষ্যতে ব্যক্তিখাতে বিদ্যুৎ কেন্দ্র স্থাপনের অনুমোদনের আগে এ বিষয়ে প্রয়োজনীয় নীতি কাঠামো গড়ে তুলতে হবে, যাতে এসব প্রতিষ্ঠান সরকারের ভর্তুকী ও অন্যান্য বিভিন্ন আনুকূল্য নির্ভর না হয়। বিদ্যুৎ কেন্দ্র স্থাপনের লাইসেন্স প্রদান পছন্দসই ব্যবসায়ী অথবা ব্যবসায়ী গোষ্ঠীকে সুবিধা প্রদানের উপায় হিসেবে ব্যবহার করা অর্থনীতির জন্য মারাত্মক কুফল বয়ে আনবে। সংক্ষেপে, বিদ্যুৎখাতের রাজনীতিকরণ প্রতিরোধ করতে হবে।

এ বিষয়ে সম্মেলন লক্ষ করে যে, সাধারণত উন্নয়নের প্রথম ধাপে বিদ্যুৎ উৎপাদনে সরকারী খাতের ভূমিকা বেশী থাকে। বিদ্যুৎ উৎপাদন একটি পুঁজিঘন প্রক্রিয়া, এবং উন্নয়নের শুরুতে ব্যক্তি উদ্যোক্তাদের এত বড় পরিমাণে পুঁজি বিনিয়োগের সক্ষমতা থাকে না। দ্বিতীয়ত, ব্যক্তিখাতে বিদ্যুৎ উৎপাদনের জন্য যে নীতি-কাঠামো এবং তা প্রয়োগের জন্য যে প্রাতিষ্ঠানিক সক্ষমতার

প্রয়োজন তা উন্নয়নের প্রথম ধাপে সরকারের থাকে না। সময়ে ব্যক্তিখাতের পুঁজি বিনিয়োগের সক্ষমতা বৃদ্ধি পায় এবং রাষ্ট্রেরও নীতি-কাঠামো এবং তা প্রয়োগের জন্য প্রাতিষ্ঠানিক সক্ষমতা বৃদ্ধি পায়। ফলে তখন ব্যক্তিখাতে বিদ্যুৎ উৎপাদনের অনুপাত বৃদ্ধি পেতে পারে। এক্ষেত্রে PSMP (2016/2018)-তে একটি বিপরীত প্রস্তাবনা লক্ষ্য করা যায়। এই প্রস্তাবনা অনুযায়ী বাংলাদেশে প্রথমেই বিদ্যুৎ উৎপাদনে ব্যক্তিখাতের ভূমিকা বৃদ্ধি পাবে এবং পরে তা হ্রাস পেয়ে অত্যন্ত নীচু মাত্রায় পৌঁছাবে। কেন বাংলাদেশের জন্য এ ধরনের একটি বিপরীত ধারা প্রযোজ্য হবে তাঁর কোনো উপযুক্ত ব্যাখ্যা PSMP (2016/2018)-তে পাওয়া যায় না। সম্মেলন মনে করে যে, বাংলাদেশে শক্তি উৎপাদনে ব্যক্তিখাতের ভূমিকার পর্যালোচনা এবং উপযোগী নীতি-কাঠামো নির্ধারণ জরুরী হয়ে উঠেছে।

(ঘ) দেশীয় এবং বৈদেশিক সংস্থা এবং প্রভাবের সঠিক সমন্বয়

সম্মেলন আরও লক্ষ্য করে যে, বাংলাদেশের জ্বালানী খাতে ক্রমান্বয়ে বৈদেশিক সংস্থা এবং প্রভাবকের গুরুত্ব বৃদ্ধি পেয়েছে। এই প্রভাব দুই ধারায় অগ্রসর হয়েছে। একটি হলো জ্বালানীর উৎস হিসেবে। দ্বিতীয় হলো, বিদ্যুৎ উৎপাদনের ক্ষেত্রে। আগে বাংলাদেশের বিদ্যুৎ উৎপাদন প্রায় শতভাগ দেশীয় গ্যাস নির্ভর ছিল। কিন্তু চাহিদার তুলনায় দেশীয় গ্যাসের অপ্রতুলতার কারণে বর্তমানে বাংলাদেশ বিদেশ থেকে তরলীকৃত প্রাকৃতিক গ্যাস (এল-এন-জি) আমদানি করছে। অন্যদিকে রামপাল, পায়রা প্রভৃতি বৃহদাকার কয়লা ভিত্তিক বিদ্যুৎ কেন্দ্র নির্মাণের ফলে বিদেশ থেকে কয়লা আমদানির পরিমাণ বেড়েছে। ফলে এসব বৈদেশিক সূত্রের জ্বালানী সঠিকদামে এবং সঠিক কৌশলে আমদানি করা হচ্ছে কিনা তা একটি গুরুত্বপূর্ণ বিষয় হয়ে দাঁড়িয়েছে। যেমন, রামপালের জন্য অস্ট্রেলিয়া এবং ইন্দোনেশিয়া থেকে উন্নতমানের কয়লা আমদানির প্রতিশ্রুতি সত্ত্বেও ভারত থেকে অপেক্ষাকৃত নিম্নমানের কয়লা আমদানি করা

হচ্ছে। অন্যদিকে দীর্ঘমেয়াদী চুক্তির অধীনে অপেক্ষাকৃত স্বল্পদামে আমদানির পরিবর্তে স্পট মার্কেট থেকে উচ্চ দামে এল-এন-জি আমদানির অভিযোগ উঠেছে। সম্মেলন মনে করে এসব বিষয়ে সরকারকে আরও সংগতিপূর্ণ এবং স্বচ্ছতাভিত্তিক আচরণ প্রদর্শন করতে হবে।

বিদেশ থেকে গ্যাস আমদানির প্রয়োজনীয়তা আছে কিনা, সে বিষয়েও বিশেষজ্ঞরা সন্দেহ প্রকাশ করেছেন। তাঁদের ধারণা যে, কিছু কিছু মহলের প্রভাবের কারণে সরকার দেশের গ্যাস অনুসন্ধান এবং উত্তোলনের পরিবর্তে বিদেশ থেকে গ্যাস আমদানির প্রতি বেশী নজর দিচ্ছে। এর একটি প্রমাণ হলো গত বিশ বছরে মাত্র বিশটির মতো কূপ খনন। তদুপরি আবিস্কৃত গ্যাসক্ষেত্রসমূহ থেকেও গ্যাস উত্তোলনে তেমন সক্রিয়তা প্রদর্শিত হচ্ছে না। যেমন, ভোলাতে দু'টি গ্যাসক্ষেত্র আবিস্কৃত হলেও, সেগুলি থেকে গ্যাস উত্তোলন করা হচ্ছে না কারণ গ্যাস সঞ্চালনের জন্য প্রয়োজনীয় পাইপ-লাইন বসানো হয়নি। একইভাবে ধারণা করা হয়েছিল যে, ভারত এবং মিয়ানমারের সাথে সমুদ্রসীমা সংক্রান্ত বিরোধ নিষ্পত্তির পর বঙ্গোপসাগরে গ্যাস ও তেলের অনুসন্ধান ও উত্তোলন আরও বৃদ্ধি পাবে। সে ধরনের কোনো তৎপরতাও পরিলক্ষিত হচ্ছে না। সম্মেলন মনে করে যে, দেশীয় গ্যাস অনুসন্ধান এবং উত্তোলনের প্রতি আরও গুরুত্ব প্রদান করা প্রয়োজন, যাতে করে বাংলাদেশকে বৈদেশিক গ্যাসের উপর নির্ভরশীল হতে না হয়। সম্মেলন সে ধারায় পদক্ষেপ গ্রহণের জন্য সরকারের প্রতি আহ্বান জানাচ্ছে।

দ্বিতীয়ত, বিভিন্ন সরকারী ও বেসরকারি প্রতিষ্ঠানের সাথে যৌথ উদ্যোগের ভিত্তিতে বাংলাদেশে বিদ্যুৎ উৎপাদনে বিদেশী সরকারী এবং বেসরকারি সংস্থার অংশগ্রহণ বৃদ্ধি পেয়েছে। সম্মেলন মনে করে যে, এক্ষেত্রেও সঠিক নিয়ন্ত্রণ-কাঠামোর উদ্ভাবন এবং প্রয়োগ হওয়া প্রয়োজন। বিদেশী সংস্থার অংশগ্রহণ সরকারী আনুকূল্য এবং ভর্তুকি নির্ভর এবং ঝুঁকিহীন মুনাফা সম্বলিত হওয়া উচিত নয়। বরং, এই অংশগ্রহণ হতে হবে বাজার-ভিত্তিক, ভর্তুকীহীন,

এবং “ঝুঁকির বিনিময়ে মুনাফা” নীতির অনুসারী। সম্মেলন সরকারকে এ বিষয়ে প্রয়োজনীয় পদক্ষেপ গ্রহণের আহ্বান জানাচ্ছে।

(ঙ) বিদ্যুৎ উৎপাদন প্রতিষ্ঠানসমূহের সঠিক আকার নিশ্চিতকরণ

সম্মেলন লক্ষ করে যে, বিদ্যুৎ উৎপাদন প্রতিষ্ঠানের আকার বিভিন্ন ধরনের হতে পারে। বৃহদাকার প্রতিষ্ঠানের কিছু সুবিধা আছে। তাঁর মধ্যে যেমন, অর্থনীতির ভাষায়, “ইকনমিস অফ স্কেল,” যার ফলে প্রতি ইউনিট বিদ্যুতের উৎপাদন খরচ কম হয়। দ্বিতীয়ত, বৃহদাকার শিল্প প্রতিষ্ঠানসমূহের বিপুল পরিমাণ বিদ্যুৎ চাহিদা সহজে পূরণ সুগম হয়। কিন্তু বৃহদাকার বিদ্যুৎ উৎপাদন প্রতিষ্ঠানের কিছু অসুবিধাও আছে। তাঁর মধ্যে যেমন দীর্ঘ নির্মাণকাল। দ্বিতীয়ত, অধিকতর সঞ্চালন ব্যয় এবং সিস্টেম লস। তৃতীয়ত, অত্যন্ত ব্যয়বহুল হওয়ার কারণে বৃহদাকার বিদ্যুৎ উৎপাদন কেন্দ্রসমূহ অনেকক্ষেত্রে সরকারী খাতে নির্মিত হয় যেখানে দুর্নীতি ও অপব্যবহারের সুযোগ বেশী থাকে। ফলে শেষাবধি ইউনিট-প্রতি উৎপাদন খরচ কম হয় না; বরং বাজারদামের চেয়ে বেশী হয় এবং লোকসানি প্রতিষ্ঠানে (তথা শ্বেত হস্তিতে) পরিণত হয়। কিন্তু বিরাট পরিমাণ লব্ধিকৃত পুঁজি (সান্স কস্ট) হিসেবে আটকে যাওয়ায় এগুলো পরিত্যাগ করা কঠিন হয় এবং তা ক্রমাগতভাবে সরকারের বাজেটের উপর চাপ সৃষ্টি করে।

সম্মেলন লক্ষ করে যে, বিগত সময়কালে বাংলাদেশ বৃহদাকার বিদ্যুৎ উৎপাদন কেন্দ্র নির্মাণের দিকে ঝুঁকেছে। বেশীরভাগ ক্ষেত্রে এগুলো সরকারের “পারচেজ গ্যারান্টি”র অধীনে এসব নির্মিত হচ্ছে। ইতিমধ্যেই এগুলোর অলস ক্যাপাসিটির জন্য সরকারকে বিরাট পরিমাণ ভর্তুকী দিতে হচ্ছে। পরিকল্পনাধীন এবং নির্মায়মান বৃহদাকার বিদ্যুৎ কেন্দ্রসমূহ বাস্তবায়িত হলে এই ভর্তুকীর পরিমাণ আরও বৃদ্ধি পেতে পারে।

সেজন্য সম্মেলন সরকারকে মাঝারি এবং ক্ষুদ্রাকার বিদ্যুত কেন্দ্র নির্মাণকে উৎসাহিত করার আহ্বান জানাচ্ছে। বস্তুত, সম্মেলন মনে করে যে, বিদ্যুৎ উৎপাদনে ব্যক্তিখাতের ভূমিকা ক্ষুদ্র এবং মাঝারি আকারের বিদ্যুৎ কেন্দ্র প্রতিষ্ঠায় সীমাবদ্ধ রাখার কথা ভাবা যেতে পারে। এসব প্রতিষ্ঠান স্থানীয় বিদ্যুৎ চাহিদার নিরিখে, নিজস্ব পুঁজি বিনিয়োগ, এবং “ঝুঁকি গ্রহণের বিনিময়ে মুনাফা অর্জন” নীতির ভিত্তিতে ব্যক্তি উদ্যোক্তারা প্রতিষ্ঠিত করবে, ফলে সরকারের বাজেটের উপর চাপ সৃষ্টি করবে না। ভোক্তাদের কাছাকাছি হওয়াতে এসব প্রতিষ্ঠানের সঞ্চালন ব্যয় এবং সিস্টেম লস কমে।

বাংলাদেশের মতো ঘনবসতিপূর্ণ অঞ্চলে বড় মাপের পারমাণবিক বিদ্যুৎ কেন্দ্র স্থাপন করা অনেক বেশি ঝুঁকিপূর্ণ বিধায় আণবিক বিদ্যুৎ উৎপাদনের ক্ষেত্রেও বৃহদাকারের পরিবর্তে সর্বাধুনিক চতুর্থ প্রজন্মের অধিকতর নিরাপদ ক্ষুদ্র ও মাঝারি আকৃতির রিয়েক্টর (Small Modular Reactors) স্থাপনের সুযোগ সৃষ্টি হয়েছে। আণবিক বিদ্যুৎ উৎপাদন প্রসারের ক্ষেত্রে সরকার এসব বিকল্প বিবেচনায় নিতে পারে।

উপর্যুক্ত পরিলক্ষণের ভিত্তিতে সম্মেলন সরকারকে কেবল বৃহদাকার বিদ্যুৎ প্রতিষ্ঠান নির্মাণে উৎসাহী না হয়ে বৃহৎ, মাঝারি, এবং ক্ষুদ্রাকারের বিদ্যুৎ প্রতিষ্ঠানের সমবায়ে একটি “সুযম আকার-বিতরণে”র (অপ্টিমাল সাইজ ডিস্ট্রিбуশান) অর্জনের দিকে অগ্রসর হওয়ার আহ্বান জানাচ্ছে।

(চ) বিদ্যুৎ উৎপাদন, বিতরণ, ও সঞ্চালন স্থাপনার সঠিক অবস্থান নিশ্চিতকরণ

বিদ্যুৎ উৎপাদন বিকাশের ক্ষেত্রে বিদ্যুৎ কেন্দ্রের ভৌগলিক অবস্থান নির্ধারণ একটি গুরুত্বপূর্ণ বিষয়। এ বিষয়ে সম্মেলন লক্ষ করে যে, বিগত সময়কালে সরকার উপকূলবর্তী এলাকায় অনেকগুলো বৃহদাকার বিদ্যুৎ প্রতিষ্ঠান নির্মাণ করছে এবং করার পরিকল্পনা করছে। যেহেতু এগুলো বেশীরভাগ ক্ষেত্রে আমদানিকৃত কয়লা নির্ভর, সেহেতু এগুলোকে উপকূলবর্তী এলাকায় স্থাপনের

একটা যুক্তি আছে। একইভাবে ঝাঁকি হ্রাসের উদ্দেশ্যে আণবিক বিদ্যুৎ কেন্দ্রও অনেক ক্ষেত্রে উপকূলে স্থাপিত হয়। অথচ রূপপুর আণবিক বিদ্যুৎ কেন্দ্র দেশের গভীর অভ্যন্তরে নির্মিত হচ্ছে। কিন্তু উপকূলে অথবা দূরবর্তী স্থানে বিদ্যুৎ কেন্দ্র স্থাপিত হওয়ার অনেক নেতিবাচক দিকও আছে। যেমন, এগুলোর সম্ভাব্য বায়ু এবং সিস্টেম লস বেশী হয়। দূরবর্তী স্থানে নির্মিত হওয়ায় এগুলোর কর্মীদের জন্য পৃথক আবাসন ও অন্যান্য সুযোগ-সুবিধার ব্যবস্থা করতে হয়, যার ফলে উৎপাদন ব্যয় বৃদ্ধি পায়। উপকূলে স্থাপিত বিদ্যুৎ কেন্দ্র অনেক ক্ষেত্রে সেখানকার স্পর্শকাতর পরিবেশের অপূরণযোগ্য ক্ষতি সাধন করে, যেমন রামপাল বিদ্যুৎ কেন্দ্র সুন্দরবনের প্রতি হুমকি সৃষ্টি করেছে। সর্বোপরি, বাংলাদেশের উপকূল প্রায়শ ঘূর্ণিঝড় ও জলোচ্ছ্বাস দ্বারা আক্রান্ত হয় এবং তা উপকূলে স্থাপিত বৃহদাকার বিদ্যুৎ প্রতিষ্ঠানের প্রতি একটা বাড়তি হুমকি সৃষ্টি করে।

উপর্যুক্ত পরিলক্ষণের ভিত্তিতে সম্মেলন বিদ্যুত উৎপাদন কেন্দ্রের ভৌগলিক অবস্থানের বিষয়ে উপকূল নির্ভরতা হ্রাস করে আরও সুষম স্থান-বিতরণ (অপ্টিমাল স্পেশিয়াল ডিস্ট্রিбуশান)-র দিকে অগ্রসর হওয়ার জন্য সরকারের প্রতি আহ্বান জানাচ্ছে। সম্মেলন লক্ষ্য করে যে, এখন যেহেতু কয়লা-নির্ভরতা কমানোর সিদ্ধান্ত হয়েছে, সেহেতু বিদ্যুৎ কেন্দ্রসমূহ উপকূলে স্থাপনের যৌক্তিকতা হ্রাস পেয়েছে। গ্যাস-ভিত্তিক মাঝারী এবং ক্ষুদ্রাকার বিদ্যুৎ কেন্দ্র দেশের অভ্যন্তরে ভোক্তাদের নিকটে স্থাপন করা শ্রেয় হতে পারে। একইভাবে নবায়নযোগ্য জ্বালানী-ভিত্তিক বিদ্যুৎ উৎপাদন সারা দেশে ছড়িয়ে দেয়া প্রয়োজন; তাতে বিদ্যুৎ উৎপাদনের জন্য প্রয়োজনীয় স্থানেরও সাশ্রয় হবে। সম্মেলন বিদ্যুৎ উৎপাদন ও বিতরণ যথাসম্ভব বিকেন্দ্রীকরণের (decentralization of production and transmission) আহ্বান জানায়।

(ছ) উপযোগী বিতরণ এবং বিদ্যুৎ এবং জ্বালানীর সঠিক মূল্য নিশ্চিতকরণ

সম্মেলন লক্ষ করে যে, বিদ্যুৎ উৎপাদনের পাশাপাশি তা সঞ্চালন ও সাধারণভাবে জ্বালানী বিতরণ বিষয়ক নীতিমালা বিশেষ গুরুত্ব বহন করে। যেমন, সাধারণভাবে ধারণা করা হয় যে, বিদ্যুৎ উৎপাদন ক্ষমতার চেয়ে বিদ্যুৎ সঞ্চালন ক্ষমতা ৫০ শতাংশের বেশী এবং বিদ্যুৎ বিতরণ ক্ষমতা ১০০ শতাংশ বেশী হওয়া দরকার। সুতরাং, বিদ্যুৎ উৎপাদন ক্ষমতা বৃদ্ধির পাশাপাশি সঞ্চালন ও বিতরণ ক্ষমতার প্রয়োজনীয় সক্ষমতা বৃদ্ধি অর্জিত হচ্ছে কিনা, তা নিশ্চিত করা একটি গুরুত্বপূর্ণ করণীয়।

এ বিষয়ে সম্মেলন আরও লক্ষ করে যে, ব্যক্তি খাতের উদ্যোগ সাধারণত বিদ্যুৎ উৎপাদনের দিকে নিবদ্ধ হয়; ফলে প্রয়োজনীয় সঞ্চালন এবং বিতরণ ব্যবস্থা নিশ্চিত করার দায়িত্ব বহুলাংশে সরকারী খাতের উপর বর্তায়। এ দায়িত্ব সঠিকভাবে পালিত হচ্ছে কিনা তাঁর দিকে নজর দেয়া প্রয়োজন। তবে এই দায়িত্ব পালন করে সরকারকে ব্যক্তিখাতকে ভর্তুকী দেয়ার প্রয়োজন নেই। সরকারী এবং বেসরকারি বিদ্যুৎ উৎপাদনকারীদের নিকট হতে যৌক্তিক হারে সঞ্চালন ও বিতরণ বাবদ চার্জ আদায়ের মাধ্যমে সরকার এ বাবদ ভর্তুকী প্রদান পরিহার করতে পারে।

সম্মেলন লক্ষ করে যে, জ্বালানী বিতরণের ক্ষেত্রে দক্ষতা এবং বৈষম্য-পরিহার – উভয় দিকের প্রতিই নজর দেয়া প্রয়োজন। যেমন ইতিপূর্বে বাংলাদেশে গৃহস্থালি ব্যবহারের জন্য সিলিভারের পরিবর্তে পাইপ-ভিত্তিক গ্যাস বিতরণের নীতি নেয়ার কারণে আঞ্চলিক, গ্রাম-শহর, এবং ধনী-দরিদ্রের মধ্যে গ্যাসের প্রাপ্তি নিয়ে বৈষম্যের উদ্ভব ঘটেছিল। আজও বাংলাদেশ সে বৈষম্য পুরোপুরি কাটিয়ে উঠতে পারেনি। বর্তমানের নতুন পর্যায়ে জ্বালানী এবং বিদ্যুৎ বিতরণের ক্ষেত্রে যাতে এ ধরনের বৈষম্যের উদ্ভব না ঘটে সেদিকে মনোযোগ দিতে হবে।

সম্মেলন লক্ষ করে যে, আমদানিকৃত জ্বালানীর দিকে অগ্রসর হওয়ার কারণে জ্বালানীর ক্রয় এবং বিক্রয় মূল্য এখন সবিশেষ গুরুত্ব অর্জন করেছে। কয়লা এবং গ্যাস ক্রয়ের উৎস, পদ্ধতি, এবং মূল্য দেশের স্বার্থ-রক্ষাকারী হচ্ছে কিনা তা বিশেষ বিবেচনার বিষয়। সম্প্রতি অভিযোগ উঠেছে যে, সাম্প্রতিককালে দীর্ঘমেয়াদী চুক্তির অধীনে অপেক্ষাকৃত স্বল্পমূল্যে কেনার পরিবর্তে স্পট মার্কেট থেকে চড়া মূল্যে গ্যাস ক্রয় করা হয়েছে এবং তাঁর ফলে সরকারকে অতিরিক্ত ব্যয় করতে হয়েছে এবং বাংলাদেশে দেশীয় এবং আমদানিকৃত গ্যাসের সহযোগে সৃষ্ট মিশ্রিত গ্যাসের দাম বৃদ্ধি পেয়েছে। সম্মেলন এ ধরনের জাতীয় স্বার্থ-বিরোধী কর্মকাণ্ড যাতে না ঘটে তা নিশ্চিত করার জন্য সরকারের প্রতি আহ্বান জানাচ্ছে। একইভাবে কয়লা আমদানির ক্ষেত্রেও যাতে জাতীয় স্বার্থ-বিরোধী কোনো সিদ্ধান্ত গৃহীত না হয়, তা নিশ্চিত করার জন্যও সম্মেলন সরকারের প্রতি আহ্বান জানাচ্ছে।

দেশের অভ্যন্তরে জ্বালানী এবং বিদ্যুতের দাম নির্ধারণের ক্ষেত্রেও অর্থনৈতিক যৌক্তিকতার পথ অনুসরণের জন্য সম্মেলন সরকারের প্রতি আহ্বান জানাচ্ছে। এই পথ অনুসারে দেশের অভ্যন্তরীণ উপকরণের দামও “সীমান্ত দাম” (ইংরাজিতে, বর্ডার প্রাইস)-এর ভিত্তিতে নির্ধারিত হওয়া প্রয়োজন। এই উত্তরণ এক লাফে করার চেষ্টা সমীচীন হবে না। তবে অর্থনৈতিক যৌক্তিকতার স্বার্থে এটাকেই চূড়ান্ত লক্ষ্য হিসেবে গ্রহণ করা প্রয়োজন, এবং জনগণকে নীতির যৌক্তিকতা সম্পর্কে অবহিত করতে হবে, যাতে তারা এই নীতি গ্রহণে সম্মতি দেয়।

বিদ্যুৎ উৎপাদকদের নিকট উপকরণ সরবরাহ এবং তাদের কাছ থেকে বিদ্যুৎ ক্রয়ের ক্ষেত্রে দীর্ঘমেয়াদে ভর্তুকী পরিহারের নীতি গ্রহণ করা প্রয়োজন। সম্মেলন লক্ষ করে যে, এই নীতি না গ্রহণ করার ফলে বর্তমানে বিদ্যুৎ উৎপাদকদের, বিশেষত ব্যক্তি খাতের বিদ্যুৎ উৎপাদকদের, বিপুল পরিমাণ ভর্তুকী দিতে হচ্ছে। সকল ক্ষেত্রে উপকরণ ও উৎপাদনের দাম নির্ধারণের

ক্ষেত্রে অর্থনৈতিক যৌক্তিকতার দীর্ঘমেয়াদী নীতি অনুসরণের জন্য সম্মেলন আহ্বান জানাচ্ছে।

(জ) জ্বালানী কৌশলের আর্থিক স্থায়িত্বশীলতা

সম্মেলন মনে করে যে, জ্বালানী খাতকে আর্থিকভাবে স্থায়িত্বশীল হতে হবে। সে আলোকে ভর্তুকী দিয়ে বিদ্যুৎ উৎপাদন ক্ষমতা সম্প্রসারণের যে নীতি বর্তমানে অনুসৃত হচ্ছে, সে বিষয়ে সম্মেলন উদ্বেগ প্রকাশ করে। ব্যক্তিখাতের বিদ্যুৎ উৎপাদকদের সরকারী আনুকূল্য, অব্যাহত ভর্তুকী, এবং “স্বাকি-বিহীন মুনাফা” অর্জনের সুযোগ দেয়ার পরিবর্তে বাজার-ভিত্তিক, ভর্তুকীহীন, এবং “স্বাকি গ্রহণ এবং দক্ষতা প্রদর্শনের বিনিময়ে মুনাফা” অর্জনের নীতি অনুসরণ করতে হবে।

সম্মেলন মনে করে যে, সরকারী খাতেও আর্থিক স্থায়িত্বশীলতার দৃষ্টিকোণ থেকে প্রশংসাপেক্ষ প্রকল্প গ্রহণ থেকে বিরত থাকতে হবে। সে দৃষ্টিকোণ থেকে ১৮ বিলিয়ন ডলার ব্যয় করে মাত্র ২,৪০০ মেগাওয়াট ক্ষমতার রূপপুর আণবিক বিদ্যুৎ কেন্দ্র স্থাপনের বিষয়ে সম্মেলন উদ্বেগ প্রকাশ করে। সম্মেলন লক্ষ্য করে যে, অনেকের মতে অন্যান্য দেশে অনুরূপ বিদ্যুৎ কেন্দ্র আরও অনেক কম বাজেটে নির্মিত হয়েছে। কেন বাংলাদেশের ক্ষেত্রে এটার বাজেট এত বেশী হলো তা ব্যাখ্যার জন্য সম্মেলন সরকারের প্রতি আহ্বান জানাচ্ছে। সম্মেলন আরও লক্ষ্য করে যে, এত বড় বাজেটের একটি প্রকল্প তেমন কোন গণআলোচনা ছাড়াই সরকার গ্রহণ করে এবং বাস্তবায়নে এগিয়ে যায়। সম্মেলন লক্ষ্য করে যে, সরকার দ্বিতীয় একটি পারমাণবিক বিদ্যুৎ কেন্দ্র স্থাপনের লক্ষ্য ঘোষণা করেছে। সম্মেলন আশা করে যে, এটার ক্ষেত্রে পর্যাপ্ত গণআলোচনা, স্বচ্ছতা, এবং জবাবদিহিতার ভিত্তিতে সরকার সিদ্ধান্ত গ্রহণ করবে। সরকারী খাতে দুর্নীতি, অপচয়, ও অব্যবস্থাপনার হ্রাস জ্বালানী খাতের আর্থিক স্থায়িত্বশীলতা অর্জনে সহায়ক হবে।

সম্মেলন লক্ষ্য করে যে, দেশীয় গ্যাস অনুসন্ধান এবং উত্তোলনের উপর আরও গুরুত্ব প্রদান বাংলাদেশের জ্বালানী খাতের স্থায়িত্বশীলতা নিশ্চিতকরণে সহায়ক হবে।

সম্মেলন মনে করে যে, জ্বালানী ও বিদ্যুৎ খাতে সরকারী প্রতিষ্ঠানসমূহের ক্রমবর্ধমান লোকসানের অন্তর্নিহিত কারণ খুঁজে বের করে সংশ্লিষ্টদেরকে জবাবদিহিতার আওতায় আনতে হবে এবং জ্বালানী এবং বিদ্যুৎ খাতকে দুর্নিতিমুক্ত করে পরিবেশ বান্ধব, অর্থনৈতিকভাবে দায়িত্বশীল এবং স্থায়িত্বশীল উন্নয়নের ধারায় ফিরিয়ে আনতে হবে।

(ঝ) জ্বালানী কৌশলের পরিবেশগত স্থায়িত্বশীলতা এবং জ্বালানী, পানি, খাদ্য/ফসল ও জলবায়ু পরিবর্তন এর মধ্যে ভারসাম্য রক্ষা

সম্মেলন লক্ষ্য করে যে, যদিও বৈশ্বিক “উষ্ণতা বৃদ্ধিকারক গ্যাস” (উবগ) উদগীরণে বাংলাদেশের ভূমিকা উল্লেখযোগ্য নয়, তবুও উবগ নিরসনে উদ্যোগী ভূমিকা পালনের মাধ্যমে বাংলাদেশ বিশ্বের কাছে একটি দৃষ্টান্ত স্থাপন করতে পারে। এ বিষয়ে সম্মেলন লক্ষ্য করে যে, বাংলাদেশ সম্প্রতি জলবায়ু পরিবর্তন রোধে প্যারিস চুক্তির অধীনে জাতিসংঘের নিকট যে “জাতীয়ভাবে নির্ধারিত অবদান” (ন্যাশনালি ডিটারমিন্ড কন্ট্রিবিউশান) পেশ করেছে তার সাথে বাস্তবে গৃহীত পদক্ষেপ এবং সম্ভাব্য অর্জনের বিপুল ফারাক পরিদৃষ্ট হচ্ছে। সম্মেলন আশা করে যে, সরকার এই ফারাক পূরণের লক্ষ্যে দ্রুত যথাযথ পদক্ষেপ গ্রহণ করবে।

সম্মেলন মনে করে যে, উবগ হ্রাসের পদক্ষেপ শুধুমাত্র বৈশ্বিক উবগ হ্রাসের জন্যই প্রয়োজনীয় নয়। তা স্থানীয় পরিবেশের জন্যও সহায়ক হতে পারে। রামপাল বিদ্যুৎ কেন্দ্র তাঁর একটি গুরুত্বপূর্ণ উদাহরণ। এই কেন্দ্র

বাতিলকরণ - অন্ততপক্ষে কয়লার পরিবর্তে গ্যাসে রূপান্তরের মাধ্যমে - বাংলাদেশ শুধু বৈশ্বিক পর্যায়ে উবগ হ্রাসেভূমিকা পালন করতে পারে তাই নয়, বাংলাদেশের সুন্দরবন রক্ষাও নিশ্চিত করতে পারে। অন্যান্য কয়লা-ভিত্তিক বিদ্যুৎ কেন্দ্রের জন্যও একই কথা প্রযোজ্য। জ্বালানী ব্যবহারের পাশাপাশি এর সাথে পানি, খাদ্য/ফসল ও জলবায়ু পরিবর্তনের মধ্যে ভারসাম্য রক্ষা করতে হবে এবং একটি খাতের বিকাশ করতে যেয়ে আরেকটি খাতের অযৌক্তিক ক্ষতি সাধন করা সঠিক হবে না।

(এ) জ্বালানী কৌশলের ঝুঁকি সহনশীল পর্যায়ে সীমাবদ্ধ রাখা

সম্মেলন লক্ষ করে যে, জ্বালানী সম্পর্কিত ঝুঁকি তিন ধরনের - পরিবেশগত, আর্থিক, এবং জীবন ও স্বাস্থ্যগত। বাংলাদেশের বর্তমান জ্বালানী নীতি এসব বিভিন্নমুখী ঝুঁকির প্রতি যথাযোগ্য মনোযোগ প্রদান করেছে না বলে সম্মেলন উদ্বেগ প্রকাশ করে। রামপাল এবং অন্যান্য কয়লা-ভিত্তিক বিদ্যুৎ উৎপাদন প্রকল্প পরিবেশগত ঝুঁকি বাড়িয়ে দিচ্ছে। বরগুনার তালতলিতে পাওয়ার চায়নার নির্মাণাধীন বরিশাল বিদ্যুৎ কেন্দ্র পায়রা, বিষখালি ও বলেশ্বর এই তিন নদীর মোহনায় নদীর জায়গা দখল করে নির্মাণ করায় জাতীয় নদী রক্ষা কমিশন যথাযথ তদন্তপূর্বক তা উচ্ছেদ করার লিখিত নির্দেশ দেয়। সুন্দরবন বিশ্ব ঐতিহ্যের বিশ কিলোমিটারের মধ্যে উক্ত বিদ্যুৎ কেন্দ্রটির অবস্থান হলেও পরিবেশ, বন ও জলবায়ু পরিবর্তন মন্ত্রণালয়ের প্রস্তুতকৃত বাংলাদেশের দক্ষিণ পশ্চিমাঞ্চলের কৌশলগত পরিবেশ সমীক্ষার খসড়ায় সরকারকে এই বিদ্যুৎ কেন্দ্রের অবস্থান ও সম্ভাব্য দূষণের বিষয়ে কোন কৌশলগত আলোচনা ও সুপারিশ উপস্থাপিত হয় নাই। পায়রা অঞ্চলে নির্মাণাধীন কয়লাভিত্তিক বিদ্যুৎ কেন্দ্রসমূহ দেশের ইলিশ ও তরমুজ উৎপাদনের উপর এবং মাতারবাড়ী-মহেশখালী অঞ্চলের বিদ্যুৎ কেন্দ্রসমূহ দেশের লবণ ও পর্যটন শিল্পের উপর

ব্যাপক নেতিবাচক প্রভাব পড়বে। সম্মেলন উদ্বেগের সাথে এই সমস্ত কৌশলগত বিষয়ে সরকারকে সতর্ক করে দিতে চায়।

ভর্তুকী-নির্ভর বিদ্যুৎ উৎপাদনের সম্প্রসারণ এবং ব্যয়বহুল আণবিক বিদ্যুৎ কেন্দ্রের নির্মাণ আর্থিক ঝুঁকি বাড়িয়ে তুলছে। দেশের অভ্যন্তরে ঘন-বসতি এলাকায় আণবিক কেন্দ্রের নির্মাণ জীবন এবং স্বাস্থ্যের উপর ঝুঁকি আরও বাড়িয়ে তুলছে। দেশের জ্বালানী নীতিকে এসব বিভিন্নমুখী ঝুঁকি হ্রাসের প্রতি মনোযোগী করার জন্য সম্মেলন সরকারের প্রতি আহ্বান জানাচ্ছে।

জীবাশ্ম জ্বালানী ব্যবহার করে বিদ্যুৎ উৎপাদনের বিভিন্ন প্রকল্প গ্রহণের কারণে বায়ুমানের সূচকের অবনতি রোধকল্পে প্রয়োজনীয় ব্যবস্থা নিয়ে জনস্বাস্থ্যের বিষয় ঝুঁকি প্রশমনের পদক্ষেপ গ্রহণ করার দাবী জানানো হচ্ছে।

বায়ুদূষকারী এবং জনস্বাস্থ্যের জন্য ঝুঁকিপূর্ণ সমস্ত জ্বালানীর উৎস (যেমন, অবৈজ্ঞানিকভাবে নির্মিত ইট ভাটা, ফিটনেস-বিহীন গাড়ী, বাস, মোটর সাইকেল, ট্রলার, লঞ্চ, স্টীমার, উড়োজাহাজ, বিভিন্ন শিল্প এবং কৃষিতে ব্যবহৃত যন্ত্রপাতি, ইত্যাদি) চিহ্নিত করতে হবে এবং পর্যায়ক্রমে সেইসব উৎস বাতিল এবং অপসারণ করতে হবে।

জ্বালানী এবং বিদ্যুৎ উৎপাদনের ক্ষেত্রে মধ্য এবং দীর্ঘ মেয়াদী পরিকল্পনা গ্রহণের ক্ষেত্রে স্থায়িত্বশীল উন্নয়নের ৭ম লক্ষ্য (Clean and Affordable Energy for All) পূরণে সহায়ক এমন নীতিমালা গ্রহণ করা প্রয়োজন যাতে সামাজিক অন্তর্ভুক্তি নিশ্চিত এবং সামাজিক আকাজ্খা প্রতিফলিত হয়।

বিদ্যুৎ উৎপাদন, বিতরণ এবং সরবরাহের ক্ষেত্রে এবং বিদ্যুৎ উৎপাদনের স্থান নির্ধারণের ক্ষেত্রে জনস্বাস্থ্যের ঝুঁকি, আর্থ-সামাজিক ক্ষয়ক্ষতি এবং পরিবেশের উপর অভিঘাত সম্ভাব্য সর্বনিম্ন মাত্রায় রাখার নিমিত্তে সকল প্রকল্পের জীবন-চক্র স্থায়িত্বশীলতা নিরূপন (Life Cycle Sustainability Assessment) করা প্রয়োজন।

(ট) জ্বালানী বিকাশে বর্জ্য ও পুনর্ব্যবহার নিশ্চিতকরণ

সম্মেলন আরও লক্ষ করে যে, কোন জ্বালানীই সবদিক থেকে বিপদমুক্ত নয়। যেমন সৌর শক্তি ব্যবহারের ক্ষেত্রে মেয়াদকাল শেষ হওয়ার পর সৌর প্যানেলসমূহের যথাযথভাবে এবং নিরাপদ উপায়ে পরিত্যাগ করা প্রয়োজন। বিশ্বব্যাপী উন্নয়নশীল দেশগুলিতে ২০৫০ সালের মধ্যে প্রায় ৮৫ শতাংশ বিদ্যুৎ নবায়নযোগ্য জ্বালানী থেকে আসবে বলে ধারণা করা হচ্ছে এবং এর ফলে ২০২০-২০৫০ সময়কালে শুধুমাত্র সৌর প্যানেল বর্জ্যের পরিমাণ ৭৮ মিলিয়ন মেট্রিক টন হতে পারে। (বায়ু-শক্তি, ব্যাটারি স্টোরেজ ইউনিট, এবং কম জীবনকালসম্পন্ন অফ-গ্রিড বিদ্যুতের বর্জ্য এর মধ্যে গণনা করা হয় নি।) এটা বাংলাদেশের জন্য নবায়নযোগ্য শক্তির বর্জ্য ব্যবস্থাপনার জন্য বিশাল চ্যালেঞ্জের পূর্বাভাস দেয়। সুতরাং, প্রথম থেকেই বাংলাদেশকে নবায়নযোগ্য জ্বালানী ব্যবহার-সৃষ্ট বিভিন্ন বর্জ্যের সঠিক ব্যবস্থাপনার উপর গুরুত্ব দিতে হবে।

সম্মেলন আরও লক্ষ করে যে, ইলেকট্রনিক্স শিল্পের মতো নবায়নযোগ্য জ্বালানীর ব্যবহারও মানুষকে অনেক বিষাক্ত বর্জ্যের সংস্পর্শে আনতে পারে। তার মধ্যে রয়েছে ক্যাডমিয়াম ও তামা-উপজাত বিভিন্ন পদার্থ, সীসা, হেক্সাফ্লুরোইথেন, পলিভিনাইল ফ্লোরাইড, টিন, লিথিয়াম এবং সিলিকন টেট্রাক্লোরাইড, ইত্যাদি, যার উঁচু মাত্রা মানুষ এবং পরিবেশের জন্য ক্ষতিকর হতে পারে। একইভাবে, পারমাণবিক বিদ্যুৎ কেন্দ্রের তেজস্ক্রিয় বর্জ্যের যথাযথভাবে অপসারণ, স্থানান্তরকরণ, ও পরিত্যাগ একটি গুরুত্বপূর্ণ চ্যালেঞ্জ। এক্ষেত্রে মনে রাখা প্রয়োজন যে, প্রচলিত জলবিদ্যুৎ (হাইড্রো পাওয়ার) – তথা নদীতে বাঁধ নির্মাণের মাধ্যমে বিদ্যুৎ উৎপাদন -- দীর্ঘমেয়াদী বিচারে নবায়নযোগ্য নয় কেননা এসব বাঁধের মেয়াদকাল সীমাবদ্ধ এবং তা অতিক্রান্ত হওয়ার পর নদীর গতিপথ ও অন্যান্য পরিবর্তনের কারণে তার পুনঃনির্মাণ সম্ভব হয় না। বাংলাদেশ যেহেতু ২০৩০ সালের মধ্যে মধ্যে ৩০% এবং ২০৪০

সনের মধ্যে ৪০% শতাংশ নবায়নযোগ্য উৎস থেকে শক্তি উৎপাদনের লক্ষ্য গ্রহণ করেছে, সেহেতু উন্নত দেশগুলির মতো বাংলাদেশেরও বিভিন্ন নবায়নযোগ্য জ্বালানীর ব্যবহার-সৃষ্ট বর্জ্য ও বিপজ্জনক পদার্থের যথাযথ ব্যবস্থাপনা, পুনর্ব্যবহার, ও পরিত্যাগ নিশ্চিত করতে হবে।

শহর ও গ্রামের কঠিন বর্জ্যববস্থাপনায় আমূল পরিবর্তন এনে বর্জ্য থেকে জ্বালানী ও বিদ্যুৎ উৎপাদনের সর্বাঙ্গিক উদ্যোগ নিতে হবে। এই লক্ষ্যে প্রাথমিক পর্যায়ে প্রতিটি জেলায় এবং পরবর্তীতে পর্যায়ক্রমে উপজেলায় স্বাস্থ্যসম্মত বর্জ্য-নিষ্ক্ষেপনাগার (Sanitary Landfill) গড়ে তুলতে হবে। এসব নিষ্ক্ষেপনাগারের চতুষ্পার্শ্বে এমন প্রতিরক্ষামূলক আবরণ দিতে হবে যাতে আশাপাশের জমি এবং বায়ু দূষিত না হয় এবং করে বর্জ্যের দূষিত পানি পার্শ্ববর্তী ভূপৃষ্ঠস্থ এবং ভূগর্ভস্থ পানিতে না পৌঁছায়।

(ঠ) সনাতনী জ্বালানী বিষয়ে সঠিক কৌশল অবলম্বন

সনাতনী জ্বালানী বাংলাদেশের অর্থনীতিতে, বিশেষত গ্রামীণ জীবনে, এখনও গুরুত্বপূর্ণ ভূমিকা পালন করে। সম্মেলন লক্ষ্য করে যে, এ বিষয়ে দু'ধরনের লক্ষ্য হতে পারে। একটি হলো যথাসম্ভব দ্রুত আধুনিক জ্বালানী দ্বারা সনাতনী জ্বালানীকে প্রতিস্থাপিত করায় সচেষ্ট হওয়া। দ্বিতীয় হলো সনাতনী জ্বালানীকে দ্রুত প্রতিস্থাপিত করার পরিবর্তে এর নেতিবাচক দিকসমূহ প্রশমন, যেমন উন্মুক্ত চুলার পরিবর্তে ধোঁয়া নিরোধক চুল্লীর ব্যবহার সম্প্রসারণ। সম্মেলন আশা করে যে, এসব বিকল্প বিষয়ে প্রয়োজনীয় গবেষণার ভিত্তিতে সঠিক লক্ষ্য এবং কর্মকৌশল গৃহীত হবে।

(ড) জ্বালানী এবং দেশের অন্যান্য গুরুত্বপূর্ণ বিষয়ে নীতি নির্ধারণ এবং পরিকল্পনা প্রণয়নে বৈদেশিক নির্ভরতা হ্রাস

সম্মেলন লক্ষ করে যে, অর্থনৈতিকভাবে বাংলাদেশ আগের তুলনায় স্বাবলম্বী হলেও, নীতি নির্ধারণ এবং পরিকল্পনা প্রণয়নে বাংলাদেশ এখনো বহুলাংশে বৈদেশিক-নির্ভরতা দ্বারা আক্রান্ত। যেমন, সরকার দেশের জ্বালানী বিষয়ক পরিকল্পনা প্রণয়ন করেছে জাপানের টোকিও ইলেকট্রিক কোম্পানির দ্বারা। একইভাবে দেখা যায় যে, দেশের “বদ্বীপ পরিকল্পনা ২১০০” প্রণীত হয়েছে মূলত ওলন্দাজ বিশেষজ্ঞদের দ্বারা। অথচ ঘনিষ্ঠ বিশ্লেষণে দেখা যায় যে, বিদেশী বিশেষজ্ঞ এবং সংস্থা দ্বারা প্রণীত পরিকল্পনা দেশের স্বার্থের জন্য সর্বাংশে অনুকূল হয় না। বরং অনেকক্ষেত্রেই তাঁর ফল হয় প্রতিকূল। টোকিও ইলেকট্রিক কোম্পানি কর্তৃক প্রণীত PSMS 2016/2018 পর্যালোচনা করলে দেখা যায় যে, এতে বহু ভ্রান্ত এবং দেশের জন্য ক্ষতিকর প্রস্তাবনা সন্নিবেশিত হয়েছে। যেমন, এতে চাহিদার সাথে সরবরাহের যথাযথ সামঞ্জস্য বিধান করা হয় নি, যার ফলে বর্তমানে বাংলাদেশ অত্যধিক রিজার্ভ মার্জিনের সমস্যা নিপতিত হয়েছে। দ্বিতীয়ত, এই পরিকল্পনা বাংলাদেশকে কয়লার দিকে ঠেলে দিয়েছে। তৃতীয়ত, এই পরিকল্পনা বিদ্যুৎ উৎপাদনে ব্যক্তিখাতের ভূমিকার এক অদ্ভুত প্রক্ষেপণ পরিবেশন করেছে, যার যুক্তি খুঁজে পাওয়া ভার। চতুর্থত, এই পরিকল্পনা বাংলাদেশকে ক্রমাগতভাবে বিদ্যুৎ আমদানির দিকে ঠেলে দিয়েছে। সব মিলিয়ে এই পরিকল্পনা জাতীয় স্বার্থের জন্য এবং পরিবেশ রক্ষার জন্য কল্যাণকর বলে প্রমাণিত হয়নি।

উপর্যুক্ত পরিলক্ষণের আলোকে, সম্মেলন সরকারকে দেশের নীতি নির্ধারণ এবং পরিকল্পনা প্রণয়নে বৈদেশিক সংস্থার উপর নির্ভরশীলতা থেকে বেড়িয়ে এসে জাতীয় সক্ষমতার ভিত্তিতে অগ্রসর হওয়ার আহ্বান জানাচ্ছে। দেশের অভ্যন্তরে জীবান্ত জ্বালানীর নতুন নতুন ক্ষেত্র আবিষ্কারের ক্ষেত্রে দেশীয় বিশেষজ্ঞদের অংশগ্রহণ বাড়ানো এবং তাদের সক্ষমতা বৃদ্ধির সমস্ত প্রচেষ্টা

অব্যাহত রাখা প্রয়োজন। জ্বালানী ও বিদ্যুৎ উৎপাদনে, শিল্প-কারখানায়, যানবাহনে, কৃষিযন্ত্র ব্যবহারে, এবং গৃহস্থালি কাজে ব্যবহৃত সমস্ত যন্ত্রপাতির দক্ষতা বাড়িয়ে কিভাবে জ্বালানী ক্ষেত্রে স্থায়িত্বশীলতা ও নিরাপত্তা বৃদ্ধির লক্ষ্যে কার্যকর পদক্ষেপ নেওয়া যায় সেই লক্ষ্যে একটি কার্যকর কমিশন গঠন করা যেতে পারে।

সম্মেলন সাধারণভাবে বিদ্যুৎ ও জ্বালানী খাতে গবেষণা ও নীতি প্রণয়নে জাতীয় সক্ষমতা বৃদ্ধির লক্ষ্যে প্রয়োজনীয় প্রাতিষ্ঠানিক কাঠামো গড়ে তোলার জন্য সরকারকে আহ্বান জানায়। এই লক্ষ্যে একটি অত্যাধুনিক জ্বালানী গবেষণা কেন্দ্র (Center for Energy Excellence) গড়ে তোলা যেতে পারে। উপর্যুক্ত কেন্দ্র গড়ে তোলায় সরকারকে বাপা-বেন-এর সহযোগিতা প্রদানের প্রস্তাব করে। সম্মেলন আশা করে যে, সরকার এই প্রস্তাব গুরুত্বের সাথে বিবেচনা করবে।

পরিশেষে সম্মেলন আশা করে যে, সরকার এই সম্মেলনে গৃহীত প্রস্তাবসমূহ গুরুত্বের সাথে বিবেচনা করবে এবং দেশের জ্বালানী নীতিকে গণমুখী, অর্থনৈতিকভাবে দায়িত্বশীল এবং পরিবেশ বান্ধব করার দিকে এগিয়ে যাবে।

দ্বিতীয় অংশ

স্থায়িত্বশীল উন্নয়নের অন্যান্য বিষয়ে সুপারিশসমূহ

সম্মেলনে জ্বালানী ছাড়াও জলবায়ু পরিবর্তন এবং স্থায়িত্বশীল উন্নয়নের অন্যান্য ইস্যু নিয়ে আলোচনা অনুষ্ঠিত হয়। বিশেষত এসব ইস্যু সম্পর্কে বাপার শাখাসমূহের নেতৃবৃন্দ দেশের বিভিন্ন স্থানের অভিজ্ঞতা তুলে ধরেন। এসব অভিজ্ঞতার আলোচনা ও বিশ্লেষণের ভিত্তিতে সম্মেলন নিম্নলিখিত পরিলক্ষণ, সুপারিশ, এবং দাবীসমূহ উপস্থিত করে।

উপকূলীয় অঞ্চলের পরিবেশ সম্পর্কে

উপকূলজুড়ে জীবান্ন জ্বালানী ব্যবহারের মাধ্যমে বিদ্যুতকেন্দ্র স্থাপনের ফলে প্রাকৃতিক পরিবেশ হুমকীর মুখে পড়েছে যেটা সাম্প্রতিককালে সরকারের পেশকৃত দক্ষিণ-পশ্চিমাঞ্চলের কৌশলগত পরিবেশ সমীক্ষায় (Strategic Environmental Assessment) সঠিকভাবে প্রতিফলিত হয়নি। বাপা ইতোমধ্যেই (অক্টোবর ২০, ২০২১) CEGIS নামের সরকারী প্রতিষ্ঠান বরাবর সুনির্দিষ্ট সুপারিশমালা পেশ করেছে। বাপার প্রস্তাবিত সুপারিশমালা আমলে নিয়ে নতুন করে একটি কৌশলগত সমীক্ষা তৈরি করতে হবে যেখানে সাধারণ মানুষ এবং উপকূলীয় অঞ্চলের ভুক্তভোগী মানুষের অংশগ্রহণ নিশ্চিত করা হবে।

জলবায়ু পরিবর্তনের ফলশ্রুতিতে সৃষ্ট অভিঘাতের ফলে ইতোমধ্যেই বাংলাদেশের কৃষি, সেচ, শিল্প-কারখানা, ব-দ্বীপ গঠন প্রক্রিয়া, এবং সুন্দরবনসহ উপকূলীয় বনাঞ্চল অস্তিত্ব সংকটে পড়েছে। তাছাড়াও, দেশের বিভিন্ন অঞ্চলে পানীয় জলের দূষণাপ্রাপ্যতা, অকাল বন্যা, খরা, জলাবদ্ধতা, এবং নদী ও উপকূলীয় ভাঙ্গন প্রবনতা বৃদ্ধি জনসাধারণের জীবনযাত্রার মান ব্যহত করছে।

উপকূলীয় অঞ্চলে অবস্থিত অনন্যসাধারণ সার্বজনীন মূল্যমান সম্পদ (Outstanding Universal Value) বাস্তবসংস্থানখ্যাত সুন্দরবন সুরক্ষার দাবী জানানো হচ্ছে এবং অন্যান্য উপকূলীয় বনাঞ্চল এবং মৎস সম্পদের অভয়ারণ্য হিসাবে স্বীকৃত উপকূলীয় পরিবেশ-প্রতিবেশ সংরক্ষণের সর্বোচ্চ প্রচেষ্টা করার দাবী জানানো হচ্ছে।

সুন্দরবন একটি বিশ্ব ঐতিহ্য এবং উপকূলীয় প্রাণ এবং সম্পদ রক্ষাকারী প্রাকৃতিক সুরক্ষা বলয়। সুন্দরবনের ক্ষতি হয় এমন যেকোন প্রকল্প থেকে দূরে থাকতে হবে এবং যেকোন মূল্যে সুন্দরবনকে রক্ষা করতে হবে।

বৃহত্তর সিলেট ও হাওর অঞ্চলের পরিবেশ সম্পর্কে

- সিলেট এবং অন্যান্য অঞ্চলে পর্যটকদের মাধ্যমে যত্রতত্র বর্জ্য নিক্ষেপনের মাধ্যমে পরিবেশ দূষণ বন্ধ করার কার্যকর নীতিমালা এবং পদক্ষেপ নিতে হবে।
- সিলেটে নির্বিচারে গাছ এবং টিলা কাটা বন্ধ করতে হবে।
- হাওর অঞ্চলের জলাভূমি অন্যায়ভাবে দখল বন্ধ করার পদক্ষেপ নিতে হবে।
- হাওর অঞ্চলে কারখানার বর্জ্য সরাসরি নদী এবং জলাভূমিতে নিক্ষেপণ বন্ধের উদ্যোগ নিতে হবে।
- হাওরসহ দেশের অন্যান্য অঞ্চলে উন্নয়ন প্রকল্প বাস্তবায়নে অবাধ দূর্নীতি রোধ করে উন্নয়ন প্রকল্পসমূহ যথাযথ বাস্তবায়ন নিশ্চিত করতে হবে।
- হবিগঞ্জের ঐতিহ্য ধংসকারী পরিবেশ ও মাটি দূষণ রোধকল্পে কার্যকর ব্যবস্থা নিতে হবে। উল্লেখ্য যে বায়ু দূষণে হবিগঞ্জ দেশে চতুর্থ স্থানে রয়েছে।

তিস্তা অববাহিকার পরিবেশ সম্পর্কে

- তিস্তা থেকে কুড়িগ্রাম পর্যন্ত সড়ক ভেঙ্গে পরিবেশ-প্রতিবেশ বান্ধব উড়াল সড়ক করার দাবী জানানো হচ্ছে।
- তিস্তা সেচ প্রকল্পের কার্যকারীতা পুনর্বিবেচনা করার দাবী জানানো হচ্ছে। সেচ প্রকল্পের পূর্বে ১৯৮৫ সাল পর্যন্ত পানি প্রবাহ মোটামুটি স্বাভাবিক ছিল এবং তিস্তা নদীর প্রাণ-প্রকৃতি ও জীববৈচিত্র্যও সমৃদ্ধ ছিল বলে স্থানীয় জনগণ মনে করে। তিস্তা সেচ প্রকল্প সানিয়াজান, লাউতারা, কুনসাই, বুড়িতিস্তাসহ তিস্তা অববাহিকার কয়েকটি আন্তর্জাতিক নদীর ন্যায়সঙ্গত পানি প্রবাহের দাবিকে নস্যাৎ করে দিয়েছে বলে স্থানীয় মানুষদের কাছে প্রতীয়মান হয়, তাই তিস্তার স্বাভাবিক প্রবাহ ফিরিয়ে আনার লক্ষ্যে আরো বেশি কার্যকর ব্যবস্থা নেওয়ার জন্য দাবী জানানো হচ্ছে।
- তিস্তা সড়ক সেতু, শেখ হাসিনা সেতু এবং তিস্তা রেলওয়ে সেতু নদীর স্বাভাবিক গতিপথে বাধা সৃষ্টি করে নদীকে সংকোচিত করে ফেলেছে বিধায় নদীভাঙ্গন প্রবনতা বেড়েছে। নদীভাঙ্গন রোধকল্পে বৈজ্ঞানিক নিরীক্ষার মাধ্যমে কার্যকর ব্যবস্থা নেওয়ার দাবী জানানো হচ্ছে।
- তিস্তা পাড়ে গড়ে ওঠা সেনা কল্যাণ সংস্থাসহ নদীর জায়গায় অন্যান্য প্রকল্পের বৈধতা নিরূপণ করে অবৈধ দখল বন্ধ করার দাবী জানাচ্ছে।

চলন বিল এলাকার পরিবেশ সম্পর্কে

- পরিবেশ বিধবংসী কার্যকলাপ এবং প্রকল্পের কারণে চলন বিলের ২৬০ প্রজাতির মাছের মধ্যে বর্তমানে মাত্র ১৮০ প্রজাতির মাছ পাওয়া যাচ্ছে। পাখী, কচ্ছপ, কুমীর, এবং শুশুক প্রজাতিও বিলুপ্তির পথে। চলন বিলে কৃষিজমির পরিমাণ আশংকা জনকহারে হ্রাস পাচ্ছে।

ফারাক্কা বাঁধের ফলেও চলন বিলের পানিপ্রাপ্যতা হ্রাস পেয়েছে। এই প্রবনতা রোধ করার লক্ষ্যে এখনই কার্যকর নীতিমালা এবং পদক্ষেপ নিতে হবে।

- চলনবিল ধংসকারী অপরিকল্পিত রাস্তা, কালভার্ট, ও অন্যান্য স্থাপনা সরাতে হবে এবং বর্জ্য নিষ্কাশন নিয়ন্ত্রন করতে হবে। চলনবিলের নদীসমূহের সীমানা সঠিকভাবে নির্ধারণ করার দাবী জানানো হচ্ছে। চলনবিলকে দখলমুক্ত করতে হবে। ব্যক্তিগত পর্যায়ে পুকুর দখল বন্ধ করতে হবে এবং পুকুর সংরক্ষণ করার উদ্যোগ নিতে হবে।
- চলনবিলকে পরিবেশগত সংকটাপন্ন এলাকা ঘোষণা করে সেখানে কারখানা স্থাপন বন্ধ করতে হবে, এবং মাছের চাষ বাড়াতে হবে। চলনবিলের উন্নয়ন কর্মকান্ড সমন্বিতভাবে করতে হবে যাতে করে এই বিশেষ অঞ্চলের পরিবেশগত গুণাবলী এবং বাস্তুতন্ত্র অক্ষুন্ন থাকে।
- চলন বিলে ভূগর্ভস্থ পানি উত্তোলন নিয়ন্ত্রন করতে হবে।

অন্যান্য বিষয়ে

- অবৈধভাবে অপরিকল্পিত উপায়ে বালু উত্তোলনের ফলে নদী ভাঙ্গন ত্বরান্বিত হচ্ছে। অসাপু রাজনৈতিক নেতৃত্বন্দ ও প্রশাসনের সদস্যদের সহযোগিতায় বালু ব্যবসায়ীরা তাদের কর্মকান্ড পরিচালনা করে। সম্মেলন এদের এই ধ্বংসাত্মক তৎপরতা বন্ধের জোর দাবী জানায়।
- ঢাকাসহ ঘনবসতিপূর্ণ সমস্ত বড় বড় শহর ও নগরে গণমুখী যানবাহনের উন্নয়ন নিশ্চিত করতে হবে। ব্যক্তিগত গাড়ী এবং

যানবাহন ব্যবহার নিরুৎসাহিত করতে হবে যাতে করে যানযট ও বায়ু দূষণের মাত্রা কমিয়ে আনা যায়।

- সাধারণভাবে সম্মেলন পরিবেশের ভারসাম্য বিনষ্টকারী উন্নয়ন কর্মকান্ড রোধ করার আহ্বান জানায়।

উপসংহার

২০২২ সনের বাপা-বেন সম্মেলনে “জ্বালানী, জলবায়ু পরিবর্তন, এবং স্থায়িত্বশীল উন্নয়নে”র বিভিন্ন দিক নিয়ে ব্যাপক ও গভীর আলোচনা হয়েছে এবং তাঁর ভিত্তিতে যথেষ্ট সামগ্রিক পরিধির সুপারিশ উপরে পরিবেশিত হয়েছে। এখন যেটা প্রয়োজন তা হলো, এসব সুপারিশ জাতির নিকট উপস্থিত করা, এসবের প্রতি সরকারের দৃষ্টি আকর্ষণ করা, এবং প্রয়োজন অনুযায়ী গণসচেতনতা ও গণআন্দোলন গড়ে তোলা।

উপর্যুক্ত লক্ষ্যে সম্মেলন পত্রপত্রিকা, টেলিভিশন কেন্দ্র, এবং অন্যান্য মিডিয়া চ্যানেলের সহযোগিতা কামনা করছে। মিডিয়া বাংলাদেশের পরিবেশ রক্ষার সংগ্রামে গুরুত্বপূর্ণ ভূমিকা পালন করছে। সম্মেলন আশা করে যে, আগামীতেও তাদের এই ভূমিকা অব্যাহত থাকবে এবং এই সম্মেলনে গণমুখী, দেশের স্বার্থরক্ষাকারী, অর্থনৈতিকভাবে দায়িত্বশীল এবং পরিবেশ বান্ধব যেসব জ্বালানী নীতি গৃহীত হয়েছে তার প্রচারে এবং সরকার কর্তৃক তাঁর গ্রহণ এবং বাস্তবায়ন নিশ্চিত করায় গুরুত্বপূর্ণ ভূমিকা রাখবে।

এবারের সম্মেলনে জ্বালানী, জলবায়ু পরিবর্তন, এবং স্থায়িত্বশীল উন্নয়ন বিষয়ক উপর্যুক্ত নীতি ও সুপারিশসমূহ জনগণের কাছে নিয়ে যাওয়ার লক্ষ্যে প্রস্তাবের প্রচার এবং তার বাস্তবায়নে সক্রিয় ভূমিকা পালনের জন্য সকল বাপা ও বেনের সদস্য এবং দেশের অন্যান্য পরিবেশ বিষয়ক সংগঠন ও সংস্থার সদস্যদের প্রতি উদাত্ত আহ্বান জানাচ্ছে।

সর্বোপরি, গৃহীত এই প্রস্তাবের যথাযথ ব্যবহারের মাধ্যমে দেশের জ্বালানী খাতের গণমুখী, অর্থনৈতিকভাবে দায়িত্বশীল ও পরিবেশ-বান্ধব বিকাশ নিশ্চিত করার লক্ষ্যে সম্মেলন বাংলাদেশের আপামর জনগণকে এগিয়ে আসার আহ্বান জানাচ্ছে।

