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Final Report
EU Study on Opportunities for Improving Efficiency in Electricity Generation in Bangladesh

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Executive summary

Bangladesh spends a significant portion of its budget on subsidies to the energy sector in general and the electricity sector in particular. At times this energy subsidy reaches nearly 1% of the GDP, of which the electricity sector receives half. Bangladesh ranks in the top 25 countries in terms of the monetary value spend on energy subsidies. The power sector produces electricity almost entirely from fossil fuels like natural gas, coal, Heavy Fuel Oil (HFO) and High Speed Diesel (HSD). The electricity sector operates at a loss due to a number of high costs and inefficiencies. The fossil fuels are imported at high prices, and domestic natural gas is supplied to the power sector at below market prices. Power plants have a fixed cost of capacity payments, which are paid out irrespective of electricity production. Therefore, plants with low plant factors have high fixed costs per unit of electricity production. Some losses are attributed to shortfalls in revenue collection. These inefficiencies place a burden on the budget and foreign currency reserve of the country, hinder electricity supply to consumers, and impede the attainment of climate targets and sustainable development goals. This study covers an in-depth analysis of the pattern of financial inefficiencies in the power plants of Bangladesh, the scope to replace them with renewable electricity sources, the sources of financing for renewable electricity projects and the opinions of investors regarding the risks of investing in the electricity sector of Bangladesh.

Among the different fuel categories of power plants, the HSD based power plants have the highest rates of loss per unit of electricity, followed by HFO, coal and imports. Only gas and hydro power are profitable. Modern renewables are still a loss making source for the power sector, but the loss rates of renewables are decreasing whereas the loss rates of fossil fuels are increasing. With respect to fixed costs per unit of electricity generated (figure 1.9), we find that the highest is for HSD followed by modern renewables. Modern renewables initially had a high fixed cost per unit of electricity generation because of the high fixed costs of the wind plants, but when solar PV came online, it started to decrease. At present it is lower than that of all the fossil fuels and imported power. The highest per unit cost of fuel is in HSD plants, followed by HFO, coal and imported power. HFO has the highest total cost of all the fuel categories, even though it does not have the highest electricity contribution. Therefore, any fluctuation in the price of furnace oil will have a disproportionately large detrimental effect on the profitability of the power sector.

Subsidies for fossil fuels in the electricity sector are given at different stages of the production process and the supply chain. In the first stage, there is subsidized supply of fossil fuels to the electricity sector, and in the next stage there is the subsidization of the operational losses of unprofitable power plants. In addition, there are indirect subsidies due to the coverage of environmental and social externalities, which are not borne by the power sector directly. In Bangladesh, residential consumers of electricity are highly subsidized but industrial consumers are not. The consumer price of gas-based electricity does not cover the greater part of the supply cost, and none of the global warming cost or cost of local air pollution. In case of coal power, the consumer price covers supply cost but not environmental costs.

In the coming decade, HSD plants will be phased out in Bangladesh, and HFO plants will be reduced. The remaining load, according to planned projects of BPDB, will be supplied by coal, gas and nuclear, which will serve both base load and peak load. Analysis has shown that the historical price of coal makes it uncompetitive with solar PV even now, given the current plant factors of coal plants. The price of coal has increased in the recent year, with no signs of reversing. Gas prices from the avarege of short- and long-term contracts makes gas an expensive option in the current market. Moreover, at the rate of decline of the prices of solar PV, solar is likely to become even cheaper than gas in a matter of years. This implies that any coal or gas plants constructed now are likely to become stranded assets a few years into their useful lives.

A review of the different policies concerning the energy sector in Bangladesh reveals some contradictory messages. There are differences in the projected amounts of renewable energy share in the different policy documents. Moreover, there is a conflict of vision, as many policy documents emphasize the need to shift away from fossil fuels, but still consider large and in fact increasing shares of fossil fuels (especially coal) in the future energy mix of the country. This makes the energy mix targets inconsistent with NDC commitments, and overall intentions of a clean energy future in Bangladesh. Increasing quantities and shares of coal will inevitably increase emissions from the energy sector.

An evaluation of the geography of Bangladesh reveals numerous potential sites for constructing solar power hubs, including floating solar in Kaptai Lake, river banks and islands in rivers, potential reclaimable land in Meghna Estuary, Khas lands (owned by the government) and protected areas on both sides of Bangabandhu Jamuna bridge and Padma bridge. Rooftop solar can also be expanded by using the rooftops of office buildings, factories, stations, cold storages and silos, cyclone shelters, ports and stadiums. Grid connected solar irrigation pumps can also be used to power the agriculture sector and the grid according to the seasons.

A survey was conducted of seven fossil fuel investors, and nine renewable energy investors, regarding risk perceptions of investing in electric power plant projects in Bangladesh. The fossil fuel investors include three from coal, two from gas and two from HFO plants. The renewable energy investors include seven from solar and two from wind energy. The investors were asked to score a number of risks of investing in power plant projects in Bangladesh. They were also asked to elaborate their opinions in depth. It was found that renewable energy investors report higher risks with respect to financial risk, expertise risk, contracts risk, construction risk, resource risk and price policy risk, than fossil fuel investors. In the case of both fossil fuels and renewables, the private sector investors report much higher risk perceptions than the public sector investors. With respect to regulatory risk, construction risk and project development risk, coal plant investors fare the worst. Gas plants face the highest resource risk, because although gas is the cheapest fuel at present, the domestic reserves of gas are declining and will potentially affect supplies of gas to the power plants in the future.

An inspection of the thermal power plants in Bangladesh shows that some natural gas-based power plants are operating at a loss. However, all the HSD, HFO and coal-based power plants operate at a loss. Losses are more prevalent in the private sector power plants and in peak load plants. A simulation-based analysis of grid flexibility of Bangladesh (DOE, 2021) has shown that even if Bangladesh does not invest in storage or transmission facilities for the near future for upto 2030, increasing the share of solar PV will still provide the least cost option for the electricity mix. The highest level of renewable energy that can be integrated into the system without significant loss of load, excess load, reserve inadequacy, insufficient inertia, model leakage or spillage, is up to 19% of electricity generation, and the levels of curtailment in this scenario are still cost effective for the grid. This analysis has used FlexTool, a simulation software developed by IRENA, to assess the power system flexibility to accommodate the largest possible shares of variable renewables (solar and wind).

Bangladesh receives more foreign investments in non-renewable energy projects than in renewable energy projects. Renewable energy projects in the past have received proportionately more grants and concessional loans [Specially the off-grid projects and rooftops]. Shares of grants and concessional loans are decreasing, as more commercial projects are initiated. Solar energy receives the most funding among renewables. The World Bank group is the biggest financier, followed by ADB, JICA, KFW and others. Investments in non-renewables are increasing, investments in renewables remains static.

In the period between 2000 and 2019, there have been around thirty-eight agencies which have invested in renewable energy and non-renewable energy projects in Bangladesh. The cumulative amount is USD 1851 million for renewables from these agencies. However, the total funding to Bangladesh in all energy projects including non-renewable fossil fuel projects and nuclear energy in the same period is USD 10.855 billion. Both renewable and non-renewable projects receive most of their financing in the form of standard and concessional loans. The same donor organization contributes funds to non-renewable and renewable energy projects. However, the non-renewable energy projects often receive more funds.

In theory any company in Bangladesh which can set up a suitable consortium is able to apply for a project. The project development is carried out by a consortium consisting of a lead partner and an operating partner. The lead partner has a majority share, and must have experience raising equity financing and debt financing for similar projects. The operating partner should have operating experience for such projects for a minimum of two years. Local companies usually have less than 2 years of experience as operating partner in Bangladesh, and compensate for this by forming consortiums or joint ventures with more experienced foreign firms. The lead partner has to have at least 51% of the project up to COD, and after that must own at least 40% for the first six years of operation. The operating partner has to own at least 20% of the project for the first 6 years after COD. These restrictions make it difficult for project developers to recover their investments quickly by selling their shares to plant owners.

Detailed feasibility studies should be conducted about the scope for large scale renewable energy projects. There should be policies enacted to encourage foreign and domestic investors to develop renewable energy projects in Bangladesh.

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Abbreviation and Acronyms

AC	Alternating Current
AM	Air Mass
AMI	Automatic Metering Infrastructure
BAU	Business as Usual
BDS	Bangladesh Standards
BEZA	Bangladesh Economic Zones Authority
BoS	Balance-of-System
BRTA	Bangladesh Road Transport Authority
CdTe	Cadmium Telluride
Ckt	Circuit
COD	Commercial Operation Date
CIGS	Copper-Indium-Gallium-Arsenide
CPP	Captive Power Plant
CSP	Concentrated Solar Power
DC	Direct Current
DSRA	Debt Service Reserve Account
EE	Energy Efficiency
EE&C	Energy Efficiency and Conservation
EPC	Engineering, Procurement and Construction
FIT	Feed-in-Tariff
FY	Fiscal Year
FYP	Five-Year Plan
GaAs	Gallium Arsenide
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHI	Global Horizontal Irradiance
GIS	Geographic Information System
GIS	Gas Insulated Substation
GNI	Gross National Income
GOB	Government of Bangladesh
GSB	Geological Survey of Bangladesh
GW	gigawatt
GWh	gigawatt-hour
GW_p	gigawatt peak
IEA	International Energy Agency
IDCOL	Infrastructure Development Company Limited
IDCP	Interest During Construction Period
INDC	Intended Nationally Determined Contribution
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
kW	kilowatt
kWh	kilowatt hour
kWh_e	kilowatt hour electricity
kW_p	kilowatt peak
kWh_{th}	kilowatt hour thermal energy
LCOE	Levelized Cost of Electricity
LGED	Local Government Engineering Department
LILO	Line in Line out
LOI	Letter of Intent
MPEMR	Ministry of Power, Energy and Mineral Resources

MPPT	Maximum Power Point Tracking
MSW	Municipal Solid Waste
$MtCO_{2e}$	million-ton equivalent of CO_2
MW	megawatt
MWh	megawatt-hour
MW	megawatt
MW_p	megawatt peak
NLDC	National Load Dispatch Center
NEM	Net Energy Metering
NREL	National Renewable Energy Laboratory
PCM	Phase Change Materials
PED	Project Effective Date
PGCB	Power Grid Company of Bangladesh
PPA	Power Purchase Agreement
PPA	Payra Port Authority
PPP	Public Private Partnership
PSMP	Power System Master Plan
PV	Photovoltaic
QRPP	Quick Rental Power Plant
RE	Renewable Energy
REB	Rural Electrification Board
REC	Renewable Energy Certificate
RPS	Renewable Portfolio Standards
RPO	Renewable Energy Purchase Obligations
SCADA	Supervisory Control and Data Acquisition
SODAR	Sonic Detection and Ranging
SPP	Small Power Plant
SPV	Solar Photovoltaic
SREDA	Sustainable and Renewable Energy Development Authority
SS	Substation
STC	Standard Testing Condition [Irradiation- 1000 W/m^2, Cell Temperature- 25^{o}C, AM- 1.5]
TJ	Tera Joule
USD	United States Dollar
UL	Underwriters Laboratories
VAT	Value Added Tax

Background

The existing power system plan and strategy is built on the premise that fossil fuel is cheaper and more reliable than renewable energy. However, this is far from the truth, whether in Bangladesh or the world. Fossil fuel subsidies cost the world USD 3.1 trillion per year, which is over 20 times the level of support to renewable energy (Lee, 2020). In Bangladesh, a large amount of government funds is dedicated to subsidize loss making coal, HSD and HFO power plants. In fact, coal, considered to be the low cost option, is not cheap, as the cost of generation is not lower than the electricity tariff. Importing electricity from neighboring countries is also not done at break-even rates. (BPDB, 2021) In some years in Bangladesh, the subsidy can reach as high as 35% of revenues in the power sector (figure 0.1). The subsidies are paid out when the power plants operate at a loss. Losses can occur for various reasons, including a high level of volatality of fuel costs leading to higher than anticpated fuel costs, the cost of generating and transmitting electricity being higher than the electricity tariffs charged, and high fixed capacity payments to power plants, even during idle times. Other sources of loss can occur due to shortfalls in revenue collections on electricity sales. The various components of costs have an increasing trend, including generation cost and average supply cost. The costs are always significantly higher than the average bulk tariff, which cannot be raised at the same rate as the increase in costs (BPDB, 2021).

Figure 0-1: Trend of operating loss in the power sector (adapted from BPDB, 2021)

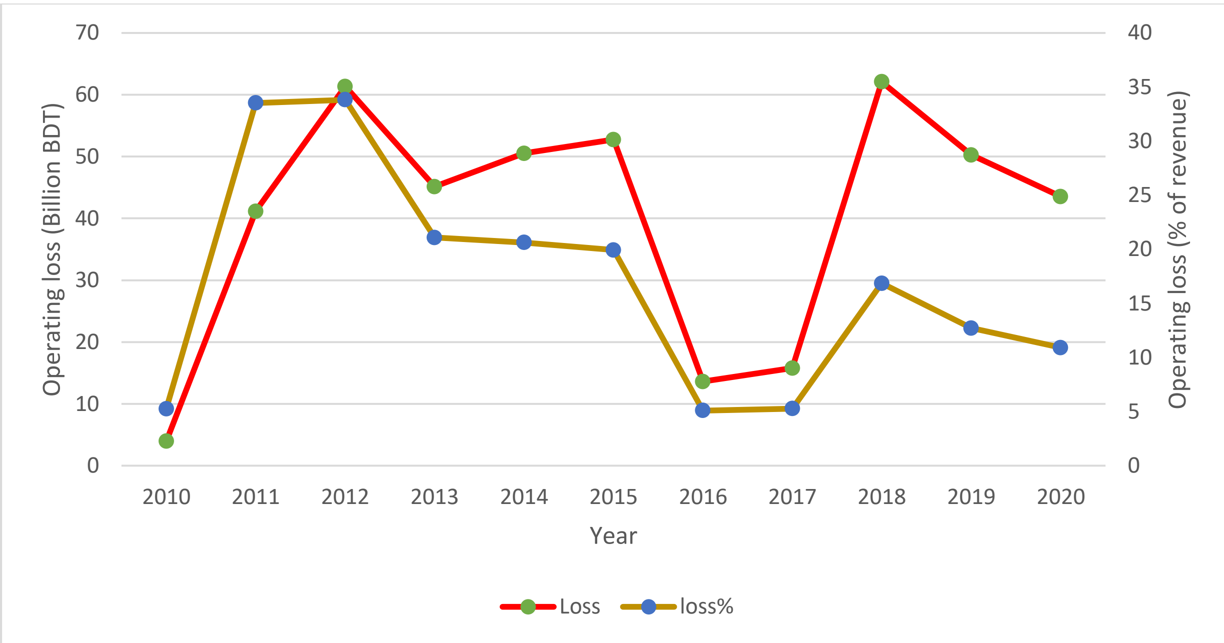
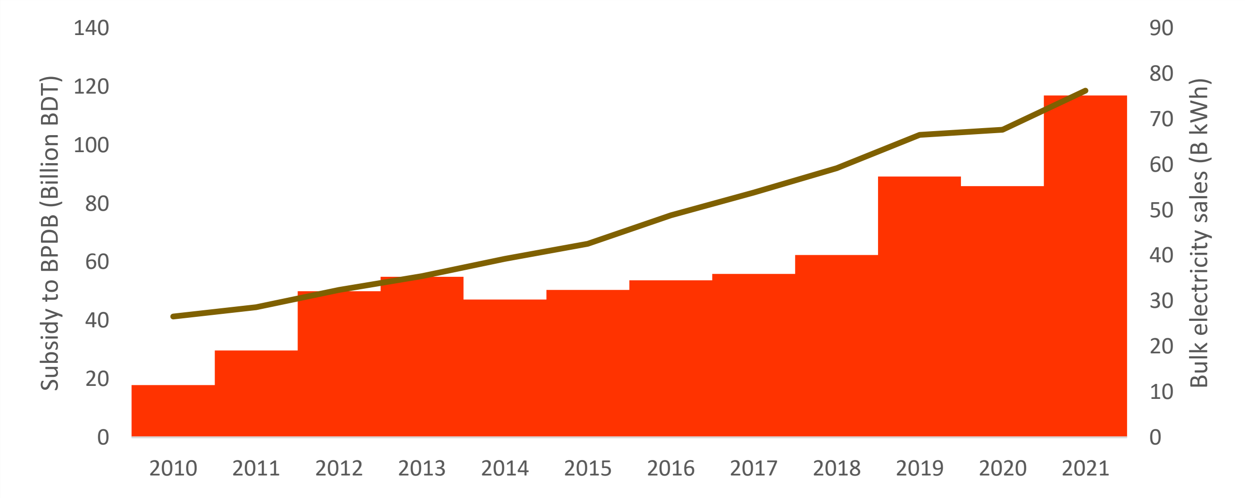
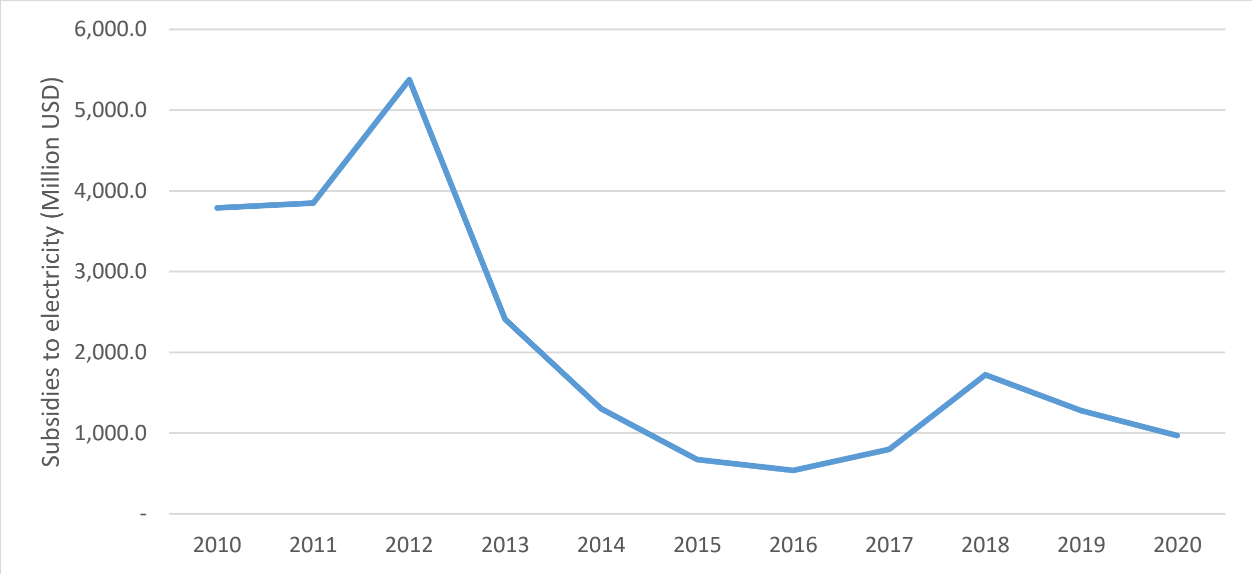


Figure 0-2: Trend of subsidy to BPDB (Billion BDT) (BPDB Annual Reports, 2010-2021)



Subsidies to the electricity sector is quite high in Bangladesh, consisting of around USD 1 billion in 2020 (figure 0.2). This comprises around half of the total subsidies given to the energy sector, which in itself amounts to 0.4% of the GDP (IEA, 2021). Bangladesh ranks in the top 25 countries in terms of the monetary value spend on energy subsidies. The electricity sector receives subsidies not only in terms of the support of operationally unprofitable power plants, but also the sale of fuels to power plants below market rates (BERC, 2019). For example, the gas based power plants purchase gas sourced from local reserves at prices far below the market price. Moreover, public sector plants can purchase them at lower rates than private sector ones. The purchase of gas at below market rates does not create any incentive to improve operational efficiency, or to invest in more efficient gas technology to make more use of a valuable resource. It has been observed that private captive power plants purchase gas at a higher rate than public power plants, but use a technology which extracts more energy from the same quantity of fuel in the form of heat energy, and so can generate electricity for captive use at commercially viable rates. This is in contrast to the allocation of higher rates of subsidies to private power plants which supply electricity to the national grid (Chowdhury, Aziz, & Hossan, 2022).

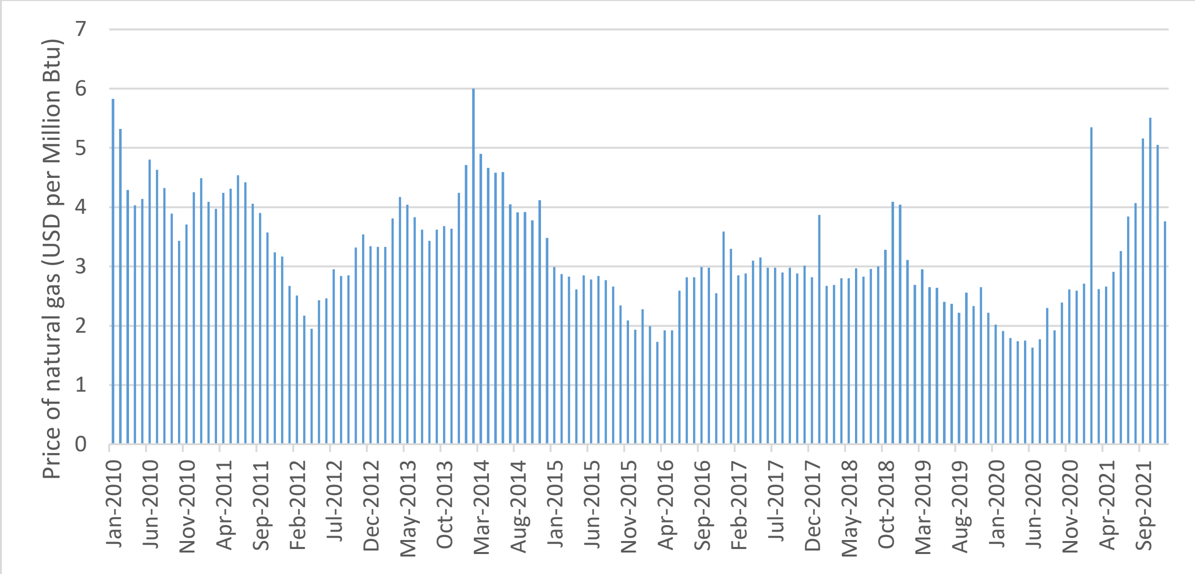
Figure 0-3: Trend of total subsidies to fossil fuels for electricity production in Bangladesh (IEA, 2022)



Although we can see from figure 0.3 that the trend to subsidies to fossil fuels for electricity production in Bangladesh is decreasing over the years, the total subsidies to the sector is actually increasing (figure 0.2). The subsidies for fossil fuels alone have been reduced by gradually increasing the prices at which fuels are sold to power plants, and increasing electricity tariffs over the years (BERC, 2019). However, this has not reduced subsidies to the sector, as several liquid fuel based power plants have been added to the fleet, which are usually peaking plants, and enjoy capacity payments even when not producing electricity. This arises from financial contracts with power plants which requires paying them a fixed amount to cover the investment costs, irrespective of electricity generation. In fact the payment of subsidies has increased at a higher rate than the amount of electricity generated (figure 0.2). From this we can infer that fossil fuel cost is only one driver of the cost of electricity generation from fossil fuels, whereas other technological and infrastructure issues have increased costs which require large subsidies. The fact that peaking power plants will necessarily be idle for a significant part of the time indicates a limitation of fossil fuel technology, where the system is forced to have idle capacity at a high cost. Therefore, a technological and infrastructural solution is required which increases efficiency of the system.

The captive power producer report that buying from BPDB costs them Tk 7.5 to 8 per unit, but producing captive power costs Tk 4.5 to 5, with gas based generation. Per cubic meter, gas price is 4.45 Tk for bpdb (1.56 USD per Mbtu), and 13.85 Tk for captive power (4.85 USD per Mbtu). However, in the international markets, the price of natural gas rarely falls below USD 2 per Million Btu and averages around USD 3 per Million Btu (EIA, 2022) (figure 0.4). Therefore, gas is offered to the local power producers at a significant subsidy, which is unviable in the long run, as gas reserves are depleting in Bangladesh.

Figure 0-4: Trend of monthly average Henry Hub natural gas spot prices (USD per Million Btu)



In the backdrop of the continued financial inefficiency and subsidy burden of the fossil fuel based power sector and the widening gap between NDC targets and actual power sector expansion direction, the purpose of this project is to analyze the patterns of financial inefficiencies in the fossil fuel based power plant fleet, and based on this to identify scopes where existing and future fossil fuel capacity can be replaced with renewable energy technologies.

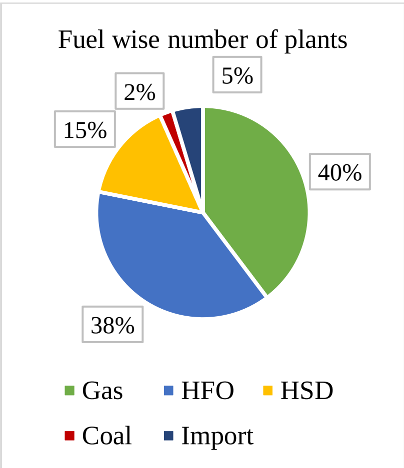
1. Analysis of economic efficiency of existing fossil fuel power plants

This section covers an analysis of the profitability and economic efficiencies of power plants in Bangladesh, categorized according to the fuels. The years covered are from 2016 to 2021. There is an analysis of the comparison and trend of the total profitability of plants of different fuels categories, their fixed costs. Fuel costs and variable operations and maintenance (O&M) costs.

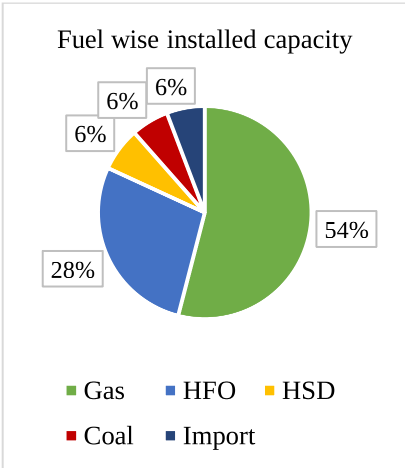
The metrics are compared in total amounts, as well as on the basis of per unit of installed capacity and electricity generation.

The following pie charts (figure 1.1) show the overall fuel mix of the thermal power plants in terms of plant number, installed capacity, and net electricity generation (as of the year 2019-2020). It can be seen that gas is the most important fuel powering thermal power plants of Bangladesh, followed by HFO. The next most noticeable feature is that the fraction of electricity generated by HSD is extremely negligible on the net generation. This is mainly due to the low utilization of the HSD-powered plants, as they are mostly peaking power plants. A similar pattern is noticeable in case of HFO-powered plants as well, the majority of which are peaking plants meant to operate for limited periods only. Gas, coal and imports are base load power plants, and so generate electricity proportionately more relative to their installed capacities.

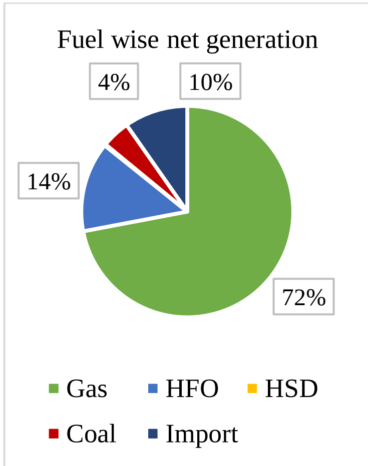
Figure 1-1: Overall fuel mix of thermal power plants of Bangladesh: (a) number of plants, (b) installed capacity, and (c) net electricity generation.



(a)



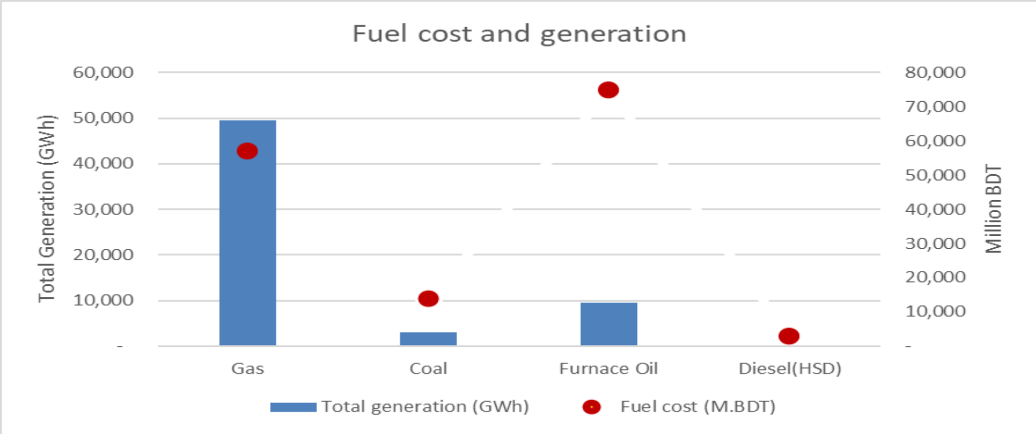
(b)



(c)

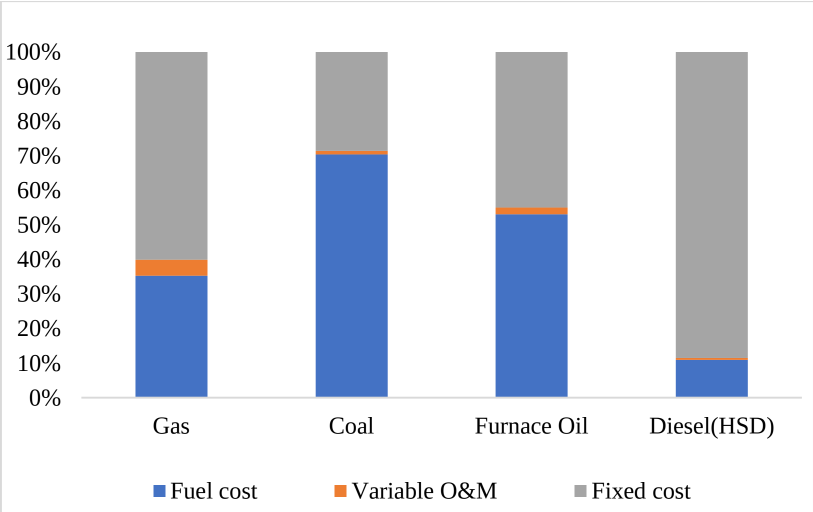
In the fossil fuel-based power plants in Bangladesh, there are four types of fuels used- gas, coal, diesel and furnace oil. Among them, we can see that the fuel costs are the highest for furnace oil-based plants, relative to the electricity generation in the year 2019-2020 (figure 1.2). In aggregate, the estimated fuel costs in year 2019-2020 alone was approximately BDT 145 billion, equivalent to USD 1.7 billion.

Figure 1-2: Fuel cost compared to total generation according to fuel type (in million BDT/GWh)



The fuel costs and fixed costs comprise the biggest portions of the costs of power plants. In coal plants, fuel costs are higher compared to fixed costs, whereas in diesel plants, the fixed costs are the highest in proportion (figure 1.3). Fixed costs in furnace oil are also relatively high. It is because the liquid fuel-based plants are operated at low plant utilization factors.

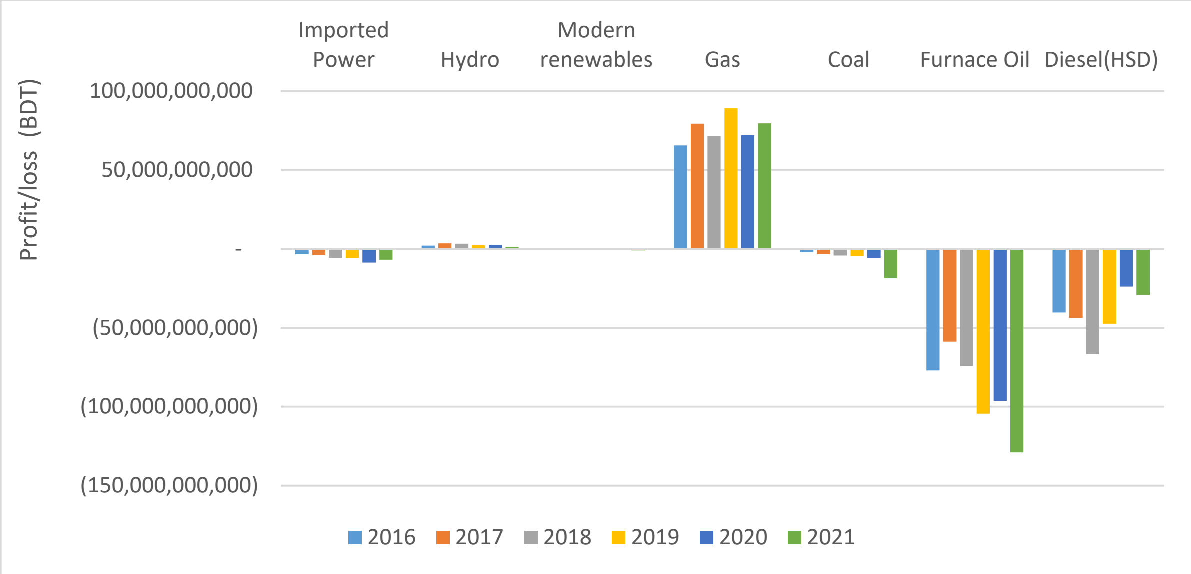
Figure 1-3: Composition of plant costs according to fuel type.



1.1 Analysis of total costs according to fuels

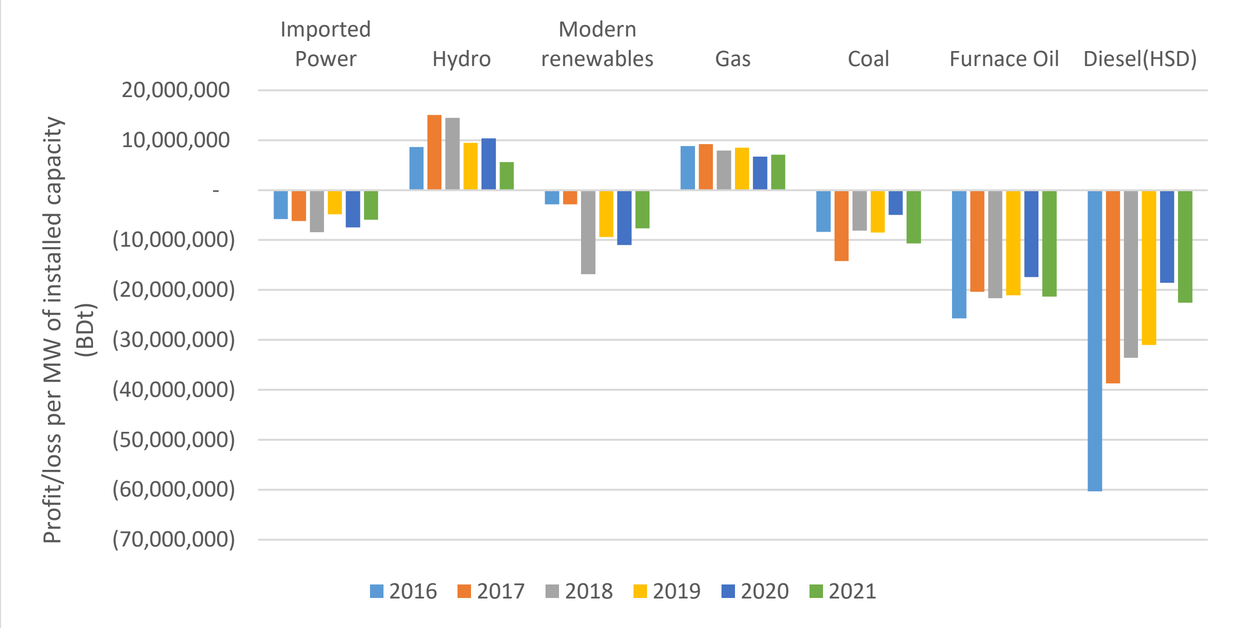
Among the different types of plants, it can be seen that there are two categories which are by and large profitable- the plants that run on natural gas, and the hydroelectricity generation (of which there is only one in the country). All the other fuels and sources, including fossil fuels and imported power, are running on a total loss in all the years. The total amount of loss fluctuates from year to year, but there is an increasing trend of loss in coal, furnace oil and even imported power (figure 1.4). Diesel generation will be phased out in the medium to long term.

Figure 1-4: Fuel wise trend of plant profitability (2016-2021)



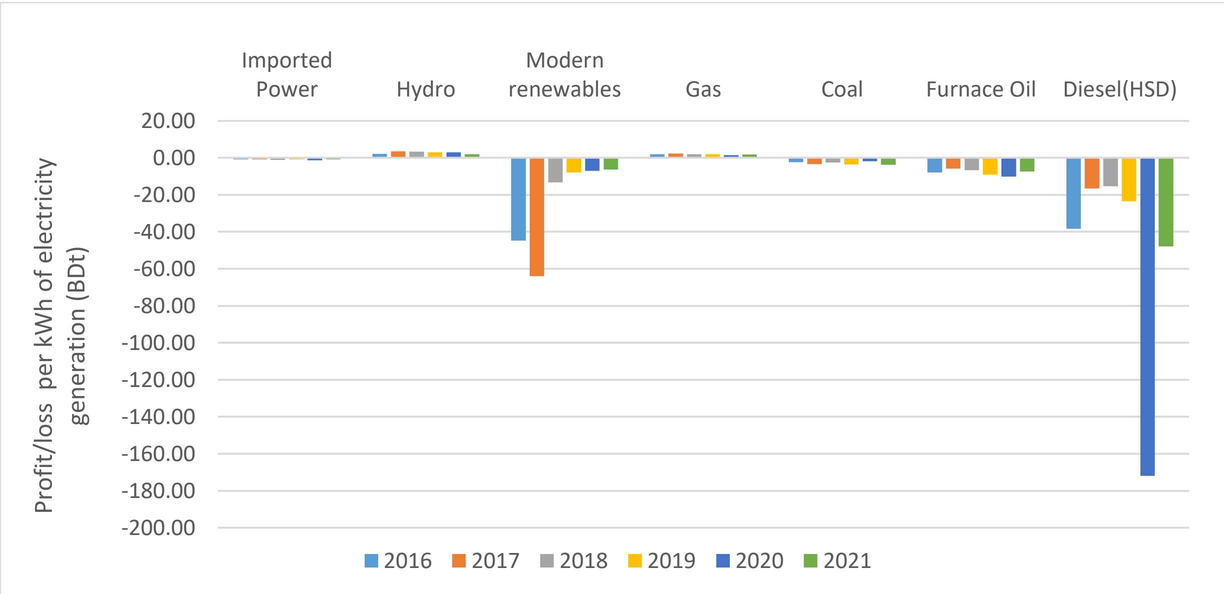
When plant profitability is examined on the basis or per unit of installed capacity, we can see that the profitability according to capacity investment is the least for HSD, which incurs the greatest loss (figure 1.5). Here, all fossil fuels are found to be unprofitable except gas. Imported power, which is also fossil fuel based, operates at a loss. Non-hydro Renewable energy has not been profitable until now but the rate of losses has been gradually decreasing in the recent years, since solar energy came into the grid in 2018. In contrast, the rates of losses in the other sources of fossil based electricity do not show the same constant decreasing trend, except for HSD, which still remains higher than other sources.

Figure 1-5: Fuel wise profitability trend of power plants as per unit of installed capacity (2016-2021)



When analyzed on the basis of per unit of electricity generation (figure 1.6), it is found that HSD plants have the highest rates of loss, and there is no clear decreasing trend. Modern renewables are loss making, but the rate of losses show a steadily decreasing trend. Only gas and hydro based generation have a marginally profitable performance. Modern renewables have become less loss making than HSD and furnace oil, and need to cut down its loss rate by half in order to be at par with coal.

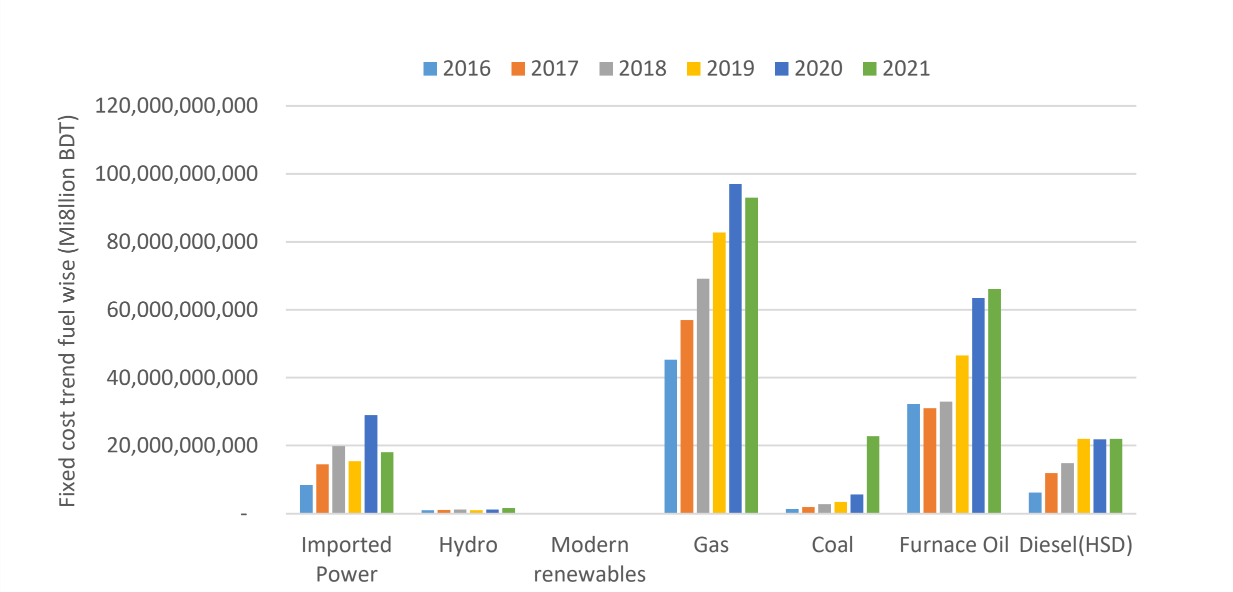
Figure 1-6: Fuel wise profitability trend of power plants as per unit of electricity generation (2016-2021)



1.2 Analysis of fixed cost according to fuels

A fuel wise analysis of the trend of fixed costs shows that the highest total fixed costs belong to gas powered plants, followed by furnace oil, HSD and import (figure 1.7). Coal power has seen a sharp increase in total fixed costs, due to increased capacity additions. Modern renewables are a small part of the generation fleet and therefore have negligible fixed costs on the whole, and the same is true for hydro power.

Figure 1-7: Fuel wise total fixed cost trend of power plants (2016-2021)



When the comparison is made on the basis of per unit of installed capacity (figure 1.8), we can see that the highest fixed costs belong to the imported power source, followed by HSD and furnace oil. Modern renewables have a relatively low level of fixed cost, and the unusual spike in 2018 occurred owing to an abnormally high cost in a small wind power. Since 2018, the bulk of renewables comprised of solar PV, and so the average fixed cost of modern renewables went down. As of 2021, there has been only 4 MW of wind in Bangladesh, compared to 123 MW of solar PV, which is up from 3 MW in 2018.

The fixed costs per unit of installed capacity of coal, gas, furnace oil and HSD have all been increasing, but for modern renewables has been decreasing. The per unit capacity fixed costs for imported electricity fluctuates from year to year.

With respect to fixed costs per unit of electricity generated (figure 1.9), we find that the highest is for HSD followed by modern renewables. Modern renewables initially had a high fixed cost per unit of electricity generation because of the high fixed costs of the wind plants, but when solar PV came online, it started to decrease. At present it is lower than that of all the fossil fuels and imported power.

Figure 1-8: Fuel wise total fixed cost trend of power plants per unit of installed capacity (2016-2021)

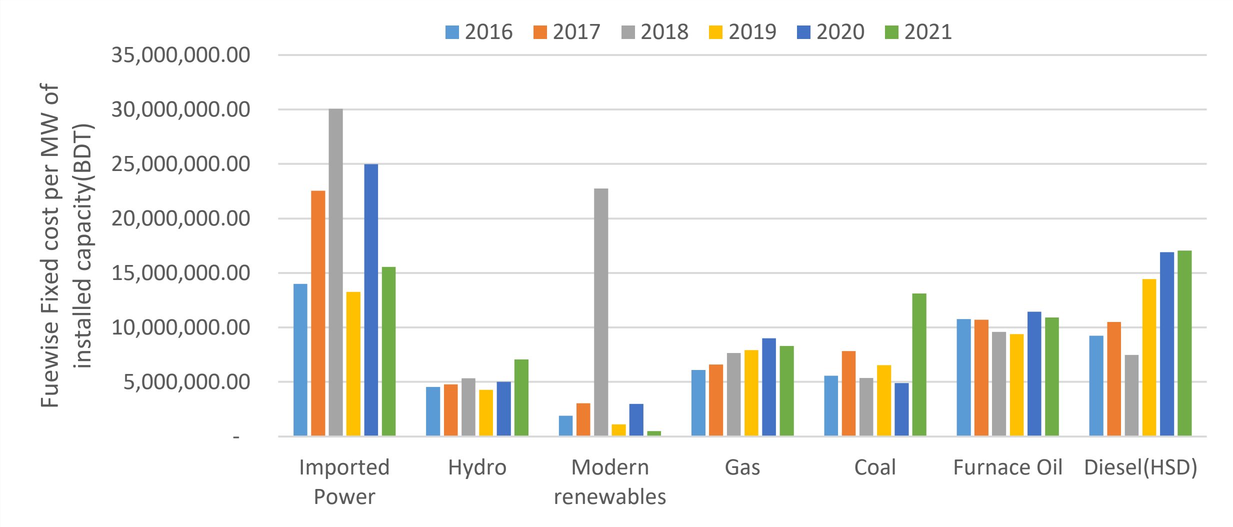
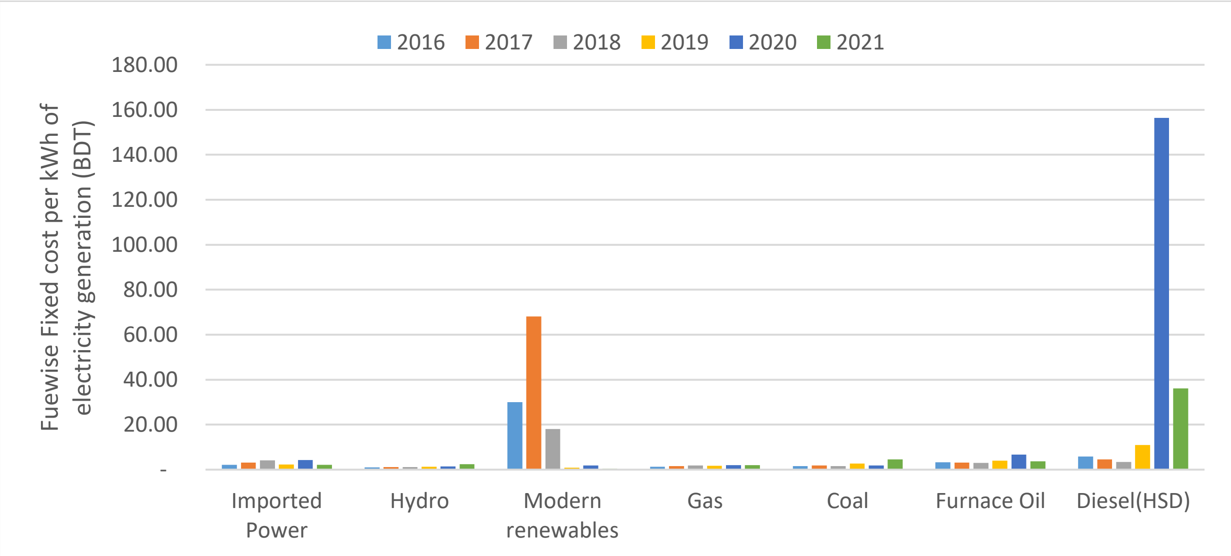


Figure 1-9: Fuel wise total fixed cost trend of power plants per unit of electricity generation (2016-2021)



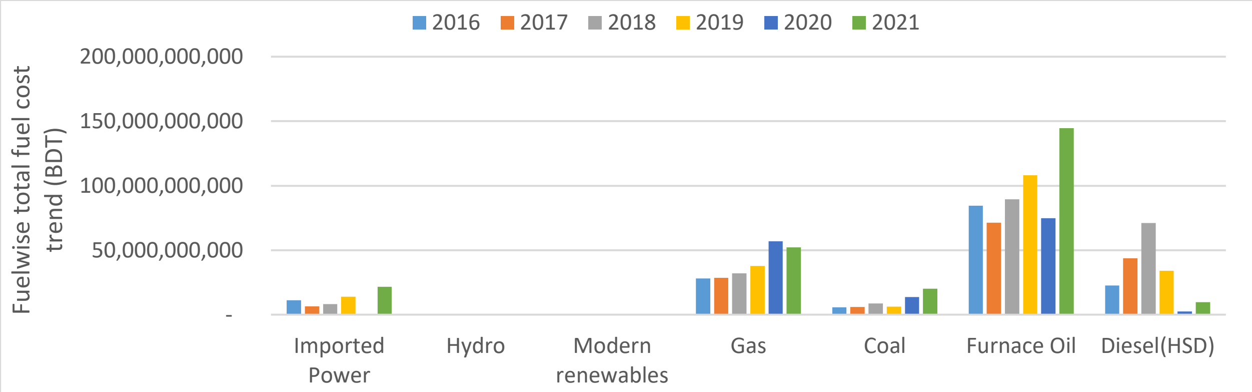
Fixed costs in thermal power plants include capacity payments, where plants have to be paid a certain contractual amount even if they do not produce electricity, in order to cover their fixed charges. These fixed costs become a disproportionately high share of total costs in liquid fuel based plants, which are usually peaking power plants and have low capacity factors. Therefore, these plants have higher levels of inefficiency with respect to fixed costs. This is evident in the case of HSD plants in the covid years of 2020 and 2021, when overall demand for electricity was low.

1.3 Analysis of fuel costs according to fuel categories

Hydroelectricity or modern renewables do not have a fuel cost component and therefore are not subject to the market fluctuations of fuel prices. However, among fossil fuel based power, we can see that for most types of fuels, the total fuel cost has been increasing over the years (figure

1.10). In case of HSD, it has been decreasing, as these plants may not have been used much in the recent Covid years.

Figure 1-10: Fuel wise total fuel cost trend of power plants (2016-2021)



A comparison of fuel costs on the per unit of installed capacity basis shows that HSD has the highest fuel cost, followed by furnace oil, coal and imported power, with gas having the lowest fuel costs (figure 1.11). The comparison of fuel cost per unit of installed capacity shows that the top three most costly fuels for electricity generation are HSD, furnace oil and coal. There is no clear change in the trend over the years except for coal, which shows a decreasing trend. A similar pattern is seen when the comparison is made on per unit of electricity generation basis (figure 1.12).. However, the exception is imported electricity, which is seen to be less costly with respect to fuel costs than coal. This is due to the contractual agreements with the exporter of electricity, where Bangladesh pays into the fuel costs of exporters as per the agreements.

Coal is considered to be the future replacement option for the depleting local reserves of natural gas. However, the cost of coal is much higher than natural gas, and has to be imported from abroad, subjecting it to fluctuations of global market prices.

Figure 1-11: Fuel wise total fuel cost trend of power plants per unit of installed capacity (2016-2021)

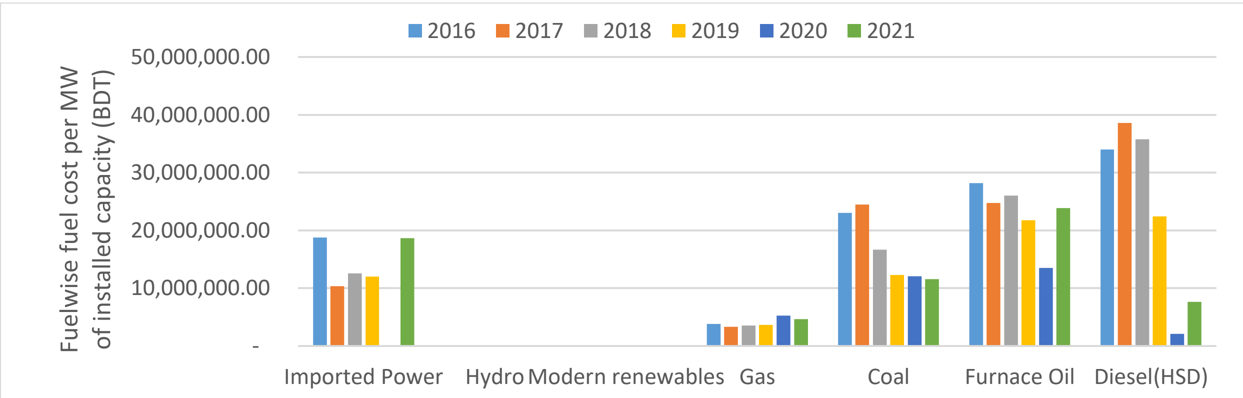
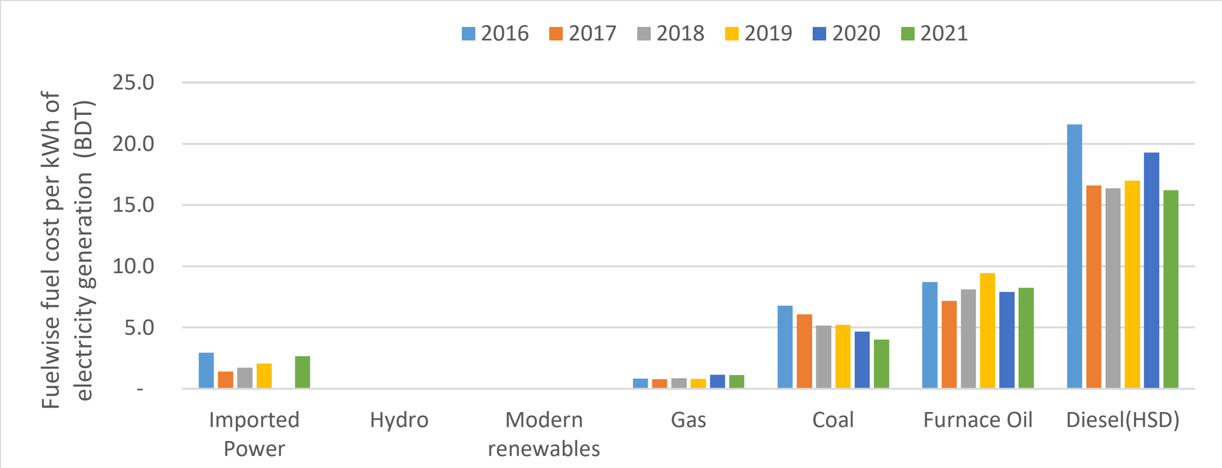


Figure 1-12: Fuel wise variable cost trend (2016-2021)



The overall analysis shows that the HSD plants have fuel costs as a larger driver of their total costs than other types of plants. This implies that not only is this type of fuel expensive, but this type of electricity generation is highly susceptible to the fluctuations of the price of fuel in the market. With respect to HSD based plants, it can be seen that not only do they have disproportionately high fixed costs relative to electricity generation, the cost of the fuel they run on is also very high. On the other hand, furnace oil has the highest total cost of all the fuel categories, even though it does not have the highest electricity contribution. Therefore, any fluctuation in the price of furnace oil will have a disproportionately large detrimental effect on the profitability of the power sector.

1.4 Analysis of variable costs according to fuels

Figure 1-13: Fuel wise variable cost trend (2016-2021)

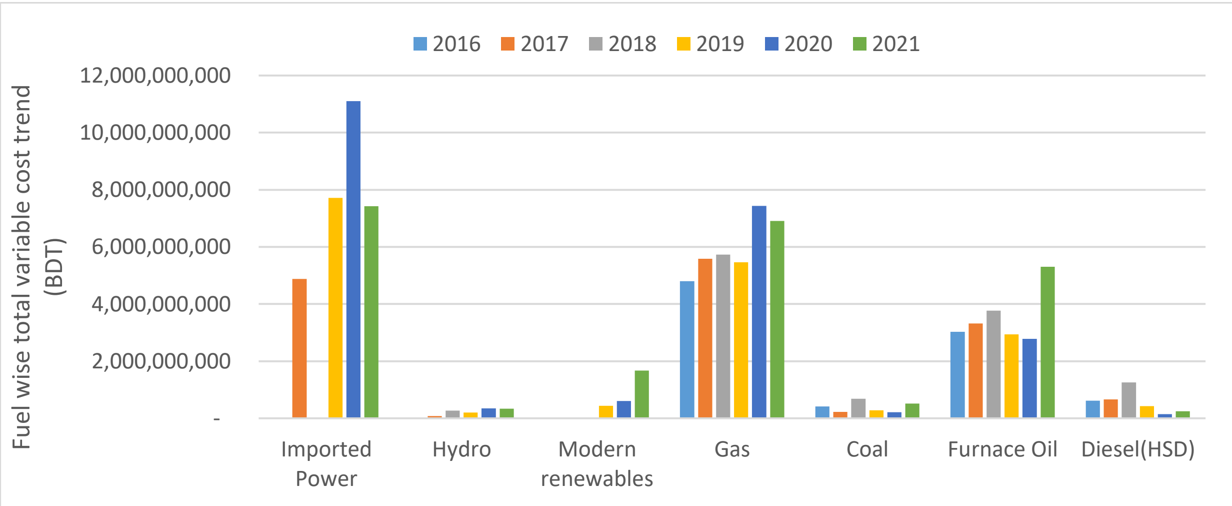


Figure 1-14: Trend of fuel wise variable cost per kWh of electricity generation.

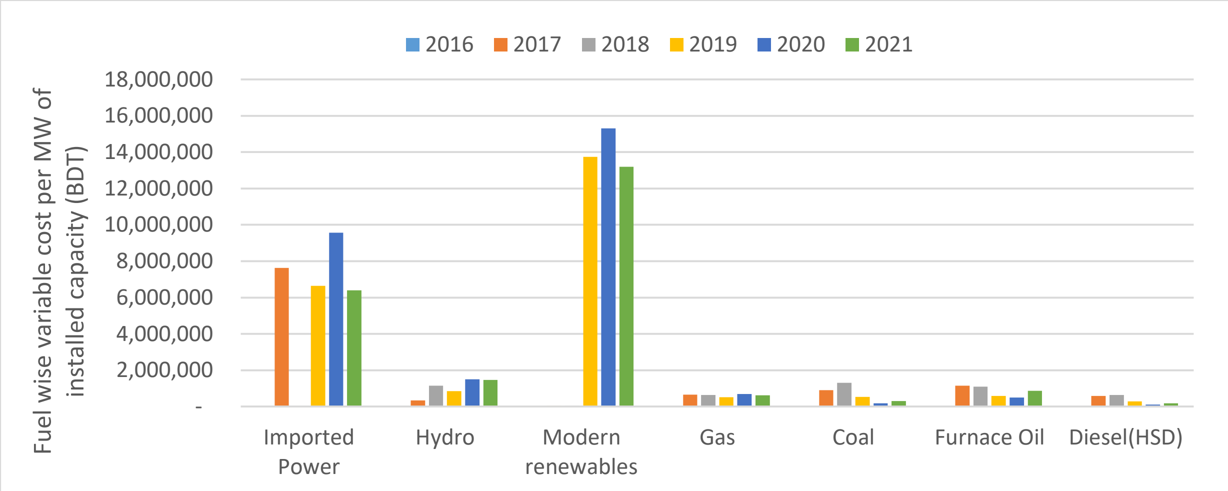
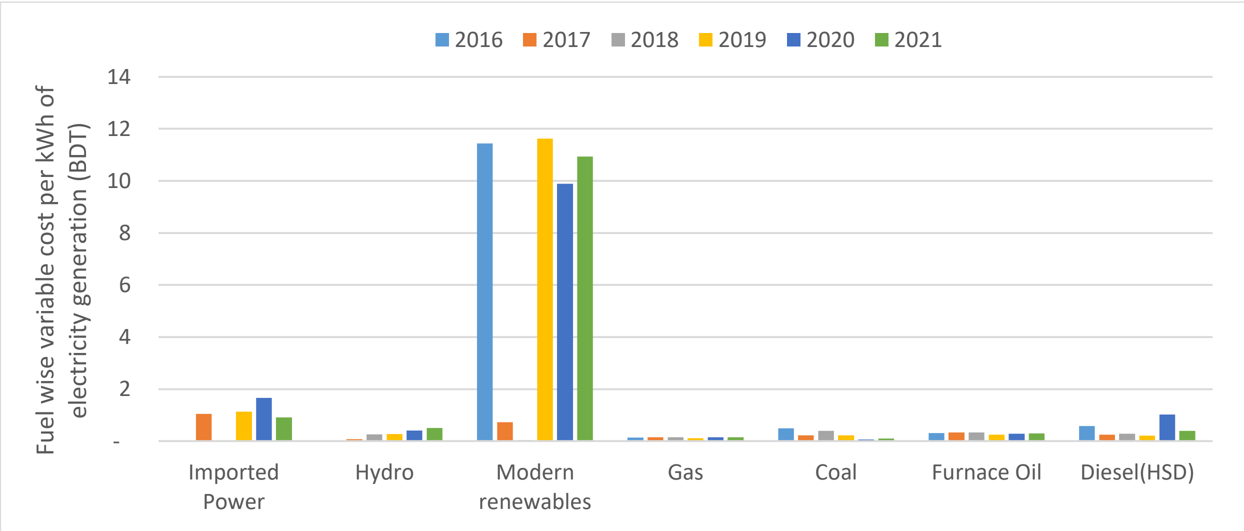


Figure 1-15: Trend of fuel wise variable cost per kWh of electricity generation.



Imported electricity has the highest variable cost, followed by gas and furnace oil (figure 1.13). The trend of this variable cost is increasing in the case of gas and oil. On the basis of per unit of installed capacity (figure 1.14), imported power and modern renewables are the highest. On the basis of per unit of electricity generated (figure 1.15), modern renewables appear to have the highest cost. This unusually high variable cost of modern renewables can be attributed to the small size of each of the solar energy projects (which are a few MW each), whereas the fossil fuel thermal power plants have an average installed capacity of around 150, and most of the plants are above 50MW, and often have a capacity of several hundred MW. Therefore, there is an economy of scale in the variable cost per unit among power plants, which is evident in fossil fuel plants. There is a negative correlation between variable cost per unit of electricity generated, and total electricity generation among thermal power plants, and the negative correlation is even more pronounced among solar power plants (author's calculations).

1.5 Impact of global fossil fuel cost trends on electricity generation costs in Bangladesh

In this section so far there has been an analysis of the impact of different cost components on the profitability of power plants using different fossil fuels, in the time period of 2016 to 2021. Next, there will be an examination of how the fluctuation of fuel prices in the global market can affect the profitability of these thermal power plants.

In the following figures 1.16, 1.17 and 1.18 are the price trends of the main fossil fuel categories which are used in electric power plants, ie, natural gas, coal and oil. The previous analysis covered a time period when fossil fuel prices fluctuated within a historically relatively low band, not even reaching the high levels before 2015. However, it can be seen that in the recent months, the prices of the fossil fuels have been climbing alarmingly to record high levels, especially high levels in the case of coal and natural gas. The prices of gas and oil in 2022 have risen to levels that are around twice that of the levels in the last five years. Therefore, any profitability advantage of gas and oil over renewables will be greatly diminished or even reversed. More marked is the rise of the price of coal, which is projected to be a much bigger share in electricity generation in the Bangladesh PSMP, and the BPDB annual report 2021. Coal prices in 2021-2022 have risen from twice as high to eight times as high as in previous years. If these prices are to persist, coal is unlikely to be a competitive source of electricity, and will be several times as loss making as the current levels for renewable electricity technology.

Figure 1-16: Henry Hub natural gas price trend (2010-2022) (Macrotrends, 2022)

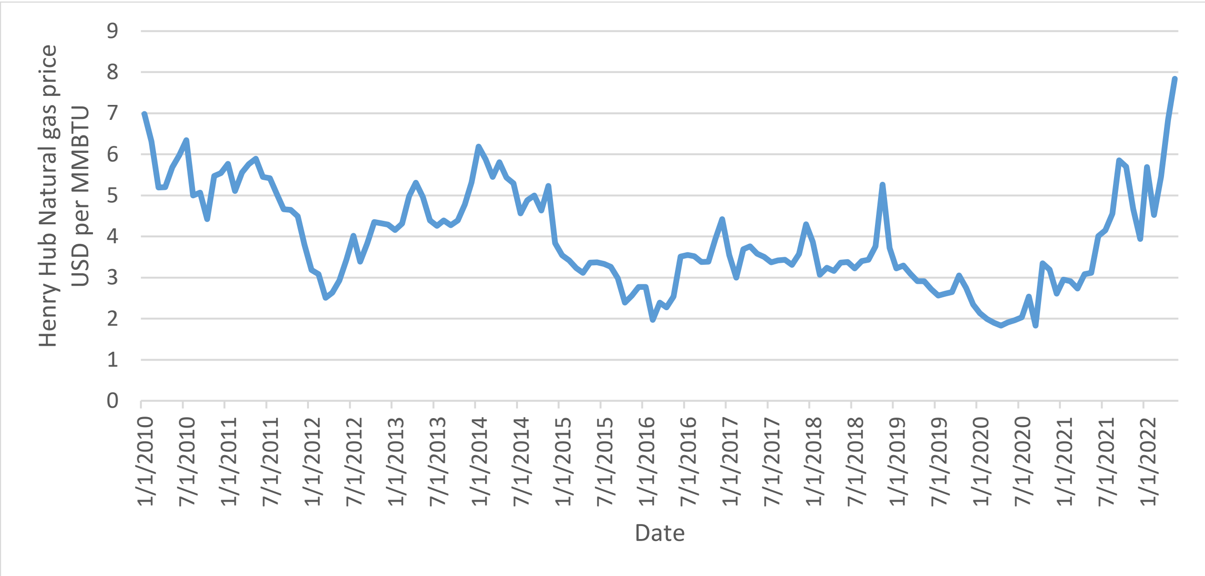


Figure 1-17: Oil prices, USD/ton (2012-2022) (Trading economics, 2022)

Figure 1-18: Coal prices, USD/ton (2012-2022) (Tradingeconomics, 2022)

1.6 Summary

In Bangladesh, renewables are becoming cost competitive with fossil fuel electricity over time, not only because of improvements in renewable energy technology, but also because of the unpredictable fluctuations and increases in fossil fuels. In the current global climate, fossil fuels have experienced a shortage in market supply, which has increased its supply exponentially. This has created immense financial burdens on the budgets of world governments as well as on the expenditure levels of ordinary people. It is also driving inflation, energy insecurity and economic slowdown (Gill, 2022).

Many countries are now suffering from energy shortages or skyrocketing prices, which are projected to cause distress for the population, and Bangladesh is no exception. Therefore, now more than ever is a good time to seriously invest in renewables in order not only to avert climate change problems, but also bring greater energy security to countries, and offer affordable energy solutions for the economy.

2. Analysis of how operational losses in power plants lead to the need for additional support, and thereby increases government's fiscal burden.

2.1 Operational losses and their relation to subsidies

The amount of subsidies required in the fossil fuel based electricity generation depends on the supply cost of the electricity and the true efficient cost. The operational losses of fossil fueled power plants in Bangladesh have been analyzed in the previous section. As the tariffs and revenues from the sale of electricity are set by the government according to what the market will support and the policies of the government, controlling the supply cost of electricity is one way in which the operational losses can be kept under control, thus reducing the subsidy burden. Subsidies for fossil fuels in the electricity sector are given at different stages of the production process and the supply chain. In the first stage, there is subsidized supply of fossil fuels to the electricity sector, and in the next stage there is the subsidization of the operational losses of unprofitable power plants. In addition, there are indirect subsidies due to the coverage of environmental and social externalities, which are not borne by the power sector directly.

In this section, there will be an analysis of how the fossil fuel based power generation in Bangladesh receives subsidies at various stages of value creation, in a direct or indirect form. In the analysis, the standards and guidelines for the computation of subsidies are taken from the International Monetary Fund research paper by Parry, Black, & Vernon (2021)

The efficient price per unit of a fossil fuel product is given by: {[unit supply cost] + [unit environmental cost]} × [1 + general consumption tax rate, if applicable] (Parry, Black, & Vernon, 2021)

Here, for a non-tradable product like electricity, the supply cost is the domestic production cost, inclusive of any transportation, processing, distribution costs, and margins. However, for an internationally tradable product the supply cost is the opportunity cost of consuming the product domestically instead of selling it abroad. This opportunity cost is measured by the import or export parity price, adjusting for domestic margins. The supply cost affects the operational losses of the power plant.

On the other hand, the environmental costs of fossil fuel combustion include global climate and local outdoor air pollution damages. Here, the climate damage is a fuel's CO_2 emissions factor times the damage per unit of CO_2 emissions. CO_2 emissions factors are very similar across countries.

To the supply cost and environmental cost, a value added tax (VAT), or general consumption taxes, is added, so as to avoids distorting relative consumer prices. This step ensures that electricity is treated as a consumer good, and does not distorting relative prices and hence the choice between different goods.

Next, explicit and implicit subsidies are defined.

The explicit subsidy for a fuel, in a sector, in a country, is defined by:

{[sectoral unit supply cost] - [price paid by fuel user]} × [sectoral fuel consumption]

And the total explicit and implicit subsidy is defined by:

{[sectoral efficient fuel price] - [price paid by fuel user]} × [sectoral fuel consumption]

The difference between the total subsidy and explicit subsidy is the implicit subsidy, which covers the environmental externalities.

2.2 Subsidy levels in different electricity markets

In Bangladesh, electricity is consumed by various levels of the industrial and the residential applications. The tariff levels for them are different. Moreover, electricity tariffs also vary according to levels of usage, where users of low amounts pay a lower tariff rate, while users of high amounts pay increasingly higher rates. Tariff rates also vary according to peak time and off peak time usage. The power plants however receive their revenues in the form of bulk, not retail tariffs (BPDB, 2022). For the purpose of simplicity, the subsidy levels are analyzed using an average level of tariff in the residential and industrial sectors. Overall data in this section is used from (Parry, Black, & Vernon, 2021).

Figure 2-1: Subsidies for residential electricity in Bangladesh (2015 to 2020)

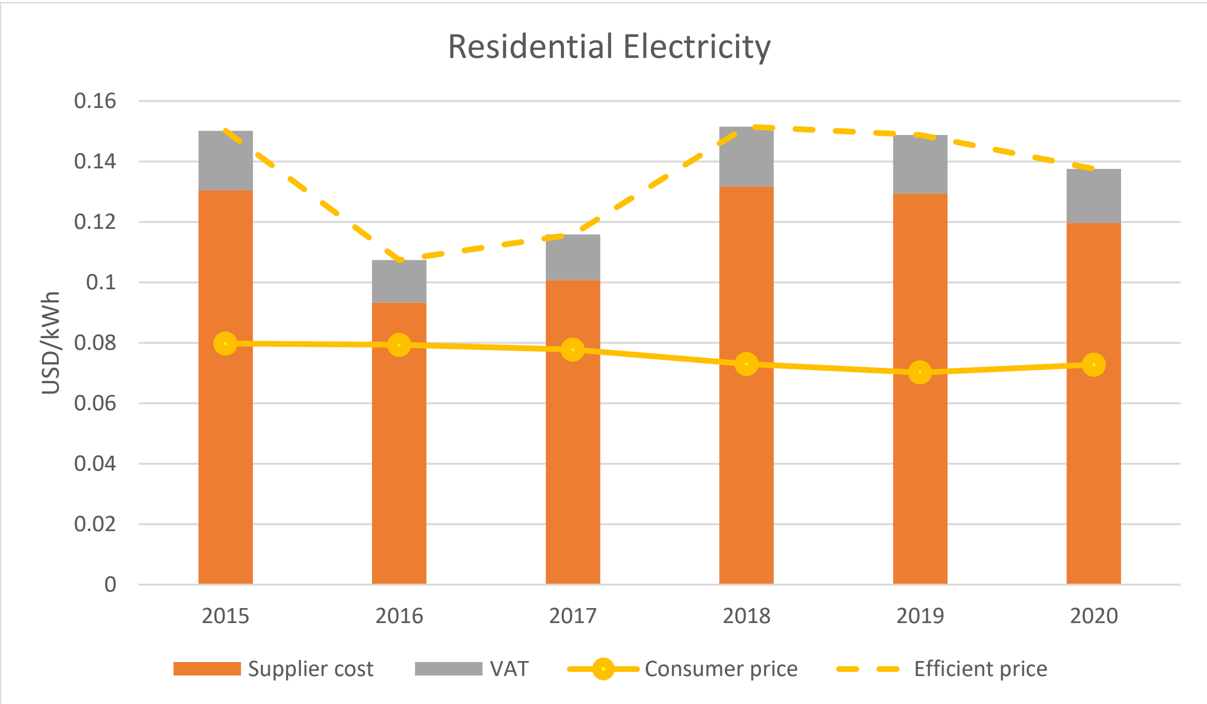
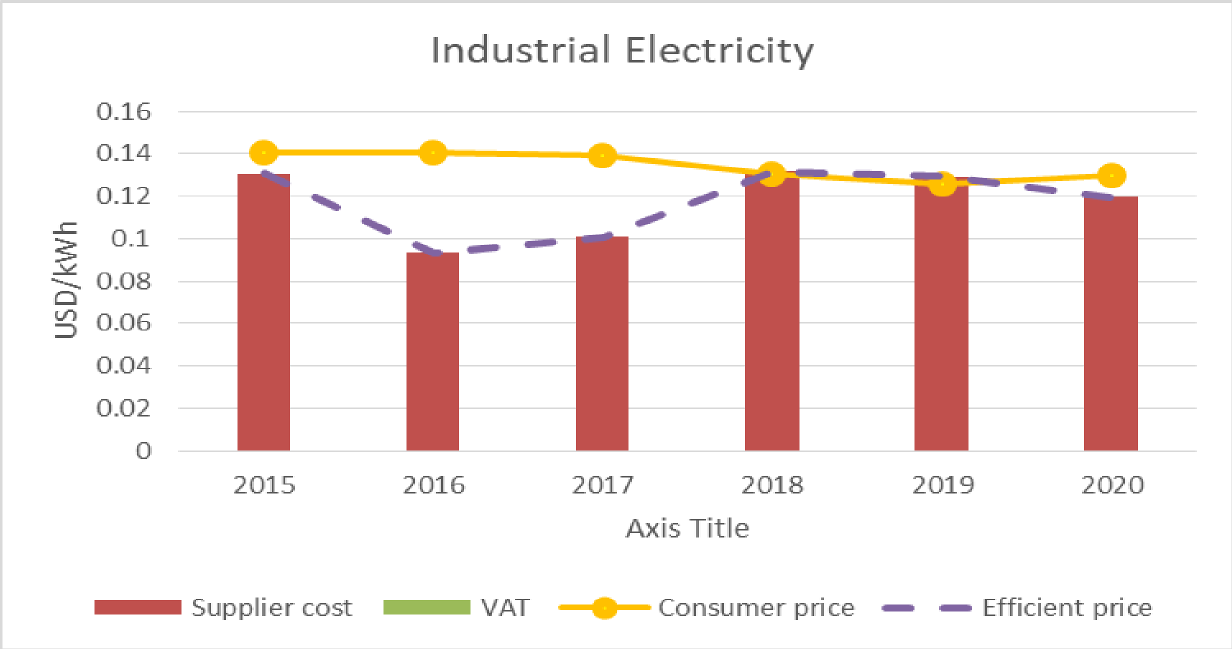


Figure 2-2: Subsidies for industrial electricity in Bangladesh (2015 to 2020).



It can be seen that as the tariff levels of consumer prices in the residential sector is low compared to the cost of supply, there is a significant amount of subsidy given to residential consumers (figure 2.1). Half of the cost of electricity is subsidized in the case of residential consumers. On the contrary, tariff levels of consumer prices are higher for industrial consumers, and the consumer price is equal to or even a little greater than the efficient price in some years (figure 2.2). This shows that selling to industrial consumers is a break even strategy, whereas residential consumers are subsidized to make non- commercial consumption more affordable in order to increase electrification rates and standards of living.

2.3 Subsidy levels for different fossil fuels in electricity generation

The total subsidies for natural gas based power generation are several times the consumer price (figure 2.3). The consumer price does not cover the greater part of the supply cost, much less the environmental cost. The consumer price has not kept pace with the increase of supply cost. In the case of natural gas, the environmental cost is comprised mostly of global warming cost, and a smaller share of local air pollution.

Figure 2-3: Subsidy component trend of natural gas (2015 to 2020).

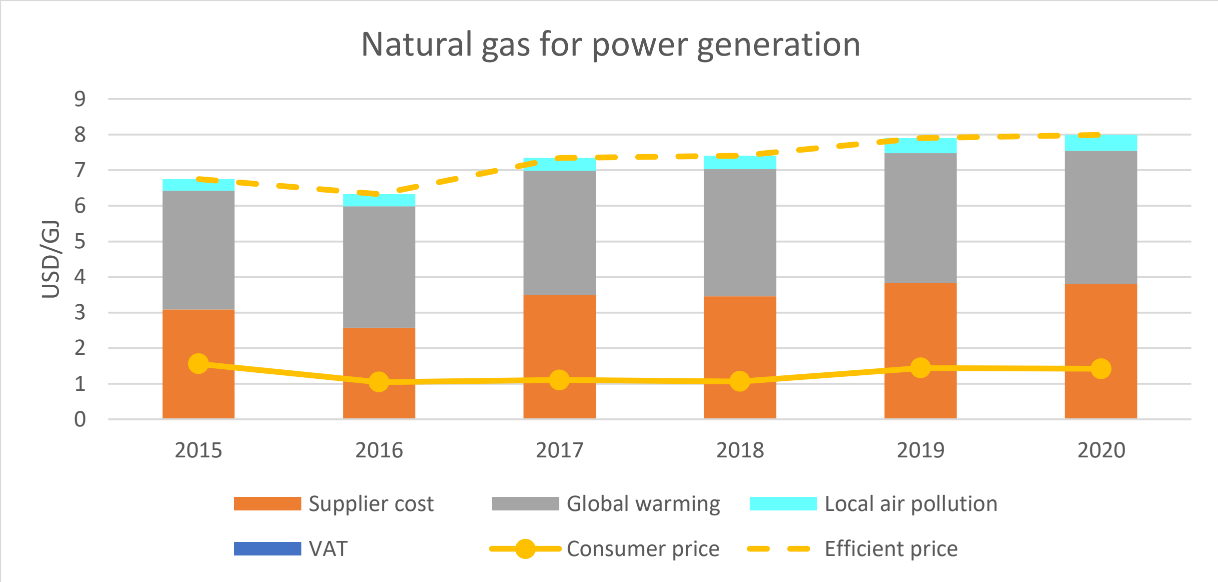
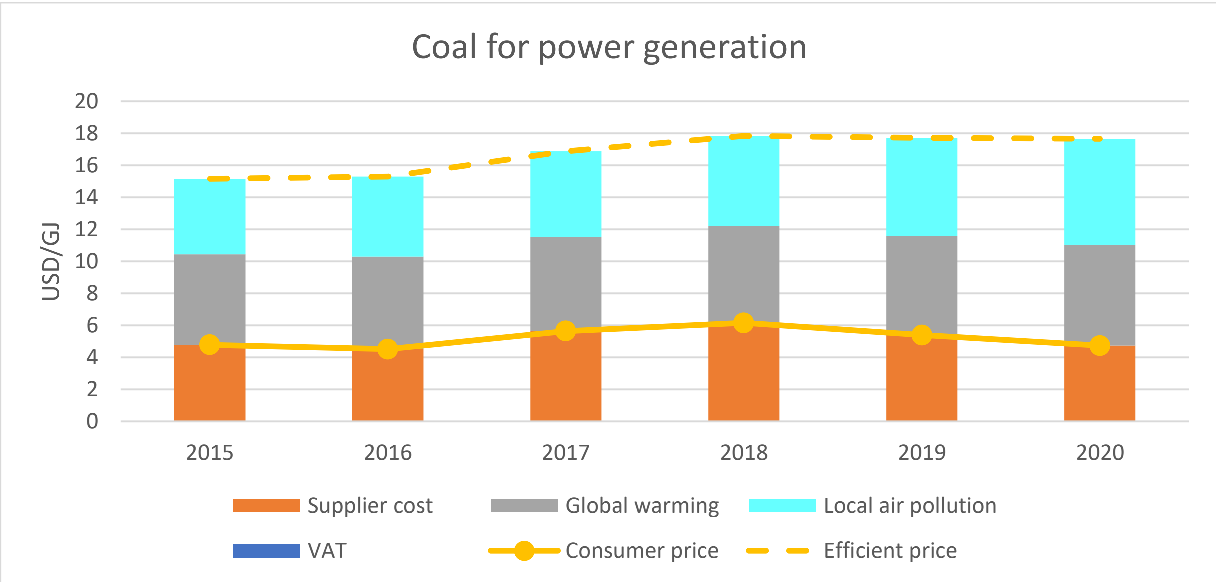


Figure 2-4: Subsidy component trend of coal (2015 to 2020).



In the case of coal powered generation the supplier cost has remained steady, and has been covered by the consumer price (figure 2.4). However, the environmental cost has not been covered.

2.4 Explicit and implicit subsidy rates for different electricity markets

An analysis of the subsidy components of electricity supplied to the residential sector shows that the bulk of the subsidy is in the form of explicit subsidy, and a smaller portion is in the form of implicit subsidy (figure 2.5). The level of subsidy in the residential sector is high compared to that in the industrial sector. One trend in the industrial sector subsidies shows that subsidies were not allocated to this area every year (figure 2.6).

Figure 2-5: Explicit and implicit subsidy trends for residential electricity (2015 to 2020).

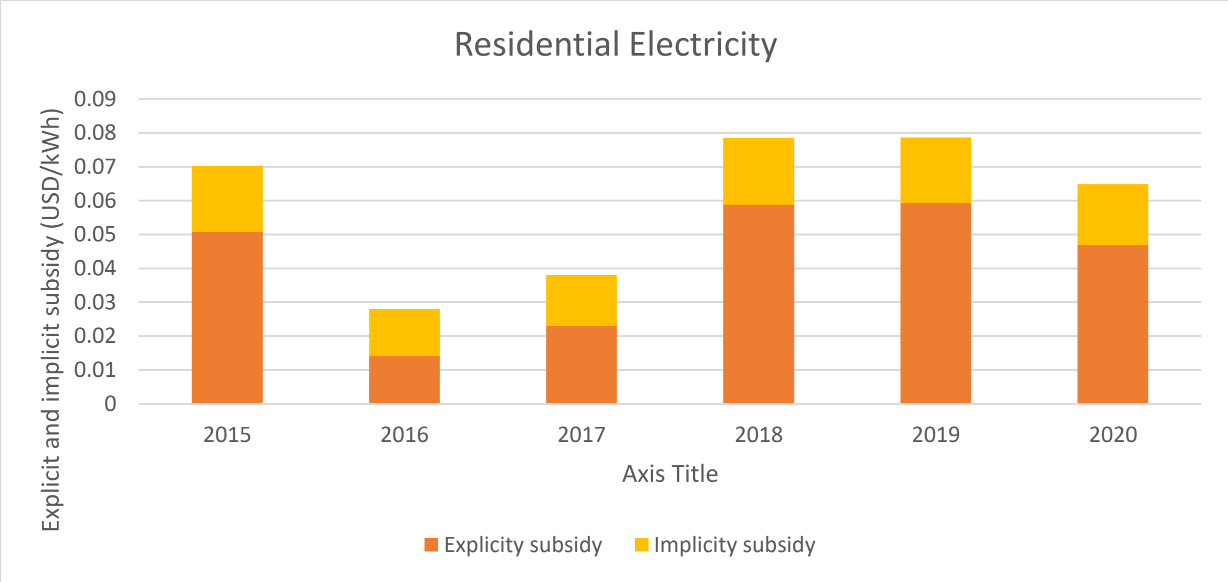
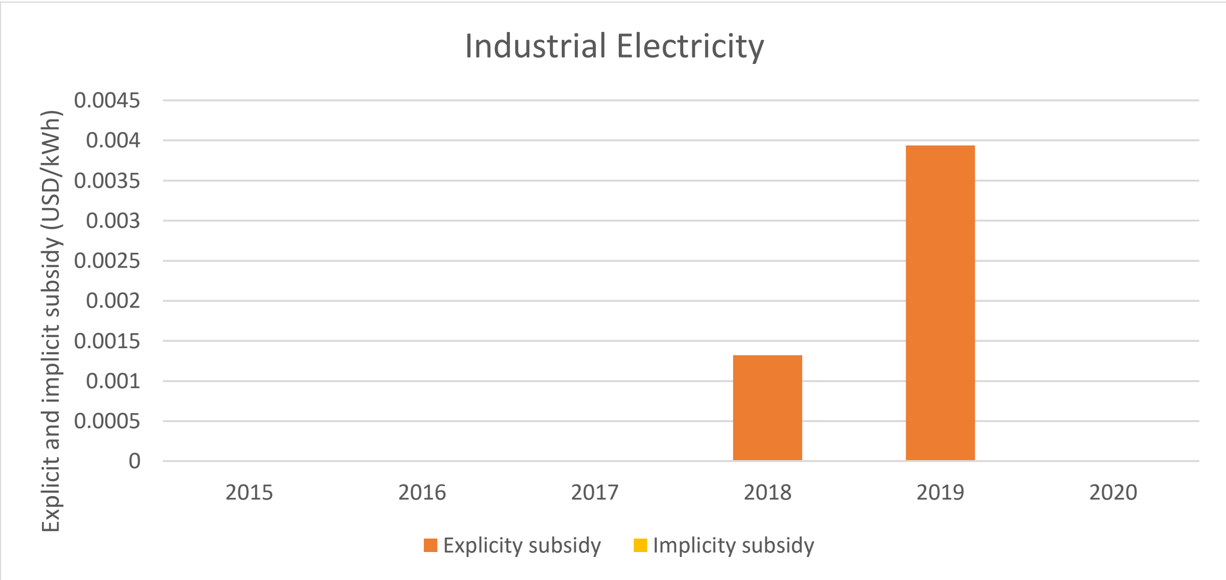


Figure 2-6: Explicit and implicit subsidy trends for industrial electricity (2015 to 2020).



2.5 Explicit and implicit subsidy rates for different fossil fuels for electricity

Overall subsidy rates for natural gas and coal are increasing, with coal having a higher rate of increase. The explicit subsidy for gas remains at a steady rate, but the implicit subsidies are gradually increasing (figure 2.7). Coal consists entirely of explicit subsidies, which are increasing (figure 2.8).

Figure 2-7: Explicit and implicit subsidy trends for natural gas electricity (2015 to 2020).

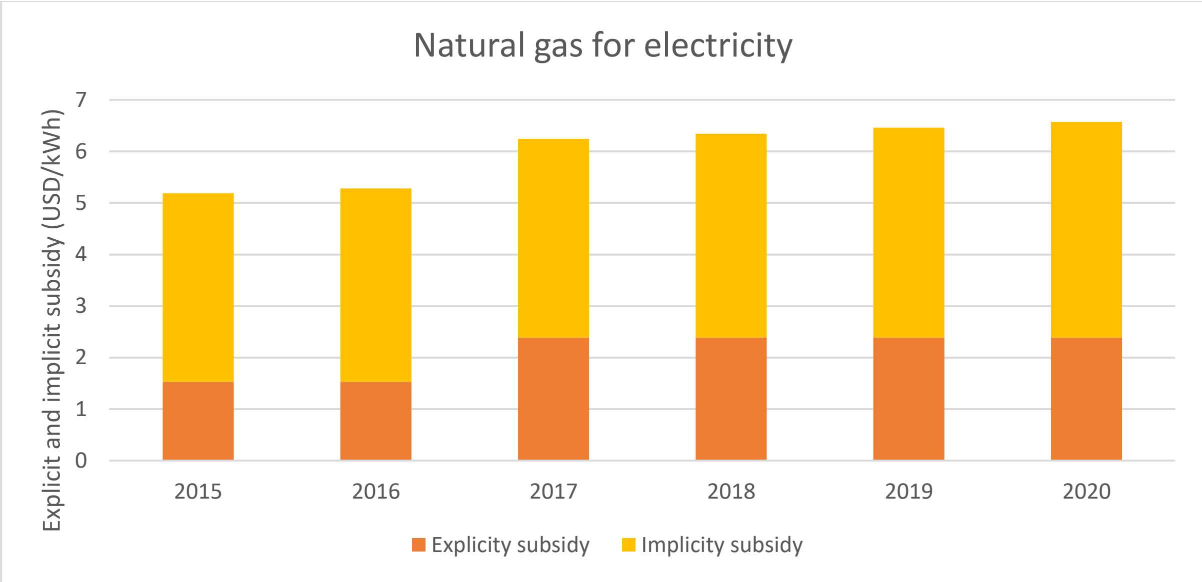
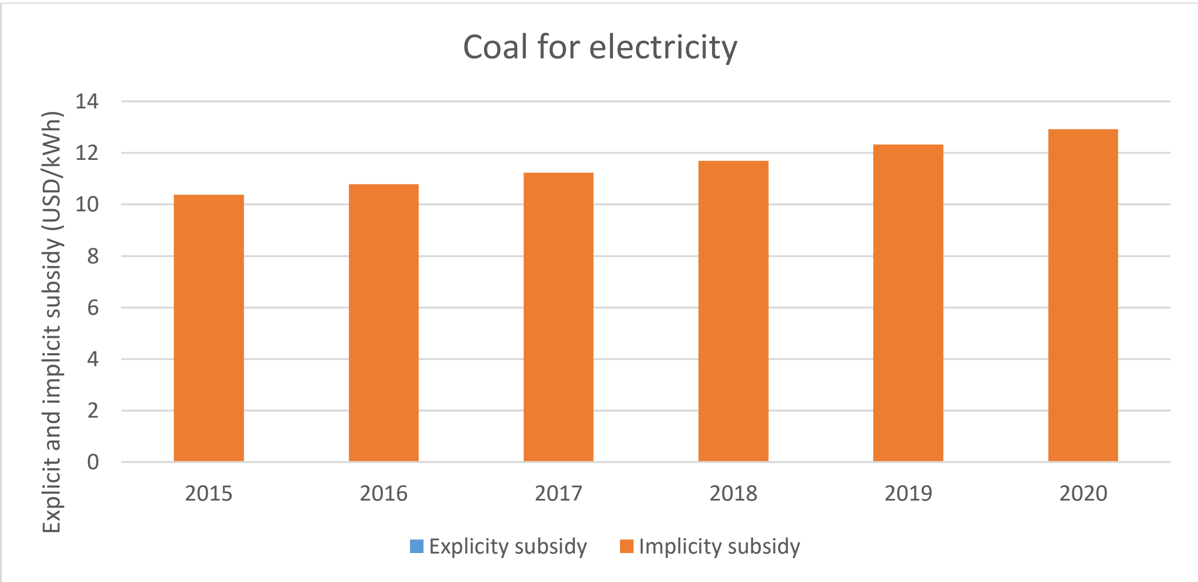


Figure 2-8: Explicit and implicit subsidy trends for coal electricity (2015 to 2020).



2.6 Total and percentage of GDP subsidy amounts for electricity

Looking at the trend of total subsidies in the residential sector, in USD and as a share of the GDP, reveals that the total subsidies do not have a decreasing trend in the long run. However, as a share of the GDP, there may be a gradual decrease of the subsidies (figure 2.9). In the industrial electricity market, the absolute amount of electricity can fluctuate, but is likely to decrease as a share of the GDP (figure 2.10).

Figure 2-9: Trend of total and proportionate subsidy for residential electricity (2015 to 2020).

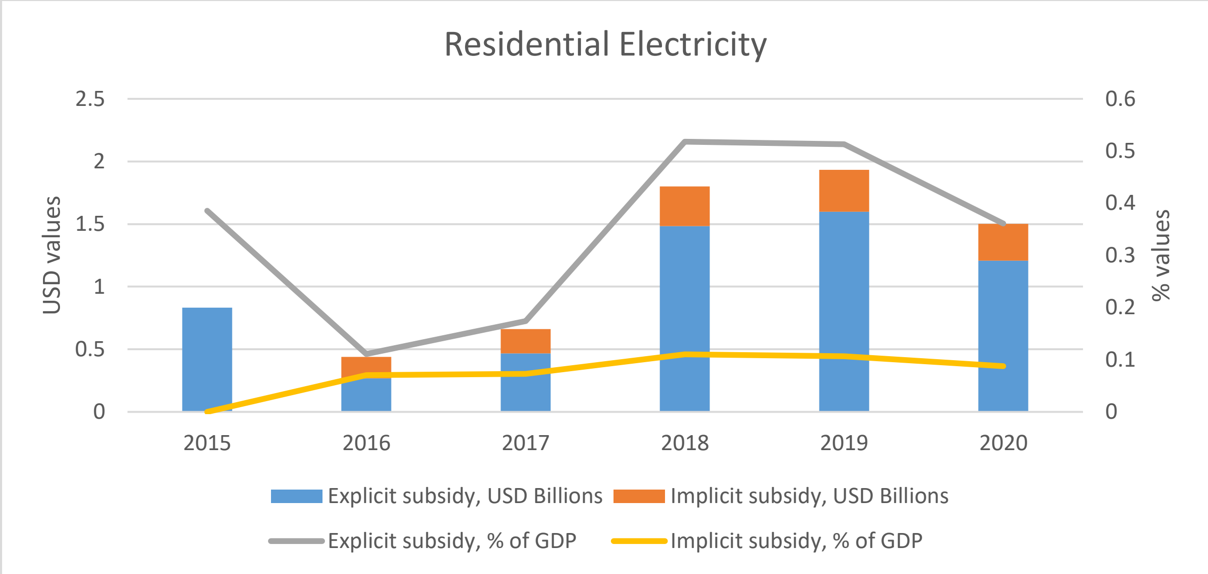
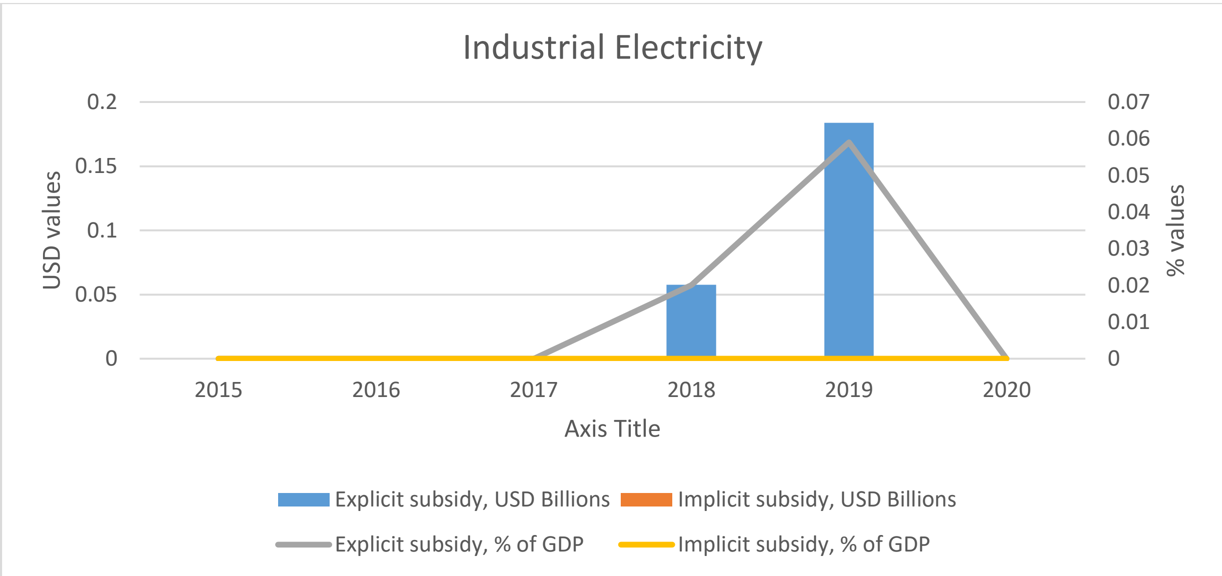


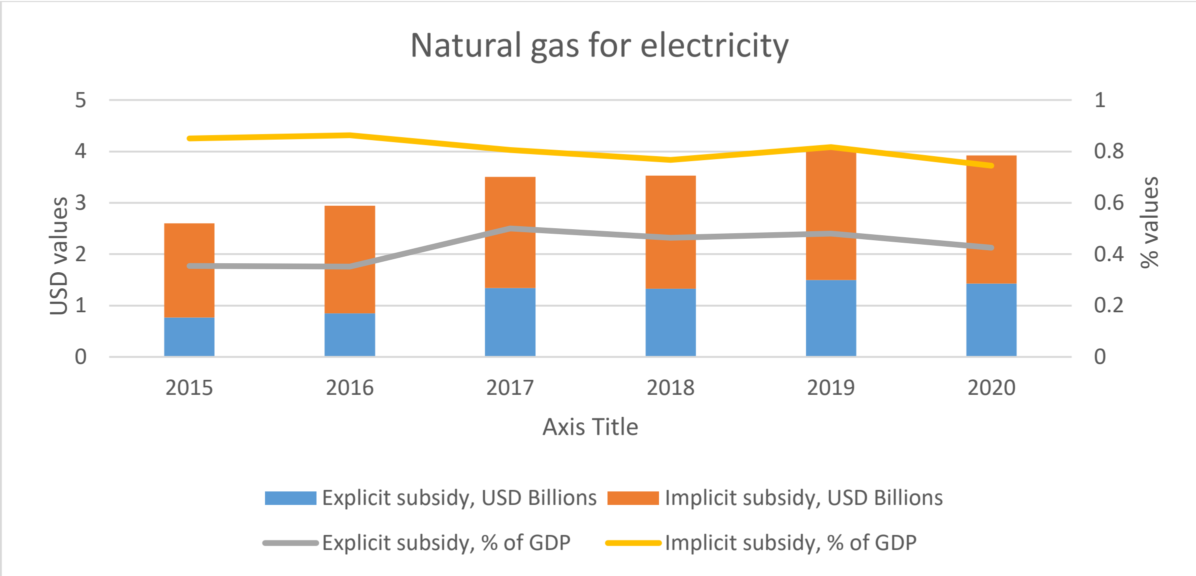
Figure 2-10: Trend of total and proportionate subsidy for industrial electricity (2015 to 2020).



2.6 Total and percentage of GDP subsidy amounts for electricity

In the case of natural gas, the amount of explicit subsidies is likely to increase steadily, but the amount of implicit subsidies increase at a faster rate, because of the increasing deleterious effects of climate change and ambient air pollution. As a share of the GDP, the subsidies for natural gas also increase, while the implicit subsidies outpace explicit ones (figure 2.11).

Figure 2-11: Explicit and implicit subsidy trends for natural gas electricity (2015 to 2020).



2.7 Summary

The consumer sector of Bangladesh has long enjoyed subsidized electricity, a lot of which is because of the subsidization of fossil fuels used in the electricity sector. This takes the form of explicit subsidies conprising the difference between the cost of the fuel to the power plant, the the market price of the fuel. It also includes implicit subsidies related to the unseen cost of air pollution and health risks. The industrial sector also benefits from implicit subsidies, as they do not account for the externalities caused by their use of fossil fuel based electricity. In Bangladesh, the government has recently withdrawn the subsidization of fossil fuels, as it has been creating a great pressure on the national budget and foreign currency reserve (Elahi, 2022). This has lead to higher costs of consumer and industrial goods, which is leading to inflation, increase in the cost of export goods, and a burden on industry (Mirdha, 2022). Although this is a great burden for the common people and a hindrance to industry, it also reveals the extent of the subsidization the consmers and businesses in Bangladesh have enjoyed until now. It reveals the true cost of fossil fuels, and thus can serve to dispell the misconception that fossil fuels are the cheapest option, and that renewables are uncompetitive. Now is an opportunity to demonstrate how renewables compare to the unsubsidized cost of fossil fuels, and to create awareness among all stakeholders and the public about the potential benefits a long term strategic investment in renewables can bring.

3. A chronological list of fossil fuel based power plants which have already become inefficient and contributing to the subsidy burden

This section covers a discussion of the existing fossil fuel power plants that are to be retired by 2030, and the fossil plants that are planned to come online within this time frame. The plants that are supposed to be retired can be predicted, as their commissioning dates are known, and based on the expected useful life, the retirement date can be forecasted. However, among the plants in the planning, different plants are in different stages. It is possible to assume that the ones that are already under construction and the work on them have already commenced cannot be discontinued or cancelled. Therefore these plants are not included in the analysis of plants to be discontinued. There are some fossil based power plants which are planned but not yet under implementation, and these plants can be considered for replacement. In the analysis, the total amount of fossil fuel capacity to be retired will be contrasted with the total new capacity to be added. The retirement and commencement schedules of different power plants, classified according to fuel, are given in Appendix 1, in tables A1 to A5. Based on this, there can be an assessment for opportunities where fossil plants can be replaced with renewables.

Table 3-1: Fuel wise capacity of electricity generation to be added or dropped up to 2030.

Fuel	Installed capacity to be retired by 2030	Capacity to be installed by 2030	Net increase (decrease)
Gas/ LNG	4179	10877	6698
HFO	715		(715)
HSD	1060		(1060)
Coal		3690	3690

From the above table 3.1 it can be seen that 715 MW of HFO will be retired by 2030, and 1060 MW from HSD. It must be mentioned that there is only one more HSD plant of 161 MW to be commissioned in 2023, and no other new HSD plants after that. The last HFO projects to be completed have been scheduled for 2022, comprising around 553 MW, and after this no more HFO projects are in the pipeline. This implies that almost all HSD plants will be phased out in the coming decade. Furthermore, there will be a net decrease in the HFO installed capacity by 2030.

On the whole, the gas and coal based power plants which are still in the planning process (table 3.1) are eligible to be reviewed for replacement with renewables. However the potential to replace them will depend on their roles in the grid, i.e. whether they are base load or peaking plants. Most of the capacity of coal and gas will be used as base load and can also be used to supply peaking load if necessary. In addition to these, there will the nuclear generation capacity. After the retirement and net addition of HFO plants, there will be enough HFO plants to supply peaking load, and any additional peaking load can be supplied by solar and storage.

As has been shown in chapter 1, the cost components of fossil based power plants are fixed costs, fuel costs and variable O&M. Out of these three, the fuel cost component is the volatile and unpredictable component. In the case of renewable energy plants like solar PV power plants, the LCOE is predictable as the fixed costs and variable O&M are determined beforehand, there are no fuel costs. Therefore, the renewable energy power plants will be more cost competitive than the fossil fuel plants if the average cost of fossil fuel rises above a certain level. Table 3.2 shows the assumptions about comparisons of LCOE for coal and natural gas with solar PV.

Table 3-2: Assumptions about comparisons of LCOE for coal and natural gas with solar PV.

	Gas (CCGT)	Coal	Reference
Initial investment cost (USD/KWel)	USD 800 /kW equivalent (up to 250MW), USD USD 667 (up to 500 MW) All are combined cycle	USD 1800 /KW equivalent (600MW plant) including cost of coal terminal	Authors investigations
Annual O&M cost excl. fuel (USD/kWel)	Fixed O&M: USD 2.5/kw/month, variable O&M USD 1.56/ MWh	Fixed: USD 3.5/kw/month, variable USD 2.5/MWh	BPDB interview

O&M Inflation	2%	2%	BPDB interview
Lifespan (years)	25	25	BPDB interview
Fuel usage rate	3412 BTU per kWh	3 units of electricity per kg of coal	BPDB interview
System Efficiency	55%	40%	BPDB interview
Capacity Factor	52%	30%	BPDB interview
Discount rate	9%	9%	BPDB interview

It can be seen in the graph below that the recorded tariffs of solar energy projects with respect to the date of LOI issuance is decreasing with time and is now below 9 US cents per kWh of electricity (figure 3.1). This trend can be contrasted with the LCOEs of coal based and gas based electricity generation in Bangladesh, and how these LCOEs are sensitive to the average price of the fuel, considering other costs to be constant. The cost assumptions for the LCOE calculations for coal and gas are given in the table 3.2 above. According to the information in chapter 1, the price of natural gas has varied between 2 and 8 USD per MMBTU in the last decade, and the price of coal has varied between 50 and 100 USD until 2021, and since then has risen from 100 to above 400 USD per ton. Considering this, the sensitivities of the LCOEs to fuel price changes are shown in the following figures.

Figure 3-1: Tariff Trend of Solar IPP of Bangladesh in Recent Years.

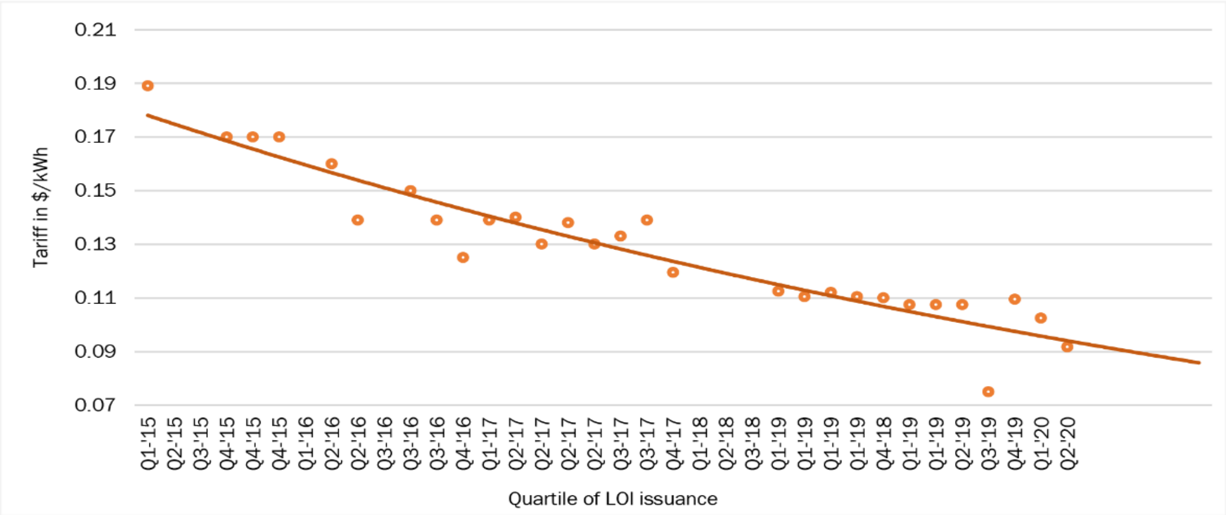
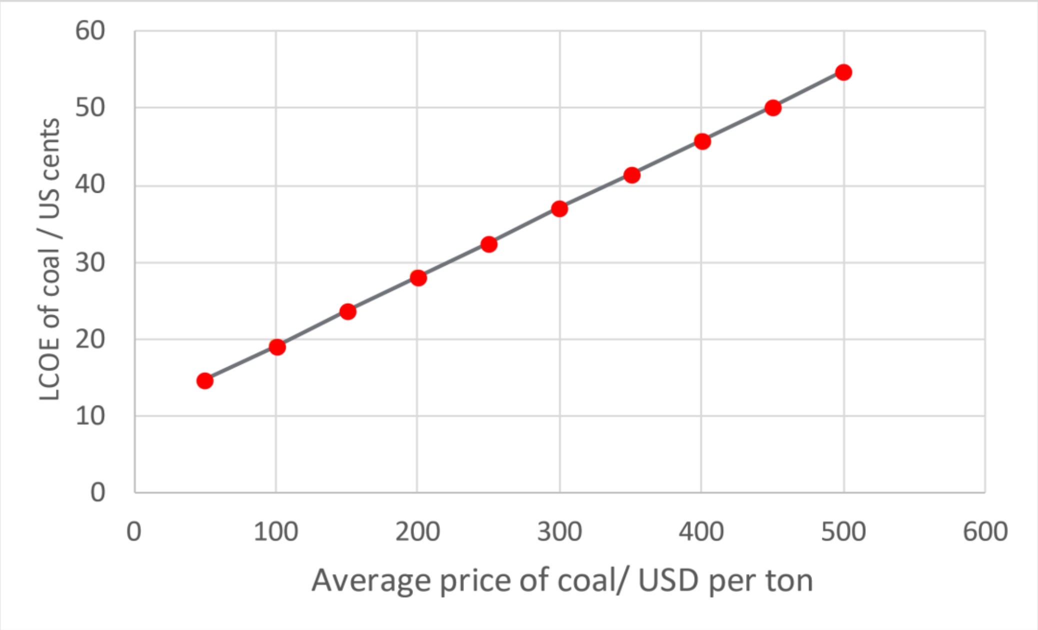


Figure 3-2: Variation of the LCOE of coal based electricity to changes in coal price.



It can be seen that even if the average price of coal is 50 USD per ton, the LCOE of coal is already higher than the tariff of solar PV in Bangladesh (assuming that the coal plants have a plant factor of 30%, which was the plant factor in 2019-2020). (figure 3.2). This means that the average price of coal in recent history already makes it less competitive than solar PV. Moreover, the life of a coal plant can last over 25 years, and so a period of abnormally high coal prices can push up the average lifetime price of coal for the power plant, thus making it uncompetitive even if the price of coal remains low for most of the lifetime. Even if we consider the average price of coal to vary between 50 and 100 USD per ton, the LCOE ranges between 15 and 20 cents per kWh. However, the current tariff for solar PV is 9 cents per kWh. This scenario is quite likely, given the recent declining trend for solar PV. This means that as the cost of solar PV continues to decline, coal plants in the near term may likely be uncompetitive with solar PV and therefore become stranded assets.

The same pattern can be seen in case of natural gas based electricity (figure 3.3). In the last 20 years, the price of gas has fluctuated between 2 and 14 USD per MMBTU, in the short term contracts market. In the long term contracts market, the prices have been much higher in the last year, usually between 20 and 40 USD per MMBTU, and sometimes exceeding 90 USD. As the cost of fuel in gas based power plants is a lower share of the total lifetime cost, changes is the price of gas affects the LCOE of gas based electricity to a lesser degree. The gas LCOE is around 5 US cents when the gas price is 5 USD/MBTU, and reaches 25 cents if the price of gas rises to 65 USD. Bangladesh purchases 25% of its LNG under short term contracts, and 75% of the LNG under long term contracts. Under this long term contract, 25% from the 75% can be denied by either party. It can be seen from the figure on the right that the price of gas in the short term market (Henry Hub) has remained below 10 USD, but the price in the long term Japan Korea Market (JKM) has fluctuated above 20 USD in the past year (figure 3.4). When the price in the market is higher than the contract price, Bangladesh has to import a third of its long term contract LNG at the higher prices. This increases significantly the average cost of imported natural gas used for power generation. As the gas reserves are decreasing in Bangladesh, a greater share of the gas demand will be met from imports.

At present the tariff for solar is around 9 cents per kWh in Bangladesh, it has halved in a five year period. If we assume that the decrease in price will continue at the present rate, the tariff for solar may become at par with gas, making solar PV competitive with gas in the coming medium term. Moreover, as gas based power plants have a lifetime of 25 years, if the cost of solar PV becomes competitive or lower than gas in the next few years, some of the existing or forthcoming gas based power plants may become stranded assets.

Figure 3-3: Variation of the LCOE of gas based electricity to changes in gas price.

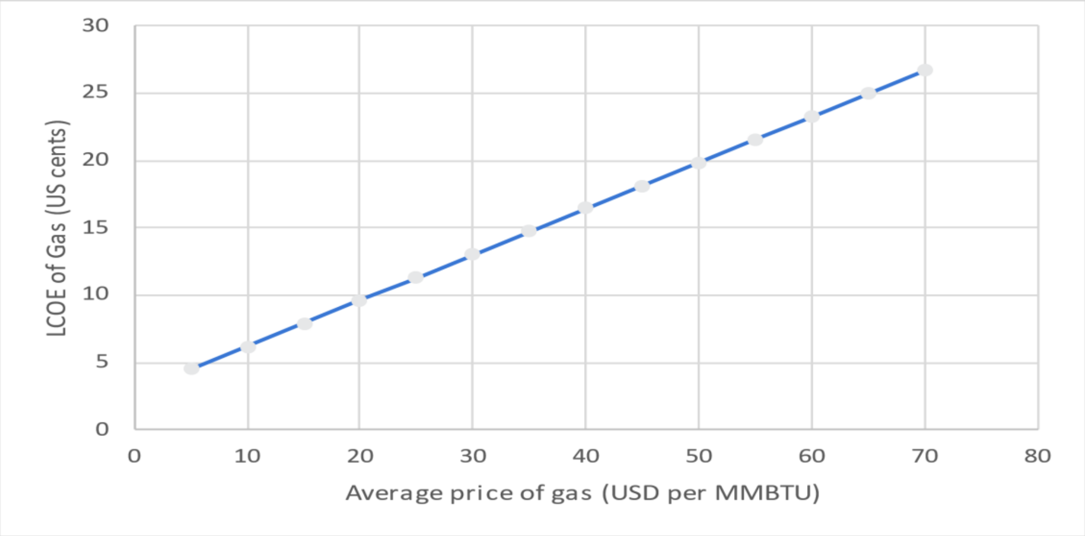
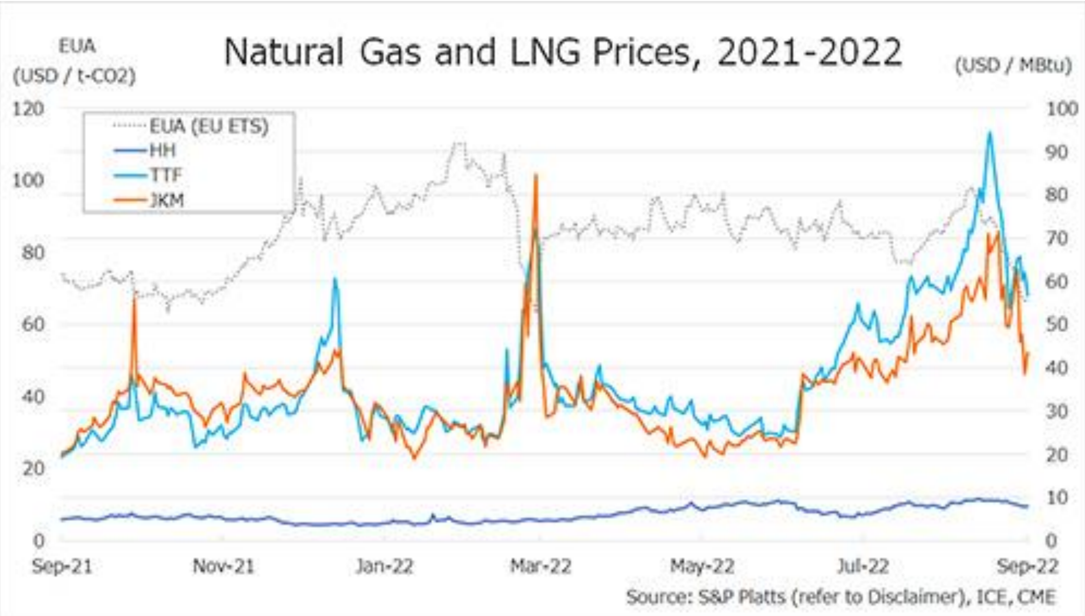


Figure 3-4: Long term and short time natural gas and LNG price trends.



4. Stocktaking of existing RE intervention taken place or in the pipeline with both public and private sector, along with potential funding opportunities.

This chapter provides a background about the policies and measures enacted in Bangladesh in order to promote renewable energy. The basic acts that concern the electricity sector in general and the renewable electricity in particular are as follows:

4.1 Sustainable and Renewable Energy Development Authority Act

The Sustainable and Renewable Energy Development Authority Act is the law enacted to establish an authority named Sustainable and Renewable Energy Development Authority (SREDA). It has been created with objectives to take necessary measures for the implementation of energy efficient and RE activities in the country. The activities of SREDA includes the following:

- Formulating necessary laws, rules and regulations for sustainable energy development.
- Preparing and updating the inventory of RE resources and associated technologies for devising short, medium, and long-term development plans to extend the use of RE with specific targets, and taking necessary steps to implement those.
- Providing technical and financial assistance in research and development, demonstrations, and training on RE.
- Taking necessary steps for creating public awareness and motivation in order to encourage the use of RE in the public and private sector.
- Making necessary arrangements to provide financial incentives to attract and encourage private investment in the RE sector.
- Coordinating with different stakeholders in matters related to sustainable energy development.
- Establishing linkages with regional and international actors, etc.

4.2 Bangladesh Energy and Power Research Council (BEPRC) Act

This Act paved the path of creating the Bangladesh Energy and Power Research Council (BEPRC). It details the composition, duties, and responsibilities of the above-mentioned Council, which is entrusted with the research and development regarding the country's power and energy sector. It also specifies the use of electricity and fuel diversification for the identification, conservation and conversion of energy to ensure the safety of the power and energy sector in the country with a view to long-term planning for the sector. The BEPRC is the apex body of energy and power research, and it has chalked out several research areas, such as, power supply, smart cities and communities, smart grids, energy efficiency and conservation, energy innovation and market uptake, etc.

4.3 Private Sector Power Generation Policy of Bangladesh

Private Sector Power Generation Policy of Bangladesh was first announced in 1996 with an aim to ensure that energy sources are properly explored, produced, distributed, and used rationally by various sectors and consumers in a sustainable manner to match the ever-increasing demand for energy. The policy was adopted with the objectives to attract private investment in power generation and to provide financial incentives and benefits to the private parties. The following incentives and benefits were declared through this policy document:

- The private power companies shall be exempted from corporate income tax for a period of 15 years;
- The companies will be allowed to import plant and equipment and spare parts up to a maximum of 10% of the original value of total plant without payment of customs duties, VAT (Value Added Tax) and any other surcharges;
- Repatriation of equity along with dividends will be allowed freely;
- Exemption from income tax in Bangladesh for foreign lenders to such companies;
- Tax exemption on royalties, technical know-how and technical assistance fees, and facilities for their repatriation;
- Tax exemption on interest on foreign loans;
- Tax exemption on capital gains from transfer of shares by the investing company, etc.
- This policy is relevant because renewable energy projects are usually implemented from the private sector.

4.4 Bangladesh Renewable Energy Policy

The Renewable Energy Policy (2008) has been developed by the Power Division of GOB with multiple objectives related to RE implementation. In general terms, the goal is to spread the utilization of RE technologies across the country by strengthening a favorable technical, financial and legal environment. In specific terms, the policy document guides the necessary institutional arrangement. In doing, so it has laid the foundation for SREDA. The policy document also outlines a few resource, technology and program development steps, and lists potential investment, fiscal and regulatory incentives. A target has been set to meet 10% of the power demand from RE by 2020.

4.5 Policy Guideline for Enhancement of Private Participation in the Power Sector

Through this 2008 policy document, the government basically opened the national grid for commercial use. The main objectives of the policy are to introduce and regulate competition by allowing private investment in the power sector, and to establish new commercial power plants and rehabilitate old ones through Public Private Partnership (PPP). The main features of this policy guidelines can be summed up as the following points (Power Division, Policy Guidelines For Enhancement Of Private Participation In The Power Sector, 2008, 2008). Private investors are allowed to build commercial power plants that comply with the existing environmental laws & regulations, technical standards of grid interconnection and operation. Considering the depleting natural gas reserve, they are allowed to use any fuel including renewable ones, and are free to find their own buyers to sell electricity at a mutually negotiated tariff. Non-competition from public utilities is ensured in case there is a contract with large consumers. However, depending on the location, they have to sell 20% electricity to public utilities at a bulk tariff rate as determined by BERC.

The private investors are allowed non-discriminatory open access to the transmission and distribution facilities owned by PGCB or any other Distribution Licensee, given that adequate capacity is available and they pay the wheeling charge and surcharge as determined by BERC. The private investors are to enjoy certain fiscal incentives, such as corporate income tax waiver for 15 years, relaxed customs duties on a certain amount of import for 12 years, possibility of land lease support from the GOB etc. and many more. Private investors can rehabilitate publicly owned, old and inefficient power plants based on Rehabilitate, Own and Operate (ROO) or Rehabilitate, Operate and Transfer (ROT) model. Public Private Partnership (PPP) is allowed for joint venture power plants under certain terms and conditions.

4.6 Bangladesh Climate Change Strategy and Action Plan

The potential risk faced by Bangladesh as a highly vulnerable victim of climate change only adds to the GOB's intention of favoring clean and environment friendly sources of energy. The Bangladesh Climate Change Strategy and Action Plan 2009 (BCCSAP) presents itself as the all-embracing strategy document addressing climate change and directs the relevant policy landscape of Bangladesh. Even though it prioritizes adaptation and disaster management measures, it reasonably includes issues like 'low carbon development, mitigation, technology transfer and the mobilization and international provision of adequate finance' (Ministry of Environment and Forests (MOEF), 2009).

The document outlines 6 main pillars or themes and lists 44 programs under these themes along with proper justification, details of activities to be undertaken and responsible parties in the Annex. Renewable energy development is listed as the 4th program under the 5th theme titled 'Mitigation and Low Carbon Development'. The recommended set of actions are:

- Investment to scale up solar power programs;
- Research and Investment to harness wind energy, particularly in the coastal areas;
- Feasibility studies for tidal and wave energy;
- Study of the techno-economic, social and institutional constraint to the adoption of improved biomass stoves and other technologies.

Apparently, the development of solar power has received the highest priority among RE programs, with an immediate timeline suggestion, and the identified responsible authorities are the Ministry of Power, Energy and Mineral Resources (MPEMR), Ministry of Environment and Forests (MOEF), and private entrepreneurs.

4.7 Guidelines for the Implementation of Solar Power Development Program

In October 2013, MPEMR has published the 'Guidelines for the Implementation of Solar Power Development Program' (SREDA, Guidelines for the Implementation of Solar Power Development Program , 2013) to meet the 10% power generation target from RE sources by 2020 as mentioned in the Renewable Energy Policy 2008. Accordingly, the GOB has launched a 500 MW Solar Power Generation Plan with two types of projects, namely, the Commercial and Social Solar Power Projects. The main distinction between these two types of projects is that the commercial project shall adopt the business model of earning from services charges paid by its beneficiaries, while the social projects shall be publicly developed and financed by grants (SREDA, Guidelines for the Implementation of Solar Power Development Program , 2013). The commercial type projects are meant to be developed mostly by the private sector. Several types of projects are then listed under each of these categories, which are mentioned below:

- Commercial projects include–
    1. Solar parks built on 'Build, Own and Operate' (BOO) basis in empty & fallow land owned either by the government or privately;
    2. Solar mini-grids in off-grid areas;
    3. Solar rooftop systems in residential and commercial buildings;
    4. Solar power systems in industries;

v. Private solar power projects in government or semi-government buildings through IPP model;
vi. Solar powered irrigation pumps, etc.

- Social projects include solar electrification of–
  i. Rural Health Centers;
  ii. Educational institutions at remote areas;
  iii. Union Information Service Centers;
  iv. Religious institutions;
  v. Railway stations at remote areas;
  vi. Government office in off-grid areas, etc.

The document then recommends specific measures that can be taken to implement each type of solar project.

4.8 Nationally Determined Contribution of Bangladesh

The Nationally Determined Contribution of Bangladesh was published in 2015 by the Ministry of Environment and Forestry (MOEF) of the GOB. The official document articulated Bangladesh's commitment in joining global force to combat climate change. It sets both unconditional and conditional (with international support) GHG emission reduction targets for three major sectors, namely power, transport and industry, and includes further mitigation actions to be carried out in other sectors like buildings, agriculture, waste, LULUCF, etc. figure 4.1 shows Bangladesh's intended contribution of GHG emission reduction under the two above-mentioned circumstances (MoEF, 2018).

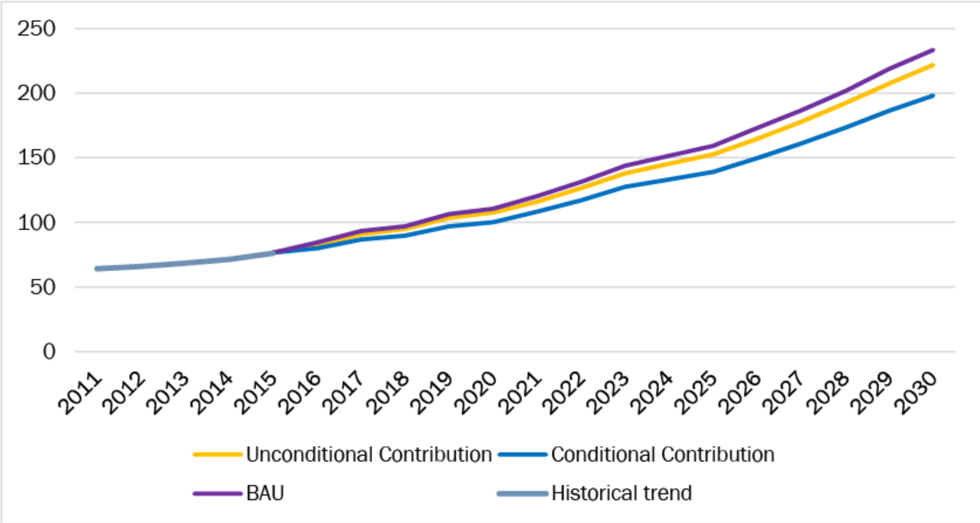
Bangladesh submitted the first NDC document in 2015, with an implementation period from 2016 to 2020. In the business as usual scenario here, Bangladesh had pledged to unconditionally reduce emissions from the power, transport and industry sectors by 5%, and by 15% conditional on adequate support from international financing (MOEF, 2015). Out of this, a 5% conditional reduction and an 18% unconditional reduction was supposed to come from the power sector. The conditional scenario stated that 1000 MW of solar energy capacity and 400 MW of wind capacity will be installed. It also estimated investment needs of USD 1.3 billion for utility scale solar, 0.6 billion for wind energy, 1.2 billion for expanding the solar home system programme, and 1.22 billion for solar irrigation, mini grids, nano grids and pico grids. However, though the target date for the reduction was set to be by 2030, and the timeframe for implementation was set as 2020-2030, the implementation was not expected to start before 2020, as mentioned in the Roadmap and Action Plan for Implementing Bangladesh NDC (MOEFCC, 2018) .

In the meantime, several large scale grid connected solar energy plants have come online, and others are in the pipeline. The interim updated NDC document, submitted in 2020, updated the plan by targeting 1700 MW of utility scale solar PV capacity by 2030.

The updated NDC was submitted in 2021, and included radical changes in plans. It included installing 911.8MW of renewable electricity (out of which 581 come from solar and 149 from wind) in the unconditional scenario, and installing 4114 MW of renewable electricity in the conditional scenario (out of which solar contributes 2277 MW, and wind contributes 597 MW). However, despite these ambitious targets of capacity investments in renewable energy, the NDC document also outlines plans to install 12147MW of supercritical coal based plants, and 5613

MW of new combined cycle gas based power plants. This is contrary to the target of reducing emissions.

Figure 4-1: Projection of GHG Emission (MtCO2e) for Three Sectors from 2011 to 2030 (MoEF, 2018).



While referring to BCCSAP, as mitigation measure the NDC rightly recommends the installation of RE technologies, especially grid-tied, utility-scale solar PV power plants to diversify the existing energy mix.

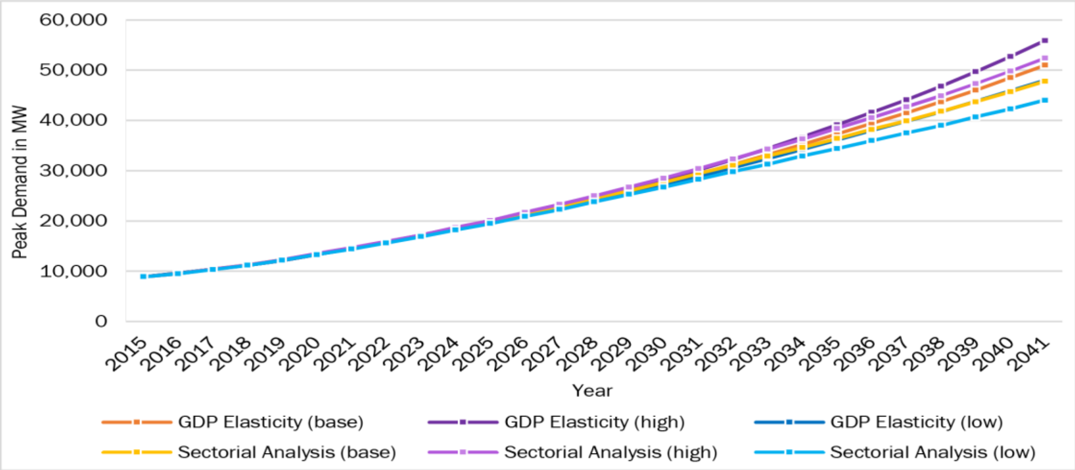
4.9 Power System Master Plan 2016

The principal objectives of the 2nd Power System Master Plan (PSMP), released by GOB in September 2016, are to set the targets and formulate an elaborate plan for the energy and power sector to achieve the national goal of becoming a high-income country by 2041 (Power Division, Power System Master Plan 2016, 2016). The document has articulated the VISION 2041, with five value-up plans. These are:

- Value-up Plan 1: Robust infrastructure for primary energy import;
- Value-up Plan 2: Domestic energy resource development and efficient use;
- Value-up Plan 3: High-quality and robust power system development;
- Value-up Plan 4: Advance deployment of green energy;
- Value-up Plan 5: Policy and human capital development for stable energy supply.

This document analyzed the country's historical trends of energy consumption in details and proposes future energy demand projections until 2041 for three different economic growth scenarios. Figure 4.2 shows a comparative picture of the peak demand projections estimated using these two methods.

Figure 4-2: Comparison among Peak Demand Projection using the GDP Elasticity and Sectorial Analysis Method (Power Division, Power System Master Plan 2016, 2016).



The Master Plan also compares the peak demand projections by taking into account the EE&C targets as detailed in the Energy Efficiency and Conservation Master Plan up to 2030. Table 3.3 and figure 4.3 show the different projected peak demand scenarios of Bangladesh by 2041 and as estimated by the PSMP 2016.

Table 4-1: Peak Demand Projection Scenarios of Bangladesh by 2041 (Power Division, Revisiting PSMP 2016, 2018)

Growth Scenario	GDP Growth rate by 2041	GDP Elasticity Method	
		Without EE&C	With EE&C and captive power to the grid
High	5.0%	67,710 MW	55,900 MW
Base	4.4%	61,681 MW	51,000 MW
Low	4.0%	57,946 MW	48,000 MW

.

From the table and figure, it is visible that the differences in peak demand projections for all the economic growth cases become quite significant when EE&C efforts are taken into account. The PSMP 2016 also attempted to integrate the peak demand projection and energy supply-demand projection. The following figure 4.4 shows the projection of total electricity consumption until 2041. The apparent gap between the consumption and available electricity from the grid is assumed to be supplied by captive plants.

Figure 4-3: Effect of EE&C Measures on Peak Demand Projection until 2041 for the Base Case (Power Division, Power System Master Plan 2016, 2016).

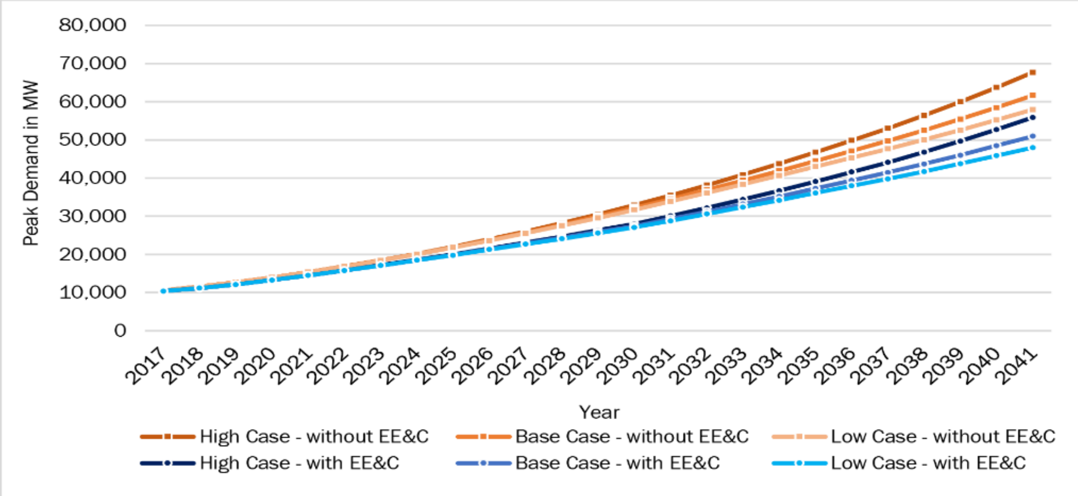
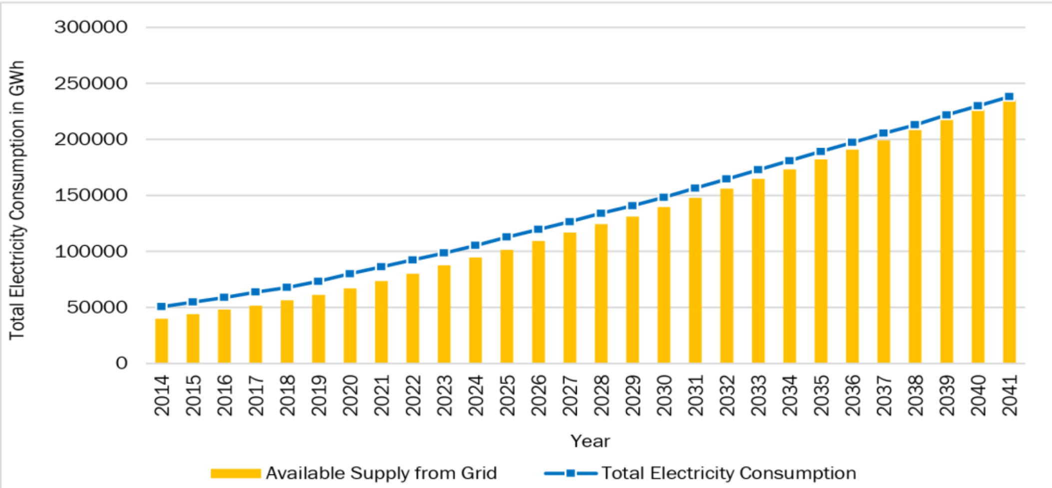
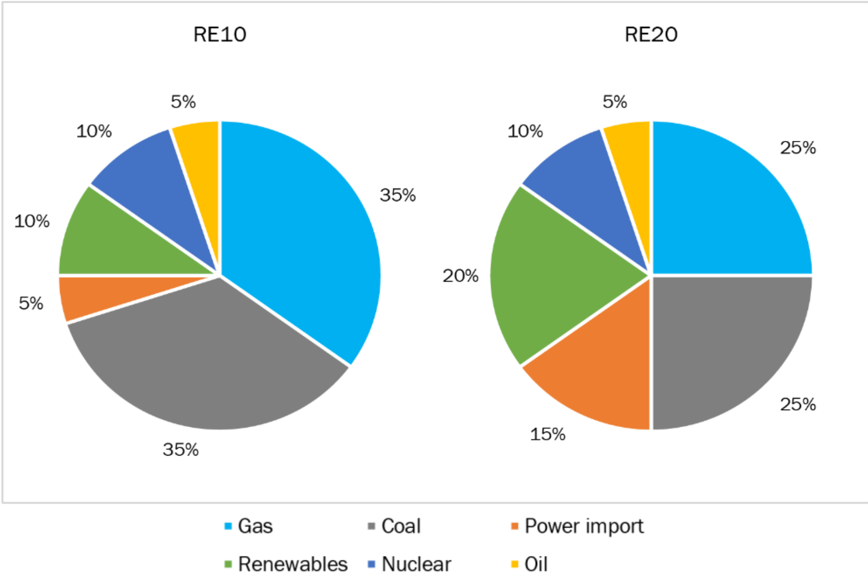


Figure 4-4: Projection of Total Electricity Consumption until 2041 (Power Division, Power System Master Plan 2016, 2016)



The PSMP 2016 analyses several possible future energy mix scenarios, having varying shares of RE. After conducting the 3E (total of economy, environment, and energy security) value analysis, two optimized cases are put forward as the best energy mixes. The projected fuel mixes for the two RE scenarios are shown in figure 4.5.

Figure 4-5: Best Energy Mixes as Proposed by the PSMP 2016 (Power Division, Power System Master Plan 2016, 2016)



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The above figure 4.5 shows that there will be a heavy reliance on fossil fuels. However, in the Section 13.2 of the PSMP, it is mentioned that even though not specified, the GOB intends to extend the 10% renewable capacity target till 2041. It also mentions that according to the latest power sector development plan of the GOB, the generation capacity of Bangladesh will be more than 56,000 MW. So, in order to meet the 10% RE target at least 5,600 MW of renewable capacity will be required. The document also indicates several challenges that lie on the path of introducing large shares of RE into the existing power systems. It also reiterates the limited land availability factor while assessing the potential for large-scale solar PV power plants in the country.

4.10 Net Metering Guidelines, 2018

In July 2018, the Power Division of the MPEMR has launched the Net Metering Guidelines-2018 that aimed to incentivize installation of rooftop solar PV systems on a massive scale (Power Division, Net Metering Guidelines-2018, 2018). The main idea behind net metering mechanism is that it allows consumers to become 'prosumers' (the consumer who also produces electricity) by connecting their RE systems to the distribution grid via a bi-directional smart meter. The prosumer consumes the electricity produced from the RE system, if there is any excess production that will fed into the grid via the net meter. The prosumers accumulate kWh credit for any excess electricity supplied to the grid after self-consumption. The kWh credit is allowed to roll-over until the end of settlement period and by the end of it, the prosumer is entitled to receive the equivalent price of net export.

Since the scheme is launched on an experimental basis and GOB does not intend to burden the distribution utilities, there is a limit imposed on the installed capacity. Also, at the preliminary stage, only three phase consumers are made eligible to adopt net metering scheme. The capacity and energy export limit of NEM system is as follows [according to revised Net Metering Guideline, 2019]:

- Any three-phase consumer can be considered eligible for the net metering system;
- A consumer can install (AC capacity of solar PV system) up to 70% of his sanctioned load;

- The maximum output AC capacity of the installed RE system for NEM can be up to 10 MW;
- For a medium voltage (MV) consumer, the installed capacity of the RE system can be a maximum of 70% of the rated capacity of the distribution transformers.

4.11 Bangladesh Environment Conservation Act

Bangladesh Environment Conservation Act (BECA) is set of laws enacted by the GOB in 1995 with an aim of conserving the nation's environment. Its main goals are to "provide for conservation of the environment, improvement of environmental standards and control and mitigation of environmental pollution" (Government of Bangladesh, 1995).

4.12 Bangladesh Delta Plan 2100

One important addition in the RE related policy landscape is the approval of Bangladesh Delta Plan 2100 in September 2018. It is the first time that GOB has ever taken up such 'a long-term strategy to prevent floods and soil erosion, manage rivers and wastes, and supply water throughout the country (bdnews24.com (Staff Correspondent), 2018). The document is important to the RE landscape from multiple viewpoints. In it, a renewed target of generating 30% of the total energy from renewable sources by 2041 has been proposed (General Economic Division, 2018).

The document also indicates significant land reclamation potential along the major river banks and in the estuary region. It speculates that the large piece of land gained by accelerating the natural reclamation process through building cross dams and other infrastructures, can be used for any preferred purposes like urbanization or industrialization.

4.13 Perspective Plan of Bangladesh 2021–2041

The General Economic Division of the Planning Commission (GOB) has published the Perspective Plan of Bangladesh 2021-2041 in March 2020 (GED, March, 2020). Chapter 8 of this long-term planning document concerns the power and energy sector. The visions set for the energy sector by 2041 include: capacity to meet the demands of a upper-middle- and high-income economy, sustained and universal access, ensure efficient supply of electricity at a globally competitive price, achieve 100% energy security, maintain consistency between environmentally safe energy production and supply, and build a nationwide pipeline network for fasters, safer and environment-friendly transportation of petroleum products.

Following these broader visions, the said document then outlines key objectives & targets and briefly discussed several strategies & policies. However, an important finding is worth discussing here. In Section 8.4, it is mentioned that "the fuel mix will need to change from excessive reliance on fossil fuel towards a balanced combination of low-cost fuel and renewable energy. More use of imported hydro and solar power from India, Nepal and Bhutan will help mitigate the domestic pressure on power production while also lowering carbon emission." In Table 8.3 of the document following the section, the fuel mix target for the year 2041 is given as: "35% gas; 35% coal; 12% nuclear; 16% import; 1% liquid fuel; 1% hydro". It is important to note that emphasis on domestic renewable power generation (excluding hydro) has not been considered in this important national policy document.

4.14 Eight Five Year Plan FY 2021 – FY 2025

In the latest Draft Eight Five Year Plan FY 2021 to FY 2025 (Commission, July 2020), there is the mention of renewable energy targets as a share of total energy. The 8th FYP has set the target for renewables including hydropower to supply 10% of the total electricity generation by the year 2025. It states that the target installed capacity by this time should be 30GW for all types of power plants. However, it shows plans for the addition of only 2.362 GW of installed capacity of modern renewable energy, and further additions would be needed to fulfil the 10% target. Moreover, the capacity factor of renewable plants are lower than that of fossil fuels, and so for renewables to supply a 10% share of electricity generation, more than 10% of the installed capacity should be renewables.

Several solar PV and wind IPP projects are mentioned in this document which are either under planning or will be implemented within the time period of FY2021–2025. The document also mentions that there is still a gap in the policy and regulatory framework concerning financial incentives and technical rules that will appear to be indispensable with the increasing grid-penetration of variable renewable energy technologies.

4.15 Observations about the policy landscape

Based on a review of the different policies concerning the energy sector in Bangladesh, the following observations are made

There are differences in the projected amounts of renewable energy share in the different policy documents. Moreover, there is a conflict of vision, as many policy documents emphasize the need to shift away from fossil fuels, but still consider large and in fact increasing shares of fossil fuels (especially coal) in the future energy mix of the country. This makes the energy mix targets inconsistent with NDC commitments, and overall intentions of a clean energy future in Bangladesh. Increasing quantities and shares of coal will inevitably increase emissions from the energy sector.

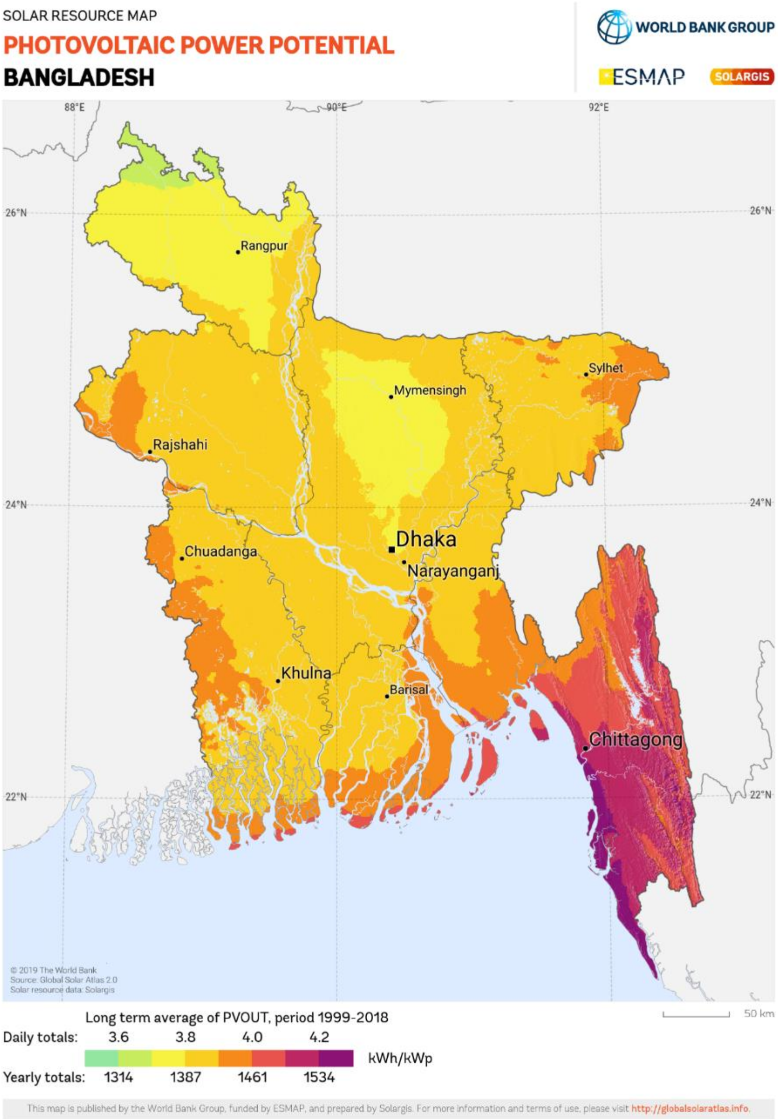
The various departments of policy making which involve energy consumptions and environmental issues should have coordinated policy making, so that the various government policies and plans are not contradictory, but can operated in a coordinated and compatible way.

5. Potential sites for establishing solar PV based power plants in Bangladesh

This chapter will provide a description of the potential for developing solar PV electricity in Bangladesh, by identifying suitable sites for them. The potential sites will be categorized according to the type of technology within solar PV.

Bangladesh has medium levels of solar energy resources, with higher intensities of solar radiation towards the south of the country (figure 5.1). The factors affecting the potential to install solar PV power plants depends on a number of factors, including solar radiation intensity, availability of land, proximity to grid connection infrastructure, and protection from natural disasters.

Figure 5-1: Solar resource map of Bangladesh (source: ESMAP)



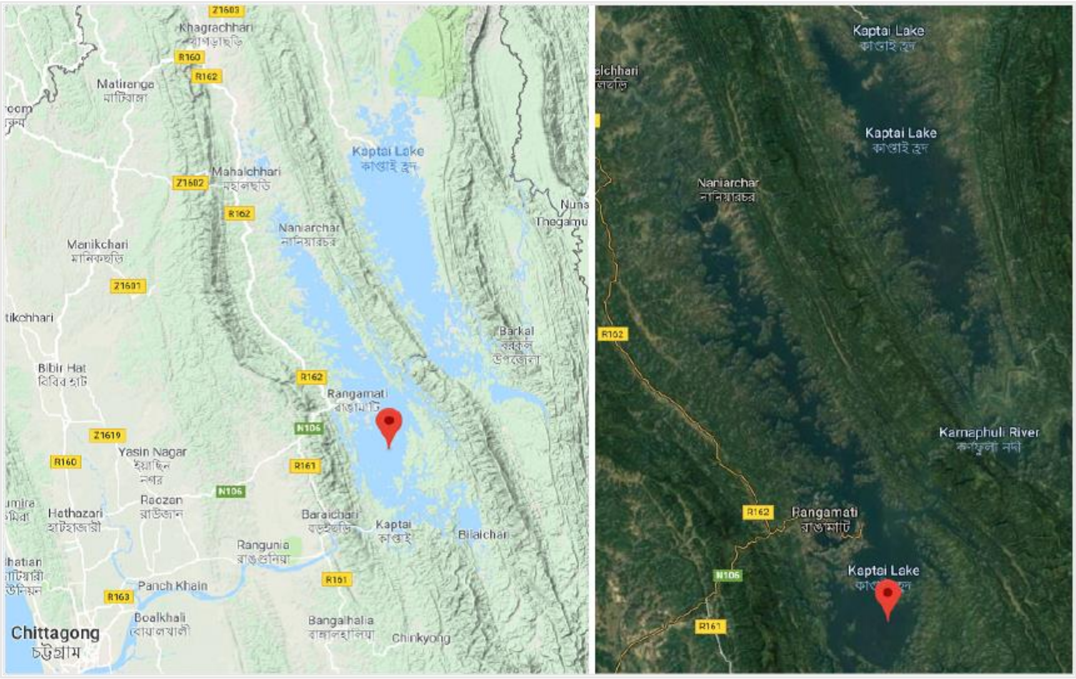
Given the resources and infrastructure availability, solar power installations can take different forms, including solar parks and solar power hubs, solar irrigation pumps and rooftop solar systems. In the following sections, there are discussions about the requirements and potential sites for such solar power plants.

5.1 Solar Parks and Solar Power Hubs

Solar power hubs are defined as clusters of solar PV power plants, with a combined capacity of at least 500 MW. The advantage of such hubs is economies of scale. The individual power plants located within the hubs' territory can be owned by either the public utilities or IPPs through a competitive bidding process. In Bangladesh, thirteen solar power hubs have been considered for development on land stretches identified, and one floating solar power hub at Kaptai lake.

Land that are considered eligible for solar power hub development should fulfill some conditions. There should be no competing use with the agriculture sector. There should be no risk of erosion and other natural disasters. There should be adequate solar radiation intensity, and the site should be near to transmission network. The process of land ownership for the power plant developer should be easy and the land should not have fragmented ownership, which will increase the transaction costs of project development. Considering these requirements, the following prospective areas are proposed for hub development.

Figure 5-2: Geographical Location of Kaptai Lake (Source: Google Maps).



Kaptai Lake: The catchment area of the Kaptai Dam is estimated to be nearly 11,000 square kilometers. The figure above (figure 5.2) shows the geographical location and the satellite view of the catchment area of the Kaptai Lake in Chattagram Division. Out of this vast area, around 750 square kilometers is a water body. If only 1% of this water surface is utilized for a floating solar power plant, nearly 500 MW of solar capacity can be installed. Even though the location is highly suitable, the transmission system should be upgraded to evacuate the generated power.

River banks and islands: Along the banks of the main rivers of the country, as well as on the low-lying river islands, there are strips of uncultivable and generally uninhabitable land. According to the Bangladesh Delta Plan 2100, some land accretion may take place under certain conditions along the major river banks from the present time up to 2035. Such potential land strips are identified and highlighted on the map in figure 5.3. If these land masses can be reclaimed, some portions of can be considered for the development of gigawatt-scale solar parks over the long term. However, these lands may be susceptible to river erosion, and far from transmission networks. Therefore, measures must be taken to develop the lands before developing solar projects.

Potential reclaimable land in Meghna Estuary: The Bangladesh Delta Plan 2100 also predicts that land accretion can take place in the southern coastal region, especially in the Meghna Estuary. **Error! Reference source not found.**5.4 shows erosion-accretion status of that region ntil 2015, while figure 5.5 depicts the potential for future land reclamation. This is one more region where large scale solar power plants may be developed, if disaster management and transmission networks can be arranged.

Khas land (land owned by the government): Khas land is government owned uncultivated land, where private property rights do not apply, and which is available for allocation as per the government's priorities. According to the list of khas land published in the Annual Report 2018-19 of The Ministry of Land (table 5.1**Error! Reference source not found.**) (Ministry of Land, 019), there are around 2 million acres of non-agricultural and uninhabitable khas land available in the country. The Government can develop these lands and make these lands ready for building solar PV projects, and the private sector can also be encouraged to develop such lands.

Protected area on both sides of Bangabandhu Jamuna bridge and Padma bridge: Vast stretches of land on the both sides of the Bangabandhu Jamuna Bridge and the Padma Bridge area are already under the river erosion protection scheme. Suitable lands from these areas can be allocated for solar PV plants.

Based on the suitability criteria and available locations, potential PV projects with estimated capacities are present in the table 5.2.

Figure 5-3: Jamuna-Padma River Stabilization Plan and Possible Land Reclamation (General Economic Division, 2018).

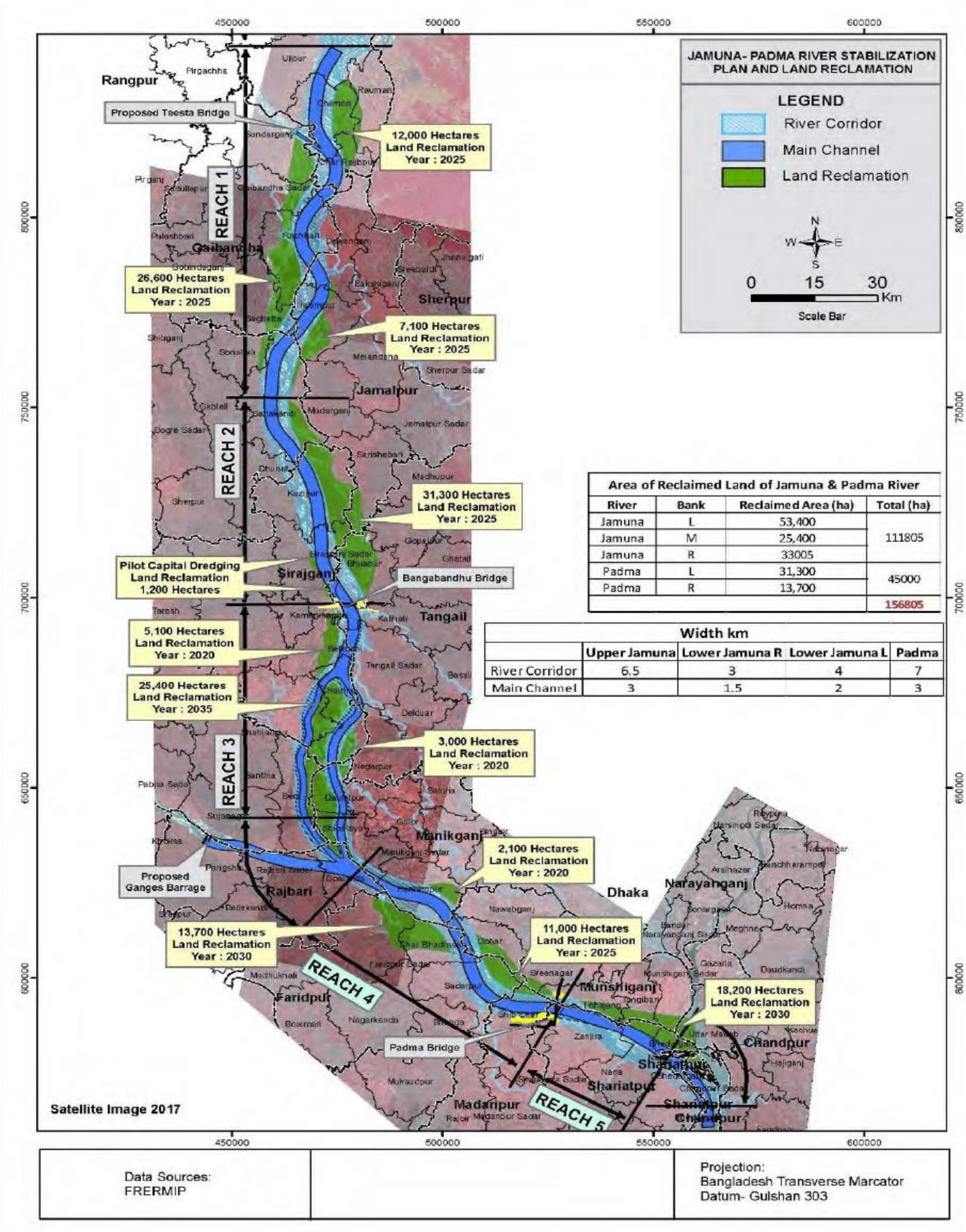
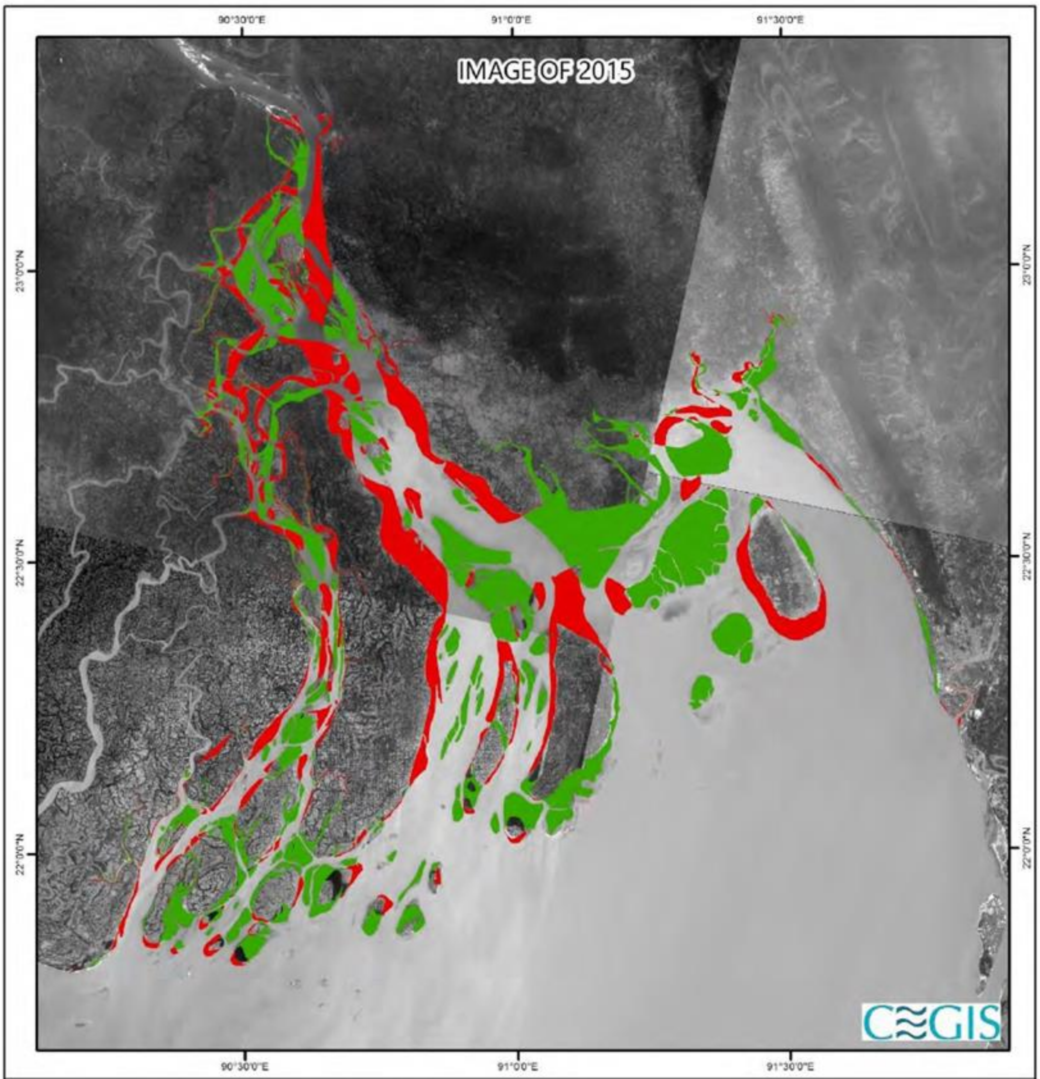


Figure 5-4: Erosion-accretion in the Meghna Estuary Area as of 2015 (General Economic Division, 2018).



Erosion-Accretion in the Meghna Estuary Area during 1973-2015

District	Erosion (km²)	Accretion (km²)	Net accreted area (km²)	Rate of net accretion (km²/y)
Barisal	169	155	-14	-0.3
Bhola	385	396	11	0.3
Chandpur	76	44	-33	-0.8
Chittagong	105	256	151	3.6
Feni	11	30	19	0.4
Lakshmipur	133	53	-80	-1.9
Noakhali	179	620	441	10.5
Patuakhali	126	230	103	2.5
Shariatpur	20	27	7	0.2
Total	**1205**	**1810**	**605**	**14.4**

Figure 5-5: Potential Land Reclamation in the Meghna Estuary Region (General Economic Division, 2018).

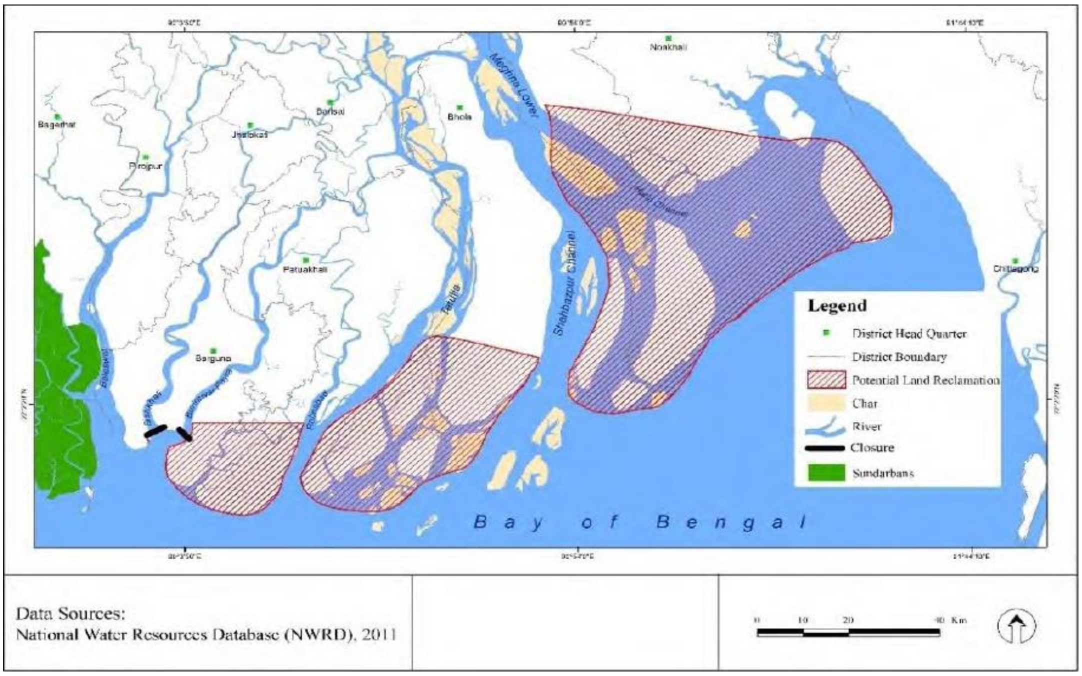


Table 5-1: Division wise Information on Khas Land of Bangladesh (Ministry of Land, 2019)

Division	Total *khas* land (acres)		*Khas* land available for settlement (acres)	
	Agricultural	Non- agricultural	Agricultural	Non- agricultural
Dhaka	179832.92	269573.44	71933.25	9600.63
Mymensingh	114821.68	91160.39	61497.78	1700.68
Sylhet	158299.95	216816.96	61871.08	13052.71
Barisal	198503.65	1616.87	23072.37	1127.70
Khulna	94501.36	132757.09	4986.28	868.79
Chittagong	756468.86	1318754.86	116077.70	90747.72
Rajshahi	111346.86	166590.57	42200.62	2672.75
Rangpur	136447.90	117303.50	73609.90	2092.40
Total	**1750223.18**	**2314573.68**	**455248.98**	**121863.38**

Table 5-2: Summary of the Proposed Solar Power Hubs.

#	Prospective location	Capacity (MW)	Land requirement (km^2) [1]	Potential land availability (km^2) [2]	Time frame

#	Prospective location	Capacity (MW)	Land requirement (km²) [1]	Potential land availability (km²) [2]	Time frame
1	Kaptai Lake *(floating solar)*	500	5	750	2021 – 2041
2	Kurigram *(Bank of river Jamuna)*	500	5	120	2031 – 2041
3	Rangpur, Nilphamari *(Bank of Teesta)*	600	6	170	2031 - 2041
4	Gaibandha *(Bank of river Jamuna)*	1300	13	266	2031 – 2041
5	Jamalpur *(Bank of river Jamuna)*	1200	12	320	2031 – 2041
6	Sirajganj *(Bank of river Jamuna)*	1200	12	317	2021 – 2041
7	Tangail *(Bank of river Jamuna)*	500	5	60	2031 – 2041
8	Rajbari *(Bank of river Padma)*	600	6	137	2031 – 2041
9	Munshiganj *(Bank of river Padma)*	500	5	110	2021 – 2041
10	Munshiganj, Shariatpur and Chandpur *(Bank of river Padma and Meghna)*	1000	10	182	2021 - 2041
11	Pabna *(Bank of river Padma & Jamuna)*	1600	16	400	2021 – 2041
12	Payra Port adjacent area [3]	500	5	-	2021 – 2041
13	Meghna Estuary	2000	20	1000	2021 – 2041
	Total	**12,000**	**120**	**3832**	**2021 – 2041**

[1] *Note: Typically, 1 km² of land is required for installing 100 MW solar PV capacity using present technology. This requirement will be lower in the future considering the higher efficient solar PV panels.*

[2] *Note: Existing non agricultural lands in river banks and reclaimed land from river banks and estuaries* (General Economic Division, 2018; Saif, 2020).

[3] *Significant land near the Payra port area were earmarked for coal based power plants development but recently the government has decided to discourage coal based power generation plants* (Editor, 2020) (Arifuzzaman, 2020) (Rahman M. M., 2020). *Some of the earmarked areas, and also other adjacent areas of Payra port (suitable for solar project development) can be used for the development of a solar power hub.*

5.2 Solar Irrigation Pump (SIP)

IDCOL aims to install 50,000 solar powered irrigation pumps by the year 2025 (Al-Matin, 2017; Rahman F. , 2015). Even if IDCOL successfully reaches the target, huge unutilized potential of the sector will remain unutilized. The SIP Draft Roadmap estimated that if all the diesel-run irrigation pumps are converted into SIP systems, the cumulative installed capacity would be nearly 4400 MW (Asian Development Bank , 2019). SIPs can be installed adjacent to agricultural lands, all over the country, and no special land demarcation is needed for this. However, the SIPs will serve the agricultural electricity demand, and may or may not be connected to the grid. The operating peak seasons of the SIPs correlate with the seasons of the country, where there is less solar radiation in the monsoon. However, SREDA reports that SIP systems in Bangladesh typically supply power for irrigation purposes for around 110 to 115 days (SREDA, Minutes of meeting to assess the progress of the RE project under Power Division (GoB), 2018). If on the remaining days, power from these systems can be fed to the national grid, significant capacity addition will be realized.

5.3 Rooftop Solar PV Systems

Rooftop solar PV systems may be installed and operated under the Net Metering System of Bangladesh. The following sites are potentially suitable for solar rooftop systems:

- Roofs of government offices with large buildings.
- The tops of buildings and structures in all Export Processing Zones and Economic Zones
- The rooftops of railway stations, platforms and adjacent land.
- The rooftops of cold storages and storage silos.
- Rooftops of garment factories, jute mills, paper mills and possibly roofs of other industries.
- Rooftops of cyclone shelter centers.
- Rooftops of civil aviation centers and land available near the airports with sufficient glare protection.
- Rooftops of public educational institutions, especially schools, colleges and universities.
- The jetties of river and sea ports.
- Tops of stadiums.

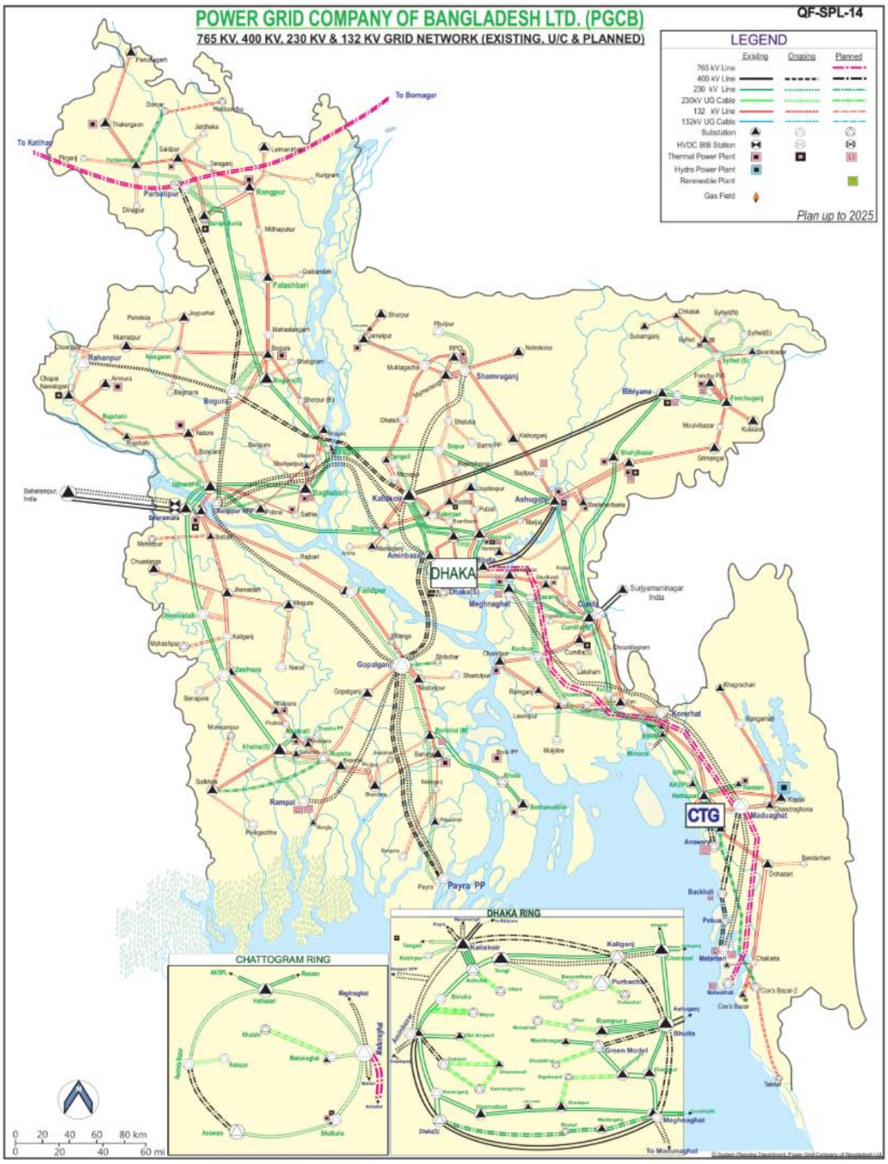
5.4 Infrastructure development for increased renewables

PGCB is in the process of formulating its long-term plan of transmission infrastructure development up to the year 2041 (table 5.3 and figure 5.6). The transmission network should be planned in a way that can connect potential solar PV power hubs.

Table 5-3: PGCB's Infrastructure Development Scenario up to 2041 (**PGCB,** *2018*).

Indicators	2021	2025	2030	2041
Overall Grid MVA	87,577	1,40,294	1,81,943	2,59,714
Dispatch Capacity (MW)	39,211	63,040	83,738	138,043
Line Length (Ckt. km)	16,242	23,659	28,507	37,057
Number of Infrastructure Projects	25	12	Under Study	
Number of Reliability Projects	01	-		
Total Number of Transmission Projects	26	12		

Figure 5-6: PGCB's Grid Extension Plan up to 2025 (**PGCB,** *2018*)



6. **A comparative analysis of potential risks associated with financing solar power plants compared to potential risks associated with financing fossil fuel based power plants.**

Investors of renewable energy projects often face a different set of risks than investors of fossil fuel projects, or the degree of risk is different for different technologies (Egli, 2020) (Tietjen, Pahle, & Fuss, 2016). Moreover, the risks of each category of technology changes over time, and as the market share of renewables becomes greater and its price decreases, it increases the risks for fossil fuel assets, especially the risk of stranded assets (Curtin, et al., 2019).

This section presents the results of a survey of investment risks related to investments in electricity power plants in Bangladesh. The survey has been conducted on power plant investors from the renewable energy sector (solar and wind) and from the fossil fuel sector (coal, gas and HFO). The investors surveyed both private and public sector entities, and the private sector entities include local and foreign companies. The results present a comparison of the perceived risks of renewable energy project investors versus fossil fuel project investors, and a comparison of private sector versus public sector entities. The risks covered have been taken from (Egli, 2020). The survey covers seven fossil fuel investors, including three from coal, two from gas and two from HFO. The renewable energy investors are nine, out of which seven are in the solar energy sector, and the other two are in wind. Although there are no running wind projects at present in Bangladesh, investors who are considering investments in wind parks in Bangladesh have been surveyed.

For each of the investment risk categories, the respondent is asked to rate the likelihood of the risk on a scale of 1 to five. If the risk is unlikely, the response is a score of 1, and if it is likely, the response is a score of 5. Next, for each of the risks, the respondent is asked to score the impact of that risk on investments, and the score can range from 1 representing low impact to 5 representing high impact. Lastly, the importance of that risk is calculated by finding the product of the likelihood score with the impact score. For example, if the likelihood of a risk is 3 out of 5, and the impact is 4 out of five, then the importance score of that risk is computed as $[(3/5)x4]=2.4$. The questionnaire used in the survey is given in Appendix 2.

After the importance score has been computed for each respondent, then the values for all respondents are averaged, according to the renewables/ fossil fuel groups. Before the survey is administered, the respondents are given a background of the survey purpose, and necessary instructions about how to fill the survey questionnaire. The identities of the respondents are kept confidential, but the industry, technology and sector categories are reported.

Following the filling of the questionnaire, the respondents are asked to elaborate about their given answers, and provide insights about their experiences in completed and ongoing projects, with respect to the given risks. Their accounts are used to provide the explanations regarding the obtained scores.

The final scores for risk importance are compared with the help of spider graphs and box whiskers plots. The following table 6.1 gives the names of the risks surveyed and their descriptions.

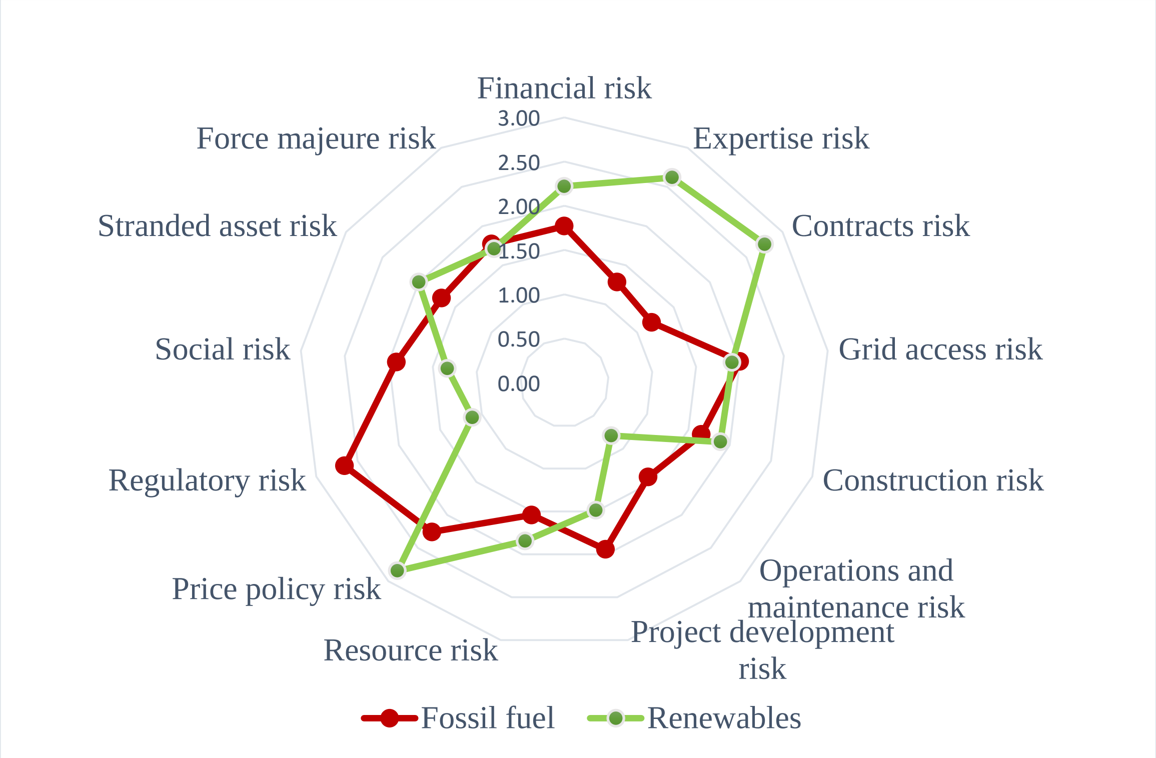
Table 6-1: Names and descriptions of risks included in investor survey.

	Risk name	Description
1	Financial risk	Financial risk refers to the availability of sufficient capital to install renewable energy or fossil fuel projects, such as equity and public financing support schemes.
2	Expertise risk	Lack of adequate expertise risks refers to the unavailability of

		experienced human resources and local knowledge and the maturity of the RE technology.
3	Contracts risk	This factor refers to risks related to the landowner agreements, engineering, procurement, and construction contracts.
4	Grid access risk	This risk concerns integrating the electricity generated from the power plant into the grid to become operational.
5	Construction risk	This risk arises from damage during transport or due to natural hazards, and unreliability of components.
6	Operations and maintenance risk	This refers to the higher operations and maintenance costs due to the novelty and unpredictability of the technology.
7	Project development risk	This refers to the revenue loss due to project delay or cancellation of the license for the commercial operation and failure to obtain all required documents to get grid access.
8	Resource risk	Resource risk refers to inaccurate resource assessment such as solar irradiation or wind speed, or fossil fuel reserves.
9	Price policy risk	This risk can arise when the policy design does not account for all revenue risks, such as price fluctuation.
10	Regulatory risk	This factor refers to the uncertainty regarding national energy strategies, such as risk increasing barriers, the involvement of independent power producers, adverse laws passed for the particular technology.
11	Social risk	This includes lack of public acceptance, public health risks from the project, and physical and economic resettlement arising from the project.
12	Stranded asset risk	Stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities. This means that the assets will become unproductive and unprofitable before the planned useful life of the asset expires.
13	Force majeure risk	These are unexpected risk events which are outside the control of all parties, and the counterparty cannot or will not fulfil their contractual obligations under these circumstances.

In the figure 6.1 below, it can be seen that in the case of some risks, renewable energy investors perceive higher risks. These are financial risk, expertise risk, contracts risk, construction risk, resource risk and price policy risk. The financial risk is obvious because renewable energy is a new technology, and ordinary commercial banks do not have the experience in this sector, and so do not easily provide long term loans for these projects. Moreover, the loan period is less than the productive life of renewable energy assets, and this is a tenure mismatch. Expertise risk is also higher as renewable energy is still a small new field in Bangladesh, and there are not many people with technical, operational or administrative expertise. Contracts risk is particularly problematic due to landowner agreement contracts, and buying up large tracts of land for solar PV projects involves a lot of paperwork with many owners of fragmented land.

Figure 6-1: Comparison of risk perceptions between fossil fuel and renewable energy power plant investors.



Construction risk is an issue because renewable energy projects are usually located in remote areas, where the communication and transportation infrastructure is not well developed. It is not easy to transport machinery and equipment over poor roads, and sometimes even roads have to be constructed to allow the transport of component parts. Resource risk is present because the actual weather often deviates from weather forecasts, resulting in less electricity generation than expected. In fact, is has been revealed that in the case of Bangladesh, the solar irradiation forecasts are based on satellite information which does not take into account the effects of lower atmosphere air pollution, which reduces radiation intensity.

Price policy risk is present because of fluctuations in exchange rates, which can change the expected cost of imported components such as solar PV panels. Stranded asset risk has been considered a risk especially from the experience of solar minigrids, where the introduction of grid connection into the mini grid areas has resulted in the loss of customers to the mini grid operators. However, this is not likely to be a problem for grid connected solar PV plants.

The perception of risks has also a lot of variation between private sector and public sector investors, as the following figure 6.2 shows. In the case of both fossil fuels and renewables, the private sector investors report much higher risk perceptions than the public sector investors. In case of fossil fuels, the greatest difference in perceived risk among private investors are in social risk, regulatory risk, financial risk and project development risk. The financial risk is higher naturally because the investors invest their own equity. Regulatory risk is higher because private sector investors do not make regulations in their own favour, and can face adverse changes in regulations. Project delay risks impose a greater penalty for private investors. Renewable energy private sector investors face higher levels of risk in almost all aspects, but markedly in case of force majeure, financial risk, expertise risk, contracts risk and stranded asset risk. This is because of the fact that public sector projects are often funded by public sector budgets, and are underwritten by the government, and do not convey the same degree of liability. Contracts risk are higher here because private investors have to manage their own project land, whereas public sector investors often use land already under the control of the government. Stranded asset risks can be higher if the renewable power plant cannot compete with any cheaper source of electricity.

Figure 6-2: Variations in risk perceptions among private and public sector fossil fuel and renewable energy investors

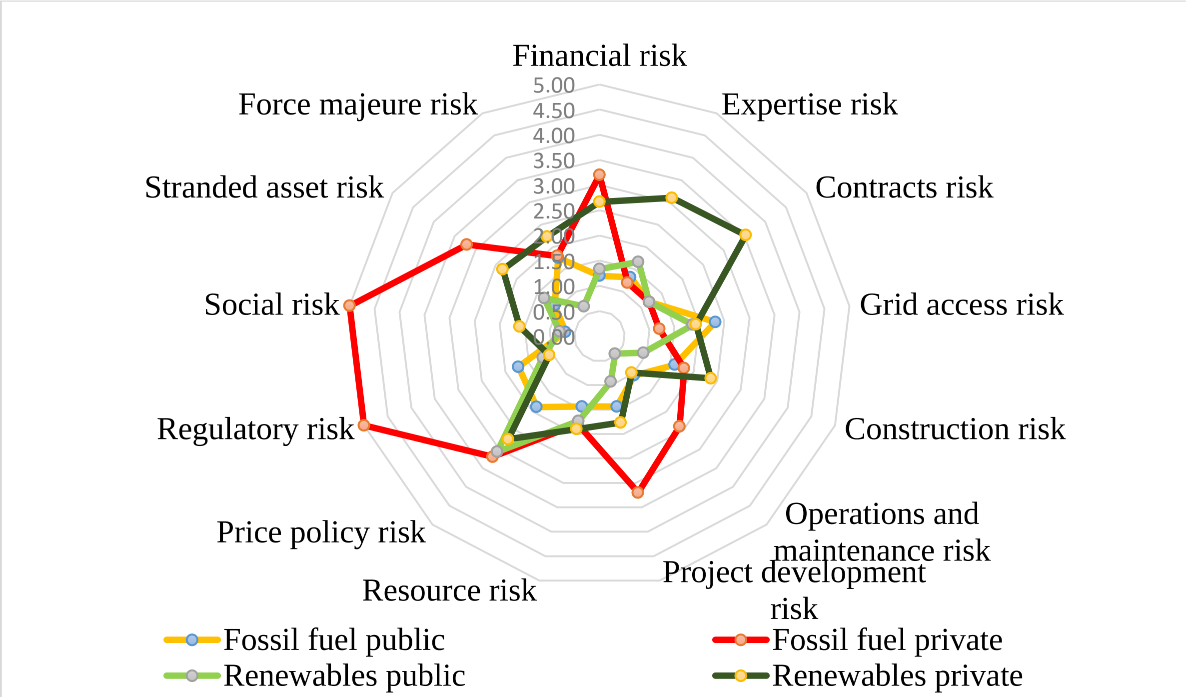
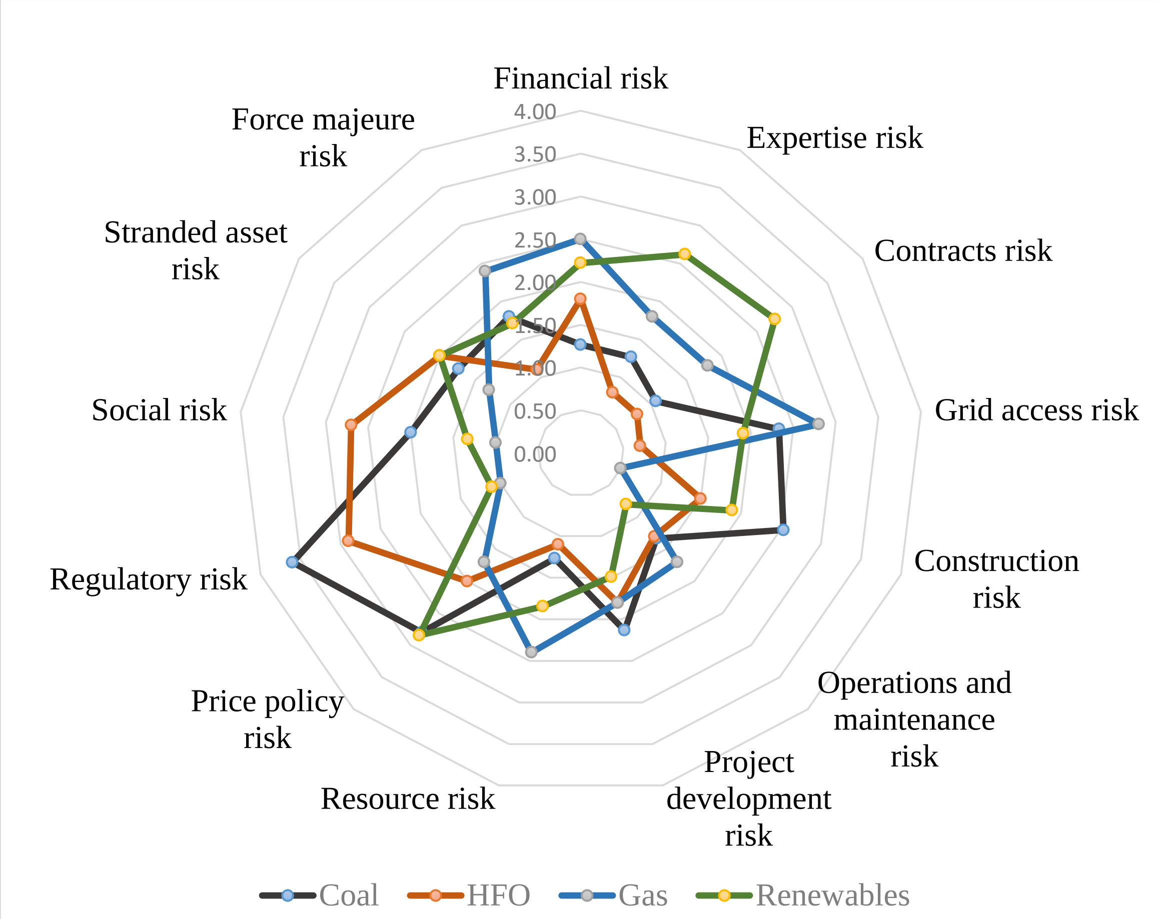


Figure 6-3: Variations in risk importance perceptions among renewable energy investors and investors of different fossil fuel based power plants.



Further insights can be obtained by comparing the risk importance perceptions of renewables investors with investors from different types of fossil fuel based power plants (figure 6.3). Although the previous analysis has shown that renewables face more challenges and risks in many cases, not all fossil fuel based plants have the same advantage over renewables. It can be seen that with respect to regulatory risk, construction risk and project development risk, coal plant investors fare the worst. This is because although many of the national policy documents (PSMP, NDC, 8th Five year Plan etc) project increasing levels and shares of coal based installed capacity, the existing coal based projects have faced many challenges. First of all coal plants have opposition from various stakeholders on environmental grounds. Many international donors and financiers do not provide funding for coal plants, and so plans for several coal plants had to be cancelled in the past years in Bangladesh. This leads to delays or cancellations in project development. Moreover, coal plants have to be accompanied by coal supply infrastructure, which increases construction risk. Gas plants face the highest resource risk, because although gas is the cheapest fuel at present, the domestic reserves of gas are declining and will potentially affect supplies of gas to the power plants in the future. As gas is the leading fuel for electricity generation in the country, any disruption in supply due to domestic or international events can cause force majeure risk and financial risk.

The following figures 6.4 and 6.5 show the risk perception comparison between fossil fuel investors and renewable energy investors. It can be seen that the median risk probability perception of renewable energy investors is sometimes higher, but the range of values are also greater (figure 6.4). That means there are more investors who consider the probability of some risks to be very high (financial risk, expertise risk, contracts risk, construction risk), whereas risk probability perception is considered very high by fossil fuel investors in only three cases (price policy risk, regulatory risk and social risk).

Figure 6-4: Box plot representation of risk probability perception distribution, fossil fuel versus renewable.

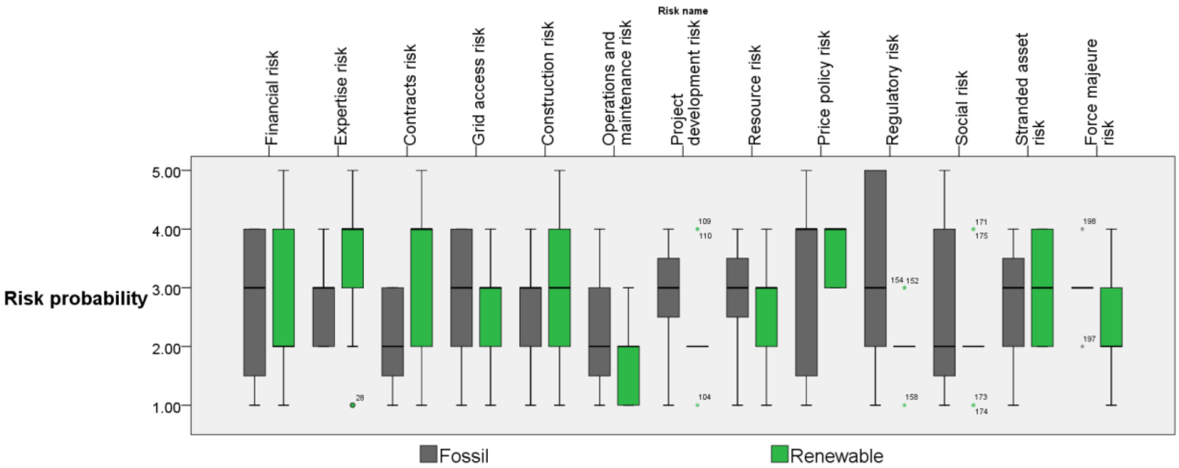
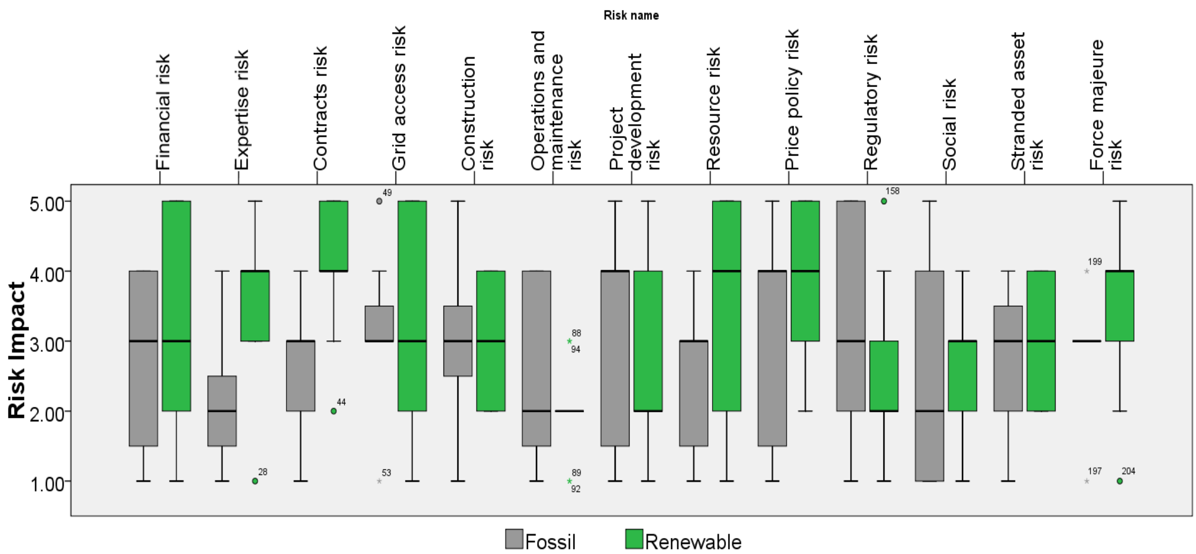
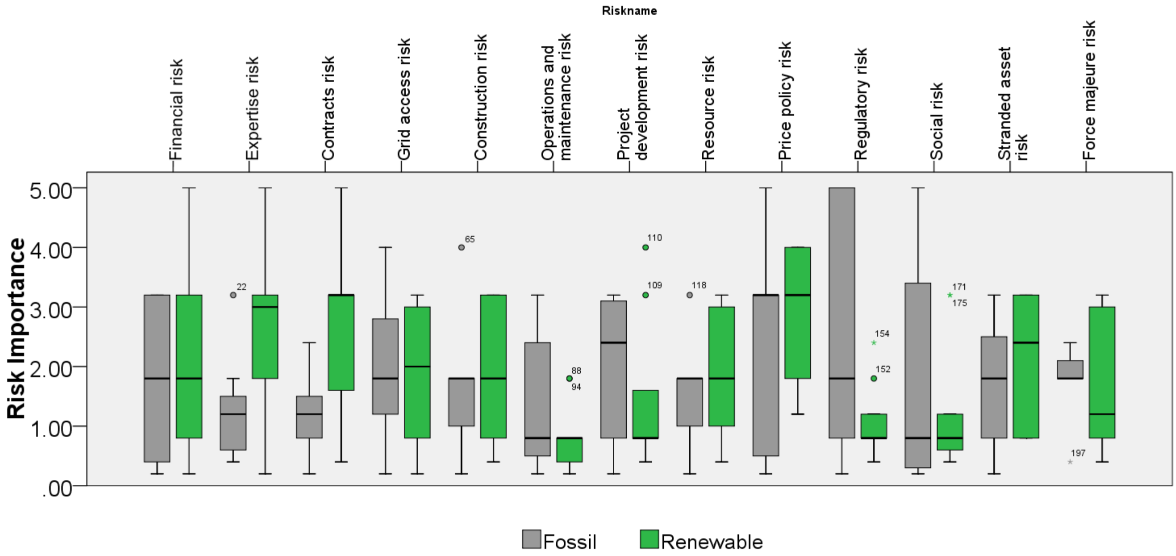


Figure 6-5: Box plot representation of risk impact perception distribution, fossil fuel versus renewable.



With respect to the perceived impact of risks (figure 6.5) it can again be seen that there are more respondents from the renewable energy group who report that the impact of the different risks are very high. High impact is reported by numerous fossil fuel investors in only regulatory risk.

Figure 6-6: Comparison of the importance of different risks as perceived by renewable energy versus fossil fuel investors.



When the overall importance of the risks are compared, high level outliers are prevalent again among renewable energy investors (figure 6.6). However, the overall importance of some risks are considered to be relatively low among renewable energy investors. These risks are operations and maintenance risk, project development risk, regulatory risk and social acceptance risk. It can be inferred from this that renewable energy projects are easier to operate once they are set up, because there is no issue of fuel supplies, and the equipment is more modern and reliable, needing less human resource and monitoring for management. They also feel that renewable energy is acceptable among regulators and the public based on their environment friendliness.

It can be summarized that the renewable energy projects can compete with fossil fuel projects with the help of adequate policy support. It has been seen that public sector renewable energy project developers believe they face lower risks than private sector fossil fuel investors. This is because public sector investors face fewer uncertainties with respect to financial and regulatory matters. This indicates that with adequate policy support, renewable energy investors from the private sector can be encouraged to invest more in projects.

7. An estimate of the amount of funds that can be used more efficiently by investing in solar powered plants, having provision for scenarios with and without storage.

At present, the bulk of electricity generation is based on fossil fuels in Bangladesh. However, even now, not all fossil fuels are the cheapest option. A summary of losses from power plants of different fuels in Bangladesh are shown in the following table 7.1.

Table 7-1: Fuel wise patterns of loss among power plants in Bangladesh (Chowdhury S. A., 2022).

Plant characteristics	Natural gas	HSD	HFO	Coal
Total number of plants	60	11	56	3
Installed capacity of plants (GW)	10.97	1.33	5.591	1.146
Number of loss making plants	8	11	56	3
Installed capacity of loss making plants (GW)	1.581	1.33	5.591	1.146
Total loss of loss making plants (Billion BDT)	6.67	23.97	95.43	5.67
Loss range of these plants (BDT per kWh)	0.03 to 5.56	21.74 to 962.21	5.42 to 266	0.93 to 4.28
Annual generation of loss making plants (GWh)	3,657	139.45	9,461	2967
Ownership of loss making plants	2 public, 6 private	5 public, 6 private	12 public, 44 private	All are public

An inspection of the thermal power plants in Bangladesh shows that some natural gas based power plants are operating at a loss. However, all the HSD, HFO and coal based power plants operate at a loss. The loss making pattern of the power plants also varies by ownership and function (base load versus peaking) (table 7.2). It can be seen that losses are more prevalent in the private sector power plants and in peak load plants. In Bangladesh, most of the peak load power plants are based on liquid fuels, which are very expensive. The range of loss can be quite high, up to Tk 962 per kWh (USD 10.12). Even among base load plants, the highest loss per kWh is Tk 605 (USD 6.27). There is a plan to phase out HSD plants in the coming years, but HFO plants are still going to be in the energy mix for the medium term. Among 56 HFO plants, the losses range from Tk 5.42 to 266 per kWh (0.057 to 2.8 USD). Out of these, 38 have losses per unit of over 10 US cents, comprising 3456 MW of installed capacity, generating 4202 GWh of electricity. A simulation based analysis of grid flexibility of Bangladesh (DOE, 2021) has shown that even if Bangladesh does not invest in storage or transmission facilities for the near future for upto 2030, increasing the share of solar PV will still provide the least cost option for the electricity mix. The highest level of renewable energy that can be integrated into the system without significant loss of load, excess load, reserve inadequacy, insufficient inertia, model leakage or spillage, is up to 19% of electricity generation, and the levels of curtailment in this scenario are still cost effective for the grid.

Table 7-2: Ownership and function wise patterns of loss among power plants in Bangladesh (Chowdhury S. A., 2022).

Plant characteristics	Public	Private	Base load	Peak load
Total number of plants	45	76	45	107
Number of loss making plants	21	58	10	85
Total loss of loss plants (Billion BDT)	26.7	102.7	21.96	120.48
Loss range of loss plants (BDT per kWh)	1.45 to 751	0.04 to 962	0.36 to 605	0.04 to 962

Installed capacity of loss plants (GW)	2.280	6.461	2.4	7.569
Annual generation of loss plants (GWh)	3,96	11,414	8940	11,359
Function/ ownership of loss plants	4 are base load	1 is base load	40 public, 1 private, 4 import	17 public, rest private

8. Mapping of potential private sector entities who can show interest in investing in solar powered power plants in Bangladesh.

The type of private sector entity which can invest in solar power plants in Bangladesh depends on the type of PV project. In Bangladesh, SREDA has classified the types of solar power capacity into four categories- large scale solar PV parks, solar rooftop projects connected to the grid through net metering, solar rooftops without net metering connections, and solar irrigation pumps (SREDA, 2022).

Table A6 in the appendix lists the companies which have received LOI for implementing Renewable Energy projects in Bangladesh, among which most are based on solar PV. These projects are ground mounted large scale solar PV parks, which are utility scale and grid connected. A review of the companies shows that in theory any company which can set up a suitable consortium is able to apply for a project. The project development is carried out by a consortium consisting of a lead partner and an operating partner. The lead partner has a majority share, and must have experience raising equity financing and debt financing for similar projects. The operating partner should have operating experience for such projects for a minimum of two years. However, although it is feasible to have local companies which can raise debt and equity financing, it is difficult for local companies to have much operating experience, because solar PV parks are relatively new in the country. Therefore, local companies compensate for their lack of experience by forming consortiums or joint ventures with more experienced foreign firms. There are so far eight ground-mounted IPP projects currently running in Bangladesh, out of which two are public-owned, and the rest are private. Among the private projects, five have local lead partners, and only one has a foreign lead partner. The lead partner has to have at least 51% of the project up to COD, and after that must own at least 40% for the first six years of operation. The operating partner has to own at least 20% of the project for the first 6 years after COD. These are bindings which many local and foreign companies find difficult, as it is not according to international practices. Usually, in the international business scenario, a developer company creates a project and immediately sells it to another company and does not retain any shares. This allows the developer to recover their investments. The restrictions in Bangladesh make it difficult for them to do so.

When the acceptance of the LOI takes place, the project developer must make a proposal security deposit for the project within a week, which amounts to USD 5000 per MW at present. The developer must also make a performance security deposit, amounting to USD 18000 per MW, before the signing of the PPA, though the amount will be later refunded. This indicates that the project developer should have sufficient funds for this.

The developer should complete the lengthy process of the procurement of land and all land related due diligence. This implies that the developer company should have some skills and resources to manage and obtain large tracts of land. Considering this, it can be suggested that companies which are in the business of land management may be suited to the solar PV park business. In Bangladesh, there are numerous companies which are in the land and real estate business. There are companies which purchase fragmented tracts of rural or suburban land, do necessary land development, and then sell residential and commercial plots in those real estate projects. These projects can involve hundreds of acres. These companies have the skills and resources for land procurement, and can consider venturing into the solar PV park development sector.

Alternatively, there are some companies which already own or lease large tracts of land for their other core businesses. For example, there are companies in the agri business, or which own tea gardens, and they already own or lease vast quantities of land. They can apply their experience or expertise to develop solar PV projects.

The figures 8.1 and 8.2 below show the modes of financing for solar PV parks in Bangladesh, among the projects that are already running, and those under construction. It can be seen that the unsolicited IPP is the most common mode of financing, and donor funding has supported only two projects so far. IPPs are also the mode of financing for the ordinary conventional fossil fuel based power plants. Given that fossil fuel based power plants have experience in the bidding and financing process, it can also be recommended that conventional fossil fuel power plant companies venture into the renewables sector, as renewables are more likely to be financially viable and competitive relative to fossil fuels in the future.

Figure 8-1: Financing sources of solar park completed projects, by number and installed capacities.

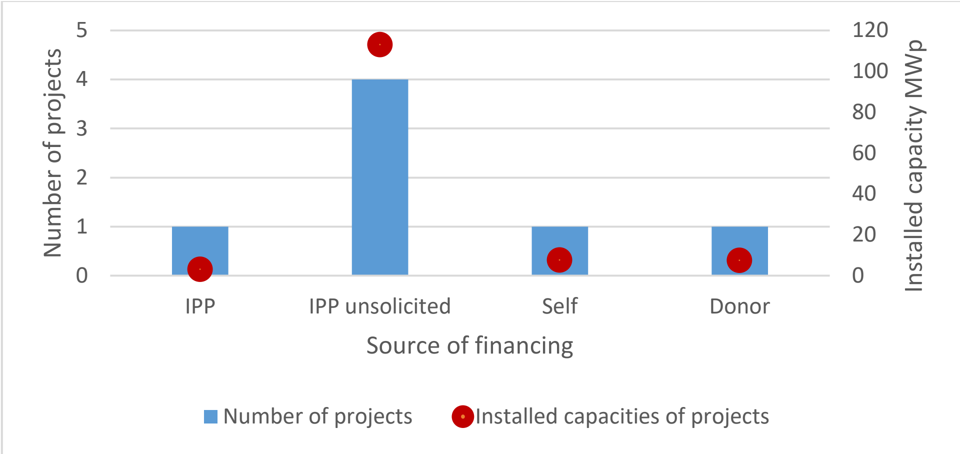
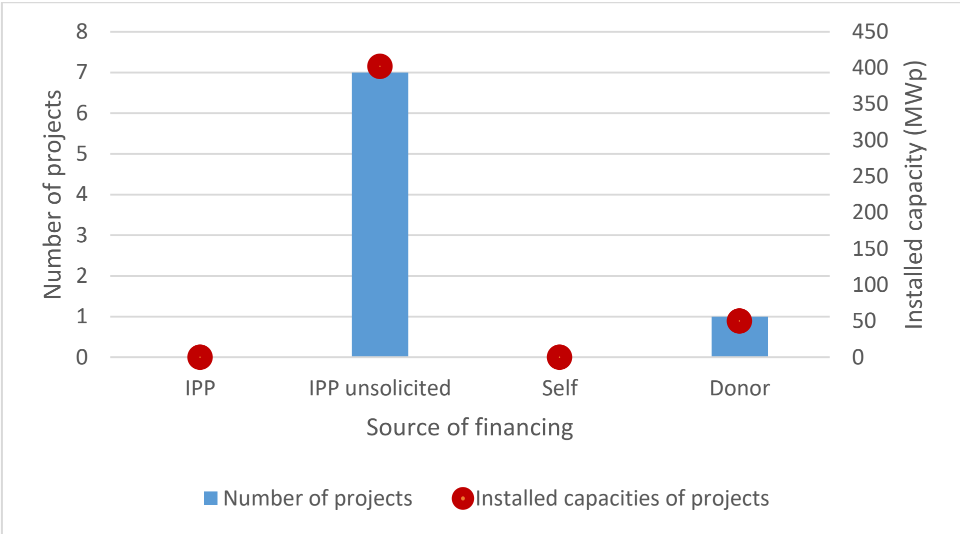


Figure 8-2: Financing sources of solar park projects under implementation by number and installed capacities.



Bangladeshi companies can also invest in large scale industrial solar rooftop projects in the MW range. Such a project has already started running in the Korean EPZ, which has a capacity of 16MW leading to 40 MW. This shows that companies which have extensive industrial plants and factories with large rooftop spaces can overcome the limitations of land and use their existing spaces. This salutation has many advantages, including not requiring the purchase of land, avoiding associated paperwork, and having territorial control over the project. Land development costs are avoided, as well as social opposition issues. Moreover, these projects can allow the developer company to have self-consumption, and sell surplus electricity to the grid. Industry accounts for 28.4% of the electricity consumption of the country (BPDB, 2021). Most of the solar rooftop systems are self-financed (SREDA, 2022).

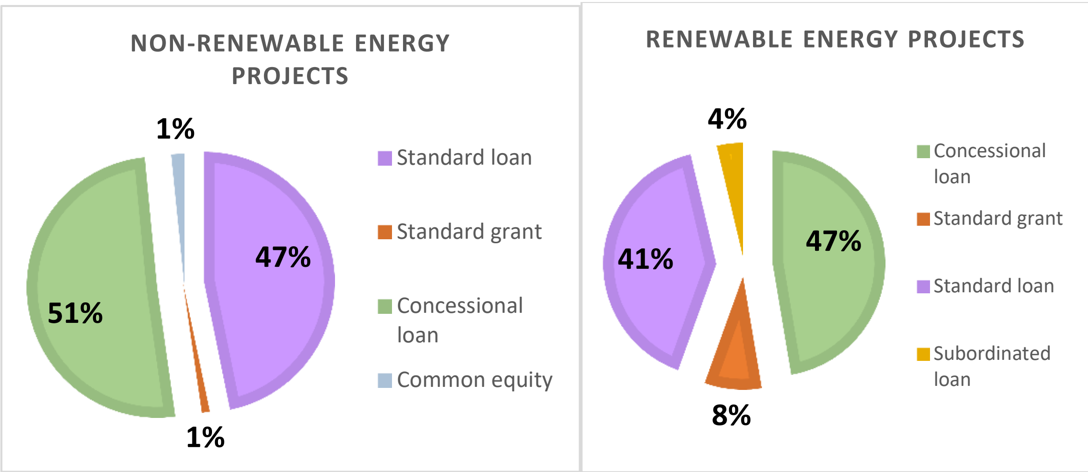
Lastly, solar irrigation pumps can be installed by farmers in their own agricultural fields. Usually, IDCOL is the biggest financier of these solar pumps, followed by the government (SREDA, 2022). They are popular and technically easy and cost effective. The advantage here is that the farmers can install them in their own fields, and so there is no need to manage large tracts of land. Moreover, it is not seen as infringing on agricultural land, which is usually protected from other types of use. Although each solar irrigation pump is of a small scale, if the entire irrigation needs of the country were sourced from solar PV, it would add up to many MW, as agriculture accounts for 2.43% of electricity consumption in the country (BPDB, 2021).

9. Mapping of potential IFIs support (possible European first: EIB, AFD, kfW, etc), EU member states, while gathering the sources and specific area of interest.

In the public financing database of IRENA, there is a list of all the international donor agencies which fund renewable energy projects in developing countries (IRENA, 2022). There are over two hundred organizations or entities which finance different types of renewable energy and non-renewables projects. Some funding organizations have a regional focus, whereas some have a focus on particularly technologies. Out of these, in the period between 2000 and 2019, there have been around thirty eight agencies which have invested in renewable energy and non-renewable energy projects in Bangladesh.

If there is a comparison of the donor list in Bangladesh to peer group countries like Vietnam, Vietnam received financing from fifty four agencies in this time period. However, Thailand received funding from thirty four agencies. In the period from 2000 to 2019, Bangladesh has received USD 1851 million for renewables from these agencies. Total investments to renewables in Thailand have been USD 953.38 million in this period, and USD 2,433.43 to Vietnam. Therefore, it can be seen that Vietnam attracts more investments.

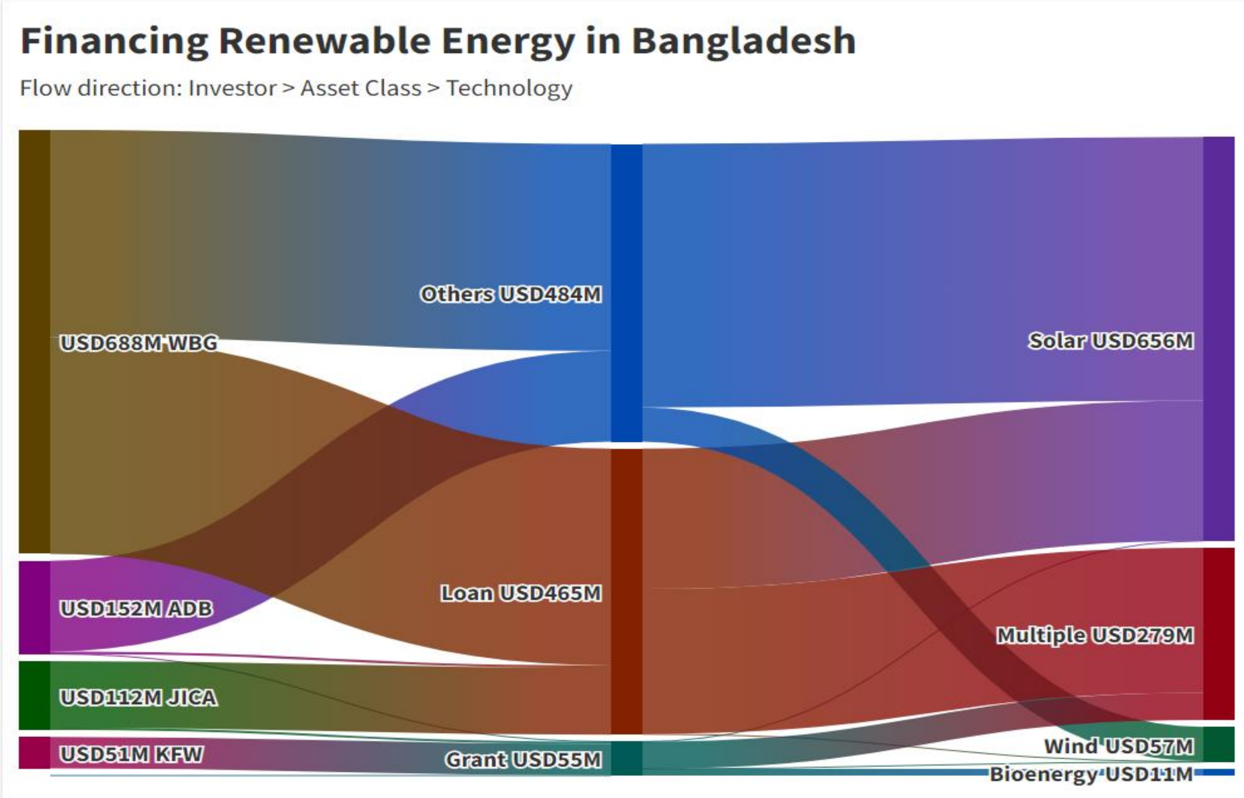
Figure 9-1: Financing composition of non-renewable energy projects (left) and renewable energy projects (right).



It can be seen that renewable and non-renewable projects both receive most of their financing in the form of standard and concessional loans, with concessional loans exceeding standard loans to some extent (figure 9.1). However, the amount of grants in non-renewable projects is marginal, whereas in renewable projects grant amounts are more significant. Moreover, there are no equity investments in renewables projects from overseas agencies.

The following Sankey diagram (figure 9.2) shows the pattern of flow of funds to renewable energy projects in the country. It can be seen that the bulk of the money goes to solar PV projects, with wind and bioenergy receiving a small share of funds. The biggest financier is the WBG, followed by ADB, JICA and KFW. In the period from 2000 to 2019, Bangladesh has received USD 1.851 billion in financing, in the form of standard grants, standard loans and concessional loans. However, the total funding to Bangladesh in all energy projects including non-renewable fossil fuel projects and nuclear energy in the same period is USD 10.855 billion. Therefore it can be seen that the fossil fuel sector has so far enjoyed more investments. The following figures shows a comparison of the financing forms for renewable energy projects versus conventional energy projects.

Figure 9-2: Flow of funds into the renewable energy sector in Bangladesh.



The figure 9.3 shows the pattern of flow of public funds to the energy sector in Bangladesh. It can be seen that the absolute amount of funds has been increasing exponentially. However, the share of funds to non-renewables has been increasing at a higher rate than the funds allocated to renewable energy projects. The largest investments in non renewables took place in 2016, as there were massive investments in the Payra and Materbari fossil fuel power plants. The Materbari power plants have again received massive investments in 2018 and 2019. The same donor organization contributes funds to non-renewable and renewable energy projects. However, the non-renewable energy projects often receive more funds. For example, JICA has so far contributed USD 3.392 billion to non renewable energy projects, and only USD 144.68 million to renewable energy projects.

Figure 9-3: Investment flows to renewable and non-renewable energy in Bangladesh (2000-2019)

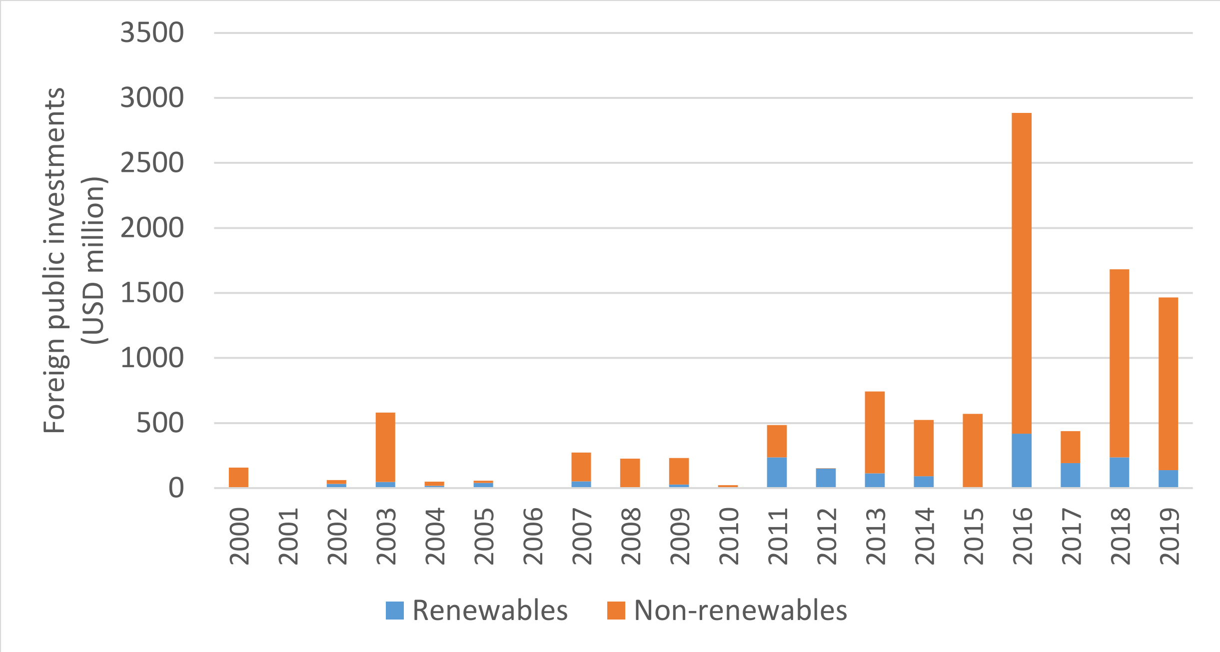


Table 9-1: Investment categories from major investors/donors to Bangladesh energy sector (million USD).

	JICA	ADB	IFC	IDA	KfW
Non-renewables	3,391.98	1,198.16	336.83	808.87	73.68
Renewables	144.68	157.74	418.08	574.64	123.1821

From the above table 9.1, it can be seen that the two largest donor organizations JICA and ADB invest much more in the non-renewable sector in Bangladesh than in renewables. Although the World Bank group (IFC) and KfW invest proportionately more in renewables, their investment amounts on the whole are small. Ironically, the International Development Association (IDA) of the World Bank Group invests more in the non-renewable sector in Bangladesh. Moreover, one of the recent major investors, the Ex-Im Bank of China, invested USD 2,085 million in the Payra coal plant in Bangladesh, but has no investments in renewables projects at all.

It can be surmised that domestic policy is required to direct international investors to prioritize renewable energy projects. This is not only for environmental reasons, but also because fossil fuel technology is becoming obsolete and economically uncompetitive with renewable energy. Moreover, allowing the construction of fossil fuel assets may impose some stranded assets in Bangladesh, as these projects may have to be run at a higher cost than the future cost of renewable based electricity.

10. Recommendation for intervention

Based on the different analyses conducted in the study, the following recommendations are proposed. These recommendations cover funding, guarantee, advocacy etc. on the part of the EU with different set of stakeholders- government, private investors, banks and financial institutions.

i. As technological and energy market realities change at a fast and unpredictable rate, Bangladesh should not commit itself to significant levels of fossil fuel capacity in preparation for the coming decades. This is because renewables can become more cost effective than fossil fuels before the useful life of the fossil fuel power plants is over, resulting is stranded assets. Alternatively, fuel prices can increase unpredictably, or supplies can be restricted, making operating fossil fuel based power plants impractical or unprofitable.

ii. There should be greater dissemination of the science and accounting of greenhouse gas emissions among policy makers in Bangladesh. This will result in more coherent policy making by regulators. The different stakeholders should understand how GHG emissions arise from energy use, especially electricity generation, and how the fuel mix plays a part in this. This is necessary to create consensus about effectively reducing emissions in order to take the country on the path to net zero carbon emissions.

iii. The high costs of coal, natural gas and other fossil fuels in the international markets not only increase the cost of energy production but also impose a serious burden on foreign exchange reserves, and affect the balance of payment of the country. Therefore, there should be emphasis on expanding the use of renewables for commercial and economic reasons. Ways should be explored to shift investments more effectively into clean energy solutions.

iv. The global scenario is rapidly changing, and the share of renewables in the energy mix across the world is increasing. Renewables are securing more annual investment when compared to fossil fuel capacity. The reasons are obvious—the pressing need for energy security and the risk posed by climate change. Already, renewable energy sources specially the solar photovoltaic, have become financially competitive with fossil fuels in many jurisdictions, and in the future, will become cheaper than any fossil fuel-based energy. Cheaper power from renewables will be the chief driving force in the energy industry. Therefore, like many other countries, Bangladesh should also adopt ambitious renewable energy targets. Since the country has a rationed amount of land, the decisions about land allocation should be prudent. Accordingly, special emphasis should be put on the solar rooftops and the solar irrigation sector.

v. Bangladesh is a land scarce country and one of the most densely populated country of the world so for development of large scale solar PV project is difficult to realize unless vast stretches of land can be made available for large scale solar PV project development. As three of the world’s main rivers flows to the bay through Bangladesh and it carries a lots of silts and every year Bangladesh is gaining on an average 30 sq. km of land. The prospect of future land accretion along the banks of the main rivers of the country and land reclamation at the Meghna Estuary as per the Bangladesh Delta Plan will be one of the most important factors. Moreover, the mere reclamation or accretion of land by itself will not prove to be sufficient. The subsequent land development and disaster (erosion, flood, etc.) protection measures will play equally important roles.

vi. The qualification criteria for the development of large-scale solar PV projects in Bangladesh should be made more flexible and hassle-free. Solar PV power plants are relatively easy to operate. At present, requirements like having operating experience and the operating partner to own a 20% share in the project until the 6th year of CoD, etc. are preventing local developers from developing projects. The operating experience can be relaxed by imposing O&M contracts with an experienced O&M contractor. At present, the lock-in period for the investor (the lead partner) and operating partner is at least until the 6th year of operation of the plant. This hinders many developers from being interested to invest in Bangladesh. Typically, the project developers are interested to develop a project and immediately after the CoD, want to sell it to potential buyers.

So, the lock-in period should be relaxed and the exit policy for the investors or project developers should be made easier to attract more investors in this sector.

vii. The policy for the energy sector must become comprehensive and well-coordinated, so that the various objectives of energy generation, such as universal electricity access, clean energy transition, and the smart grid transformation plan, all work in tandem. The capacity addition in solar energy should be coordinated with the capacity addition or retirement of fossil fuel plants in order to avoid duplication or wastage of resources. Provisions must be made for the monitoring of projects over the entire lifetime, so that stranded assets are not created due to technological obsolescence of long-lasting projects in a highly technologically evolving industry.

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Appendix 1: Thermal power plant retirement schedule

Table A1: Gas based power plants to be retired by 2030

Name of Power Station/ Location	Ownership	Retirement Date (DD/MM/YY)	Installed Capacity (MW)	Age at Retirement Date (yrs)
Ashuganj 150 MW ST4	Public	5-Apr-2022	150	35
Ghorasal 210 MW ST unit4	Public	30-Jun-2022	210	REP
Sylhet 20 MW PP	Public	30-Jun-2022	20	36
Haripur 32 MW GT1	Public	30-Jun-2022	32	35
Baghabari 71 MW GT	Public	30-Jun-2022	71	31

Fenchuganj 91 MW CCPP (GT1)	Public	30-Jun-2022	32	28
Fenchuganj 91 MW CCPP (GT2)	Public	30-Jun-2022	32	27
Fenchuganj 91 MW CCPP (ST)	Public	30-Jun-2022	33	27
Bhola 80 MW Q. Rental PP (3 Years, Aggreco)	Private	17-Mar-2022	95	11
Bhola 3 Years RPP (Venture)	Private	11-Jul-2022	33	13
Bogra 3 Years RPP (Energy Prima)	Private	12-Nov-2022	20	11
Summit_Ashulia_2nd Phase(REB)	Private	3-Dec-2022	34	15
Summit_Chandina_2nd Phase(REB)	Private	14-Nov-2022	14	16
Summit_Madubdi_2nd Phase(REB)	Private	15-Dec-2022	24	16
Ashuganj 150 MW ST5	Public	21-Mar-23	150	35
Shazibar 2x35 MW PP	Public	25-Oct-23	70	23
Ashuganj 55 MW 3 Yrs RPP (Precision Energy)	Private	6-Apr-2023	55	13
Bogra 15 Years RPP (GBB)	Private	16-Jun-23	20	15
Summit_Chandina_1st Phase(REB)	Private	31-Aug-2023	11	20
Summit_Madubdi_1st Phase(REB)	Private	31-Aug-2023	11	20
Summit_Ashulia_1st Phase(REB)	Private	31-Aug-2023	11	20
Tangail SIPP (Doreen)	Private	11-Nov-23	22	15
Haripur 360 CCPP	Private	30-Nov-23	360	22
Narsindi SIPP (REB)	Private	20-Dec-2023	22	15
Baghabari 100 MW GT	Public	24-Nov-24	100	23
Hobiganj SIPP (REB)	Private	9-Jan-2024	11	15
Shahjibazar 86 MW PP (15 Yrs RPP)	Private	9-Feb-2024	86	15
Feni SIPP (Doreen)	Private	15-Feb-2024	22	15
Ullapara SIPP (REB)	Private	1-Mar-2024	11	15
Kumkargoan 50 MW PP (15 Years RPP) (Desh Energy)	Private	17-Mar-2024	10	15
Feni SIPP (REB)	Private	24-Apr-2024	11	15
Mouna, Gazipur SIPP (REB)	Private	11-May-2024	33	15
Barobkundo SIPP (Regent Power)	Private	22-May-2024	22	15
Rupganj , Narayanganj SIPP (REB)	Private	8-Jun-2024	33	15
Jangalia, Comilla SIPP (Summit)	Private	24-Jun-2024	33	15
Fenchuganj 15 Years RPP (Barakatullah)	Private	23-Oct-2024	51	15
Raozan 210 MW Unit-1	Public	30-Jun-25	210	32
Raojan 210 MW Unit- 2	Public	30-Jun-25	210	28
Tongi 105 MW PP	Public	27-Mar-2025	105	20
Ghorasal 210 MW ST 5	Public	30-Jun-26	210	32
Ashugonj 50 MW Engine	Public	29-Apr-26	45	15
Meghnaghat power Ltd. (450 MW)	Private	25-Nov-2026	450	24
Shajahanullah Power Com. Ltd. (REB Mer)	Private	10-Jan-28	25	15
Ashugonj 51 MW IPP (Midland)	Private	06-Dec-28	51	15
Ghorasal 108 MW IPP (Regent Power)	Private	15-Jul-29	108	15
RPCL (Mymenshing) 210 MW CCPP	Private	18-Jul-29	210	30
Shikalbaha 150 MW PP	Public	17-Aug-30	150	20
Ashugonj 195 MW Modular PP (United Power)	Private	07-May-30	195	15
Total			**3924**	

Table A2: HFO based power plants to be retired by 2030

Name of Power Station/ Location	Ownership	Retirement Date (DD/MM/YY)	Installed Capacity (MW)	Age at Retirement Date (yrs)
Amnura, Chapainawabgonj Q.RPP (Sinha Power)	Private	12-Jan-22	50	10
Julda, 100 MW Q.RPP (5 Years, Acron Infra Service)	Private	25-Mar-2022	100	10
Keranigonj 100 MW Q.Rental PP (Power Pack)	Private	26-Mar-22	100	10
Katakhali 50 MW Q. Rental PP(NPSL)	Private	21-May-22	50	10
Natore 52 MW IPP (Raj-Lanka)	Private	23-Jan-29	52	15
Baraka-Potenga 50 MW IPP	Private	03-May-29	50	15
Gognagar 102 MW PP (Summit)	Private	08-Jun-29	102	15

Jangalia, Comilla (Lakdanvhi)	Private	27-Dec-29	52	15
Potiya, Chttagong 108 MW IPP (ECPV)	Private	13-Jan-30	108	15
Kathpotti, Munshigonj 50 MW Power Plant	Private	19-Feb-30	51	15
Total			**715**	

Table A3: HSD based power plants to be retired by 2030

Name of Power Station/ Location	Ownership	Retirement Date (DD/MM/YY)	Installed Capacity (MW)	Age at Retirement Date (yrs)
Rangpur 20 MW PP	Public	31-Dec-2022	20	34
Saidpur 20 MW PP	Public	31-Dec-2022	20	35
Noapara 100 MW PP (Bangla Trac)	Private	17-Apr-23	100	5
Doudkandi 200 MW PP (Bangla Trac)	Private	26-Apr-23	200	5
Bramongao 100 MW PP (Aggreko)	Private	29-May-23	100	5
Aorahati 100 MW PP (Aggreko)	Private	28-Jun-23	100	5
Pangao 300 MW PP (APR)	Private	09-Aug-23	300	5
Baghabari 200 MW PP (Paramount)	Private	15-Feb-2024	200	5
Bheramara 20 MW PP GT1	Public	30-Jun-2025	20	49
Total			**1060**	

Table A4: Coal based power plants to be added by 2030.

Name of coal power plant	Capacity	Ownership	Expected commissioning date	Status
Mirshorai 1320 MW Coal Fired PP (Hangzhou Group)	1,240	Private	June, 2027	Ongoing
RNPL, Patuakhali	1320	IPP	December, 2023	Ongoing
BIFPCL, Rampal	1320	Bangladesh-India JV	2023	Ongoing
IPP, Barishal	307	China	2023	On going
Chattogram Coal Fired Power Project	1224	IPP	2023	
Moheskhali 1200 MW USCPP (ECA)	1,320	Public	December, 2028	Planning
Matarbari 1200 MW USCPP (Phase 2)	1,200	Public	December, 2030	Planning
Total	**7931**			

Table A5: Gas based power plants to be added by 2030.

SN	Name	Capacity	Ownership	Expected commissioning date	Status
1	Raojan 400±10% MW CCPP (1st Unit)	400	Public	January , 2025	Planning
2	Anowara 590 MW CCPPC (United)	590	Private	June, 2025	Ongoing
3	Meghnaghat 500 MW CCPP (Anlima)	450	Private	June, 2025	Ongoing
4	Ghorasal 225 MW CCPP	225	Public	June, 2026	Planning
5	Mymenshingh 400 MW CCPP	400	Public	June, 2026	Planning
6	Jamaldi, Gazaria 660 MW PP (EDRA)	660	Public	Dec, 2026	
7	Shiddirgonj 600±10% MW CCPP	550	Public	June, 2027	Planning
8	LNG based 1200 MW CCPP at Moheskhali-Phase-1	1200	Public	June, 2027	Planning
9	Gazaria 600 MW LNG Based Power Plant	550	Public	June, 2027	Planning
10	Payra 1200 MW LNG based CCPP (2nd Phase)	1200	JV	June, 2027	Planning

11	Mirsorai 660 MW PP (Confidence)	660	Private	March, 27	Planning
12	Sonagazi, Feni 500-600 MW CCPP (1st Unit)	550	Public	December, 2028	Planning
13	CPGCBL-Mitsui 500-600 MW LNG based CCPP (Phase-1)	600	JV	June, 2028	Planning
14	LNG based 1200 MW CCPP at Moheskhali-Phase-2	1200	JV	December, 2028	Planning
15	Megnama 1200 MW	1200	Private	June , 2029	
16	Bharamara 600±10% MW CCPP	550	Public	December, 2030	Planning
	Total	**10985**			

Table A6: Companies and consortiums which have received LOI for Renewable energy projects in Bangladesh. All projects are based on solar PV unless mentioned in the parenthesis.

SN	Sponsor	Location	Capacity (MW)	Tariff (USD/ kWh)	Date of LOI issuance
1	Concord Progatti Consortium Ltd.	Sharishabari, Jamalpur	3.28	0.189	15.02.15
2	Edisun- Power Point & Haor Bangla- Korea Green Energy	Dharmapasha, Sunamganj	32	0.17	17.12.15
3	BPDB	Kaptai, Rangamati	5		
4	NWPGCL	Sirajganj	6		
5	Hetat-Ditrolic-IFDC Solar (HDFC Sinpower Ltd.)	Sutiakhali, Mymensingh	50	0.17	21.12.15
6	Intraco CNG Ltd. & Juli New Energy Co. Ltd.	Gangachora, Rangpur	30	0.16	18.04.16
7	Joules Power Ltd.	Teknaf, Cox's Bazaar	20	0.139	19.05.16
8	Beximco Power Co. Ltd. & TBEA XinJiang SunOasis Co. Ltd.	Sundarganj, Gaibandha	200	0.15	05.09.16
9	Eiki Shoji Co. Ltd. (Japan) & Sun Solar Power Plant Ltd.	Goainghat, Sylhet	5	0.139	06.09.16
10	Green Housing & Energy Ltd.	Patgram, Lalmonirhat	5	0.125	22.11.16
11	Beximco Power Co. Ltd. & Jiangsu Zhongtian Technology Co. Ltd. (China)	Panchagarh	30	0.139	15.01.17
12	Zhejiang DunAn New Energy Co. Ltd. (China) & National Machinery Import & Export Corporation, Solar Tech Power Ltd. & Amity Solar Limited	Nilphamari & Lalmonirhat	100	0.14	05.04.17
13	Energon Technologies FZE (UAE) & China Sunergy Co. Ltd. (CSUN)	Bagerhat	100	0.138	12.04.17
14	JV of Paragon Poultry Ltd. & Parasol Energy Ltd. (Bangladesh) and Symbior Solar Siam Ltd. (Hongkong)	Panchagarh	8	0.13	22.04.17
15	8 minutenergy Singapore Holdings 2 Pvt. Ltd.	Panchagarch	50	0.133	20.08.17
16	Consortium of Spectra Engineers Ltd. & Shunfeng Investment Ltd.	Manikganj	35	0.139	29.08.17
17	Shapoorji Pallonji Infrastructure Capital Co. Pvt. Ltd. (India)	Pabna	100	0.1195	31.12.17

18	Joint Venture Company of CREC International Renewable Energy Co. Ltd. (CIRE), China and BPDB-RPCL Powergen Ltd. Bangladesh	Madarganj, Jamalpur	100	0.1105	
19	Scatec Solar ASA, Norway	Nilphamari	50	0.112	27.09.2021
20	Symbior Solar Siam & Holland Construction	Moulvibazar	10	0.11	04.02.2019
21	Consortium of ib Vogt GmbH (Germany), Milner Vermogensverwaltungs GmbH (Germany) and SS Agro Complex Ltd (Bangladesh)	Dhamrai, Dhaka	50	0.1075	10.07.2019
22	Rahimafrooz-Shunfeng Consortium	Panchagarh	20	0.1075	
23	Saudia Agro Solar PV 3.77 MW Grid Tied Power Plant	Pabna	3.77		
24	Appolo Engineering & Construction Limited, and S.M.E Electrical Private Limited. Consortium	Baburhat, Chandpur	7	0.1025	06.09.2020
25	Hero Solar Energy Pvt. Ltd. India and BRIC, Panama Consortium	Terokhada, Khulna	50	0.1025	09.11.2021
26	IBV-SS Agro Consortium	Dhamrai, Dhaka	50		
27	DAEHAN GREEN ENERGY Co. Ltd., Korea, HI Korea Co. Ltd., Korea and Pabna Solar Power Ltd., Bangladesh	Pabna	70	0.1015	30.01.2022
28	Total Eren S.A., France; Norwegian Renewables Group AS, Norway and Urban Services Ltd, Bangladesh	Muktagasha, Mymensingh	50	0.1015	28.02.2022
29	Sonagazi Solar Power Ltd. (IBV-AG Agro Consortium)	Sonagazi, Feni	50	0.1094	15.12.2019
30	Cyclect Energy Pte. Ltd. Singpore	Chuadanga	50	0.1020	05.01.2022
28	Western Monpura Solar Power Ltd. (Offgrid Solar Hybrid)	Monpura, Bhola	3	0.2125	03.01.2022
31	US DK Green Energy Ltd. (Wind)	Khuruskul, Cox's Bazar	60	0.12	
32	Mongla Green Power Ltd (Consortium of Envision Energy China; Envision Energy Hongkong and SQ Trading Bangladesh (Wind)	Mongla, Khulna	55	0.132	
33	JV of Bhagwati Products Limited (India), Regen Powertech Private Ltd (India) and Siddhant Wind Energy Pvt. Ltd. (Wind)	Sonagazi, Feni	30		27.01.2019
34	China Machinery Engineering Corporation (CMEC) (Waste to Energy)	Amin Bazar, Dhaka	42.5	0.2178	
36	Consortium of UD Environmental Equipment Technology Co. Ltd, Everbright Environmental Protection Technical Equipment (Changzhou) Limited and SABS Syndicate. (Waste to Energy)	Narayanganj	6	20.91	
	Total		**1536**		

Appendix 2: Investment risk assessment survey questionnaire

EU Study: Risk Assessment for Electricity Generation Project Investments

Survey questionnaire

Name:	
Designation:	
Institution	
Address	
Contact	
Type of technology (Investor is involved)	Fossil fuel (Coal) ☐, Fossil fuel (gas) ☐, Fossil fuel (HFO) ☐, Renewable energy (solar) ☐, Renewable energy (wind) ☐

Note: The purpose of this survey is to obtain opinions from different stakeholders about the likelihood and impact of various risks which may affect investments in renewable energy projects and fossil fuel electricity generation projects in Bangladesh. For each type of risk, there is a brief description and examples of what is covered in that risk category. Please select the answer you think best describes the probability and financial impact of the following risk categories. Clicking over the box will result in selection ☒

1. **Financial risk:** Financial risk refers to the availability of sufficient capital to install renewable energy or fossil fuel projects, such as equity and public financing support schemes.

Q1a: In your opinion, what is the likelihood of financial risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q1b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

2. **Expertise risk:** Lack of adequate expertise risks refers to the unavailability of experienced human resources and local knowledge and the maturity of the RE technology.

Q2a: In your opinion, what is the likelihood of expertise risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q2b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

3. **Contracts Risk:** This factor refers to risks related to the landowner agreements, engineering, procurement, and construction contracts.

Q3a: In your opinion, what is the likelihood of contracts risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q3b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

4. **Grid access risk:** This risk concerns integrating the electricity generated from the power plant into the grid to become operational.

Q4a: In your opinion, what is the likelihood of grid access risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q4b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

Construction risks: This risk arises from damage during transport or due to natural hazards, and unreliability of components.

Q5a: In your opinion, what is the likelihood of constructions risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q5b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

5. **Operations and maintenance risk:** This refers to the higher operations and maintenance costs due to the novelty and unpredictability of the technology.

Q6a: In your opinion, what is the likelihood of operations and maintenance risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q6b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

6. **Project development risk:** This refers to the revenue loss due to project delay or cancellation of the license for the commercial operation and failure to obtain all required documents to get grid access.

Q7a: In your opinion, what is the likelihood of project development risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q7b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

7. **Resource risk:** Resource risk refers to inaccurate resource assessment such as solar irradiation or wind speed, or fossil fuel reserves.

Q8a: In your opinion, what is the likelihood of resource risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q8b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

8. **Price policy risk:** This risk can arise when the policy design does not account for all revenue risks, such as price fluctuation.

Q9a: In your opinion, what is the likelihood of price policy risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q9b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

9. **Regulatory risk:** This factor refers to the uncertainty regarding national energy strategies, such as risk increasing barriers, the involvement of independent power producers, adverse laws passed for the particular technology.

Q10a: In your opinion, what is the likelihood of regulatory risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q10b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

10. Social risk: This includes lack of public acceptance, public health risks from the project, and physical and economic resettlement arising from the project.

Q11a: In your opinion, what is the likelihood of social risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q11b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

11. Stranded asset risk: Stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities. This means that the assets will become unproductive and unprofitable before the planned useful life of the asset expires.

Q12a: In your opinion, what is the likelihood of stranded asset risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q12b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

12. Force majeure: There are unexpected risk events which are outside the control of all parties, and the counterparty cannot or will not fulfil their contractual obligations under these circumstances.

Q13a: In your opinion, what is the likelihood of force majeure risk?

Unlikely	☐	☐	☐	☐	☐	Very likely

Q13b: In your opinion, what is the impact of this risk?

Low impact	☐	☐	☐	☐	☐	High impact

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