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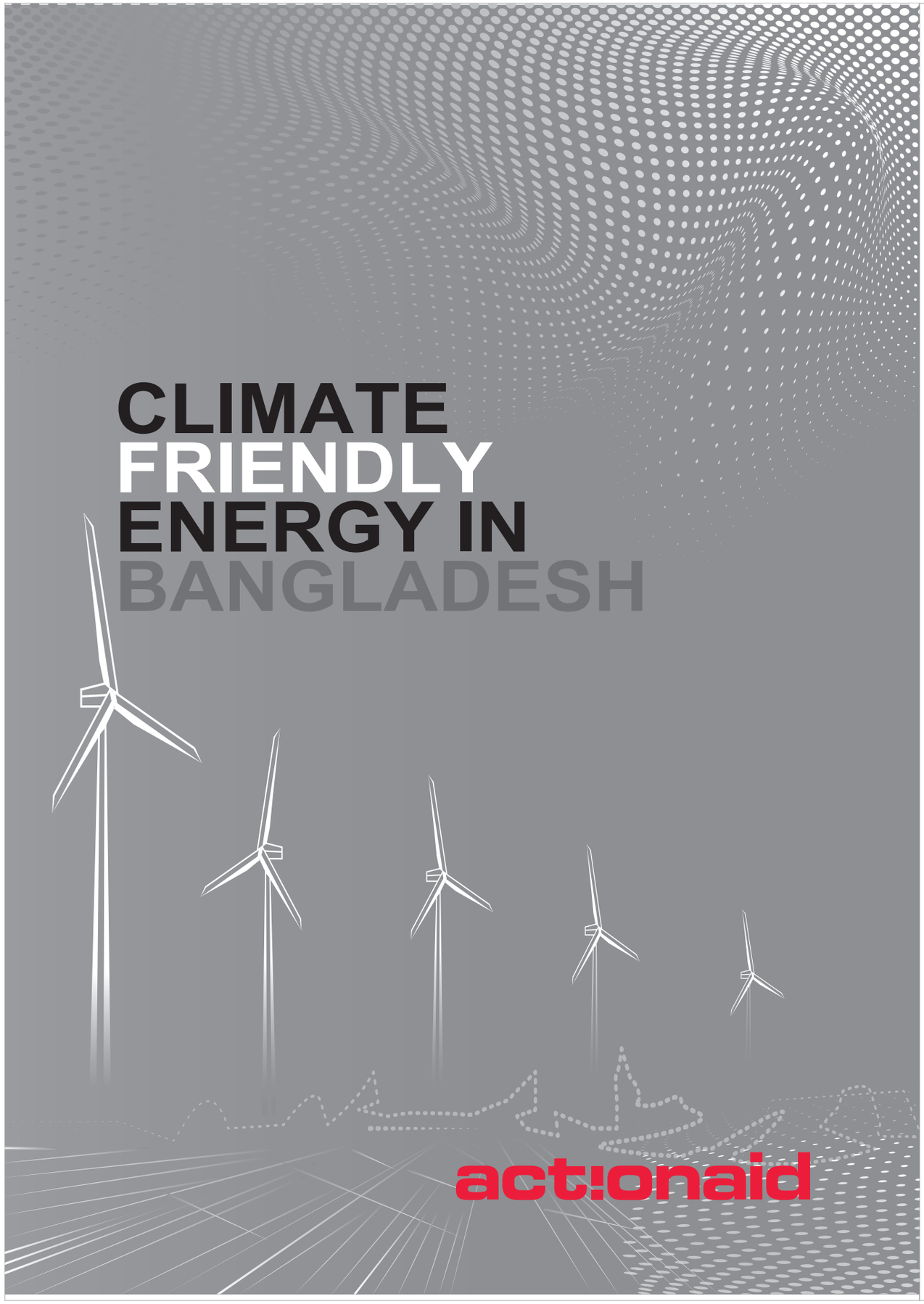

Climate Friendly Energy in Bangladesh

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CONTENTS

Preface

It is my immense pleasure to introduce the Energy Literacy Handbook titled, 'Climate Friendly Energy in Bangladesh'. This handbook is a result of the commitment towards clean and sustainable energy solutions in Bangladesh. Access to clean, affordable, and sustainable energy is crucial for achieving climate justice in communities and reducing carbon emissions nationally for global, net zero targets.

The handbook presents an analysis on the energy production in Bangladesh, its history, information on renewable technologies, demographic opportunities, financing, and policy frameworks. We hope that the handbook will enhance mass awareness and inspire policy stakeholders to take necessary action towards a just and sustainable energy transition.

I would like to thank the Bangladesh Power Development Board (BPDB), Sustainable and Renewable Energy Development Authority (SREDA), Infrastructure Development Company Limited (IDCOL), National Housing Authority (NHA), and Bangladesh Rice Research Institute (BRRI) for providing us with resourceful information without which this handbook would not have been possible. The team at ActionAid Bangladesh worked relentlessly for the publication of the handbook.

We hope this publication will contribute to the collective efforts for creating a just and sustainable world.

Farah Kabir
Country Director
ActionAid Bangladesh

Acknowledgment

We extend our sincere gratitude to everyone who contributed to the development and publication of this handbook on 'Climate Friendly Energy in Bangladesh'.

We appreciate the contributions of the content development team, project coordinator and Head of Humanitarian, Resilience and Climate Justice Priority of ActionAid Bangladesh. We would also like to acknowledge the contribution of Print and Publication Committee, Resilience and Climate Justice Priority team, and Admin team their extensive support.

Our sincere gratitude to Khozaima Fatehali Ziauddin, provided editorial support for this handbook. We hope this handbook will serve as a useful resource for those seeking to adopt sustainable and clean energy solutions.

Thank you all for your support and collaboration.

Executive Summary

Energy, particularly electricity has always been an essential factor in the economic development of a country. Electricity is critical in communication, industrialisation, utility services, transportation, education, food, marketing, shopping, management, etc.

Most of the world's energy production is derived from fossil fuels. Global studies including IPCC Reports have found that the excessive dependence on fossil fuel sources has led to global warming, climate change, ecological losses, and damage, impacting all the living beings on earth. Bangladesh is one of the most affected countries by climate change cause by global warming. The government of Bangladesh has set a target of 30% production of renewable energy by 2030, and 40% by 2041.It also aims to significantly reduce its fossil fuel consumption, in line with its domestic and international commitments, such as the Mujib Climate Prosperity Plan, Vision 2041, Kyoto Protocol, Paris Agreement, COPs, etc. The Intent is to ensure net zero target by 2050.

The renewable energy generation capacity of Bangladesh is around 4% and as of 2023, Bangladesh's electricity generation capacity is about 26,018 MW (SREDA). On the demand side, the maximum requirement of electricity in the country is about 14,000 MW, especially during the summer. This indicates there is a significant gap between electricity generation and demand, resulting in a huge cost of capacity charges. The lack of proper utilisation of plans in the energy sector, particularly for transmission and distribution, is one of the key factors of the gap between capacity and demand.

To fulfil the future electricity demand of the country and comply with global net zero commitments, the Government of Bangladesh has initiated the preparation of the Integrated Energy and Power Master Plan (IEPMP), with the goal of establishing a zero-carbon energy demand and supply system to ensure energy security and economic viability. However, the IEPMP's target for clean energy is set for only 20% by 2041 and 30% by 2050. In addition, IEPMP planned to use ammonia, hydrogen, and nuclear as new sources of clean energy, targeting to reduce carbon emissions. However, it is not clear whether the energy will be extracted by using green technologies from the above-mentioned new sources. The government's plan to increase fossil fuel-based power plants to generate electricity and to import a significant amount of electricity from neighbouring countries by 2050,contradicts the zero-carbon goal of the country. It could be considered as a potential threat for the energy security and sovereignty of the country. Bangladesh has immense potential for renewable energy, especially in solar, wind, biogas, tidal-wave, and micro-hydro technologies. However, there are some challenges in promoting of renewable energy in Bangladesh. These are (i) adopting advanced technology (ii) incompetent expatriates (iii) inadequate policy support and investments (iv) lack of domestic renewable energy-related industries.

This handbook aims to increase energy literacy among the young population and electricity user communities by highlighting significant information on the energy sector of Bangladesh. The idea is to raise awareness about the potential of renewable energy as well as highlight the threads and challenges posed by fossil-fuel dependency.

By adopting renewable energy technologies, we can save money on electricity, reduce global warming by reducing the use of fossil-fuels like diesel and gasoline, improve public health by reducing harmful emissions caused by burning fossil-fuels, create green jobs and more importantly be energy independent.

Acronyms

AC	Alternate Current
235U/U-235	Uranium-235
ADB	Asian Development Bank
ATR	AutoThermal Reforming
BADC	Bangladesh Agricultural Development Corporation
BAEC	Bangladesh Atomic Energy Commission
BARD	Bangladesh Academy for Rural Development
BARI	Bangladesh Agricultural Research Institute
BCSIR	Bangladesh Council of Scientific and Industrial Research
BER	Bangladesh Economic Review
BMD	Bangladesh Meteorological Department
BMDA	Barind Multipurpose Development Authority
BNBC	Bangladesh National Building Code
BPDB	Bangladesh Power Development Board
BREB	Bangladesh Rural Electrification Board
BRRI	Bangladesh Rice Research Institute
BTS	Base Transceiver Stations
CAPEX	Capital Expenditure
CO2	Carbon Dioxide
COP	Conferences of the Parties
CPGCBL	Coal Power Generation Company Bangladesh Ltd.
CRI	Centre for Research and Information
DB/SDB/BDB	Distribution Board
DC	Direct Current
DESCO	Dhaka Electric Supply Company Ltd.
DFID	Department for International Development
DPDC	Dhaka Power Distribution Company Ltd.
GDP	Gross Domestic Product
GHG	GreenHouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GOB	Government of Bangladesh
GPOBA	Global Partnership on Output-Based Aid
GW	Gigawatt
HFO	Heavy Fuel Oil
IAEC	International Atomic Energy Agency
IDCOL	Infrastructure Development Company Ltd.
IEPMP	Integrated Energy and Power System Master Plan
INES	International Nuclear and Radiological Event Scale

IRENA	International Renewable Energy Agency
JICA	Japan International Cooperation Agency
KfW	Kreditanstalt für Wiederaufbau
KW	Kilowatt
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MCPP	Mujib Climate Prosperity Plan
MoCHTA	Ministry of Chittagong Hill Tracts
MoDMR	Ministry of Disaster Management and Relief
NDC	Nationally Determined Contribution
NEI	Nuclear Energy Institute
NEM	Net Meter
NESCO	Northern Electricity Supply Company Ltd.
NWPGCL	Northwest Power Generation Company Ltd.
OPEX	Operating Expenses
PGCB	Power Grid Company of Bangladesh
PSMP	Power System Master Plan
PV	Photovoltaic
RDA	Rural Development Academy
RDCD	Rural Development and Cooperative Division
RE	Renewable Energy
SDGs	Sustainable Development Goals
SHS	Solar Home System
SIP	Solar Irrigation Pump
SIS	Solar Irrigation System
SMR	Steam Methane Reforming
SREDA	Sustainable Renewable Energy Development Authority
STE	Solar Thermal Energy
UN	United Nations
UNFCC	United Nations Framework Convention on Climate Change
USA	United States of America
USAID	United States Agency for International Development
VAT	Value Added Tax
WB	World Bank
WNA	World Nuclear Association
WZPDCL	West Zone Power Distribution Company Ltd.

1 Background of Energy

Electricity has been known to exist in nature since the beginning of the world. It were the ancient Greeks who first observed static electricity from rubbing amber (Williams, 2012). However, it was not until the late 18th century that the concept of electricity, as we know it today, began to take shape, with the discovery of electric currents and the relationship between electricity and magnetism. Electricity is also an essential component of all living beings with electrical impulses controlling a wide range of bodily functions, including muscle movement and the transmission of information in the nervous system. The kinetic energy of moving electrons is what allows these impulses to occur.

The history of electricity generation can be traced back to the late 19th century when the widespread use of electricity began. Thomas Edison's development of the first practical incandescent light bulb in 1879 paved the way for electricity to become a practical source of light. In 1882, Edison's Pearl Street power station in New York City began providing electricity to homes and businesses (Orrick, 2014). This was followed by the development of the alternating current (AC) system by Nikola Tesla and George Westinghouse in the late 1880s, which allowed for the transmission of electricity over longer distances (McPherson, 2012). Today, electricity is an essential part of modern life and is used to power everything, i.e. homes, schools, business, factories and beyond.

Electricity generation globally is largely dependent on fossil-fuels such as oil, coal and natural gas which are available in finite quantities only. As we keep extracting them, they will run out sooner or later. On the other hand, renewable energy derived from natural resources that replenish themselves without depleting the planet's resources are virtually inexhaustible. And what is even more important, they cause little climate or environmental damage. It is for this reason stronger policies to promote renewable energy and technology (despite the rising costs) are made. Renewable not only cause little climate or environmental damage but also offer a way out of import dependency, allowing countries like Bangladesh to protect themselves from the unpredictable price swings of fossil-fuels.

Bangladesh has immense potential for renewable energy, especially in solar, wind, biogas, tidal-wave, and micro-hydro technologies. Among these renewable energy sources, solar power has emerged as a viable alternative, which can be harnessed even in areas with less sunlight, using advanced photovoltaic cells that transform sunlight into electricity. Sunlight is not only a source of energy, but also a source of vitamin D and other essential nutrients for all living beings on the earth (Holick, 2004).

As society continues to place emphasis on reducing our reliance on non-renewable energy sources, renewable energy will need to be considered by policy makers and corporate as an alternative and as a prime source of electricity generation.

2 Energy Industry of Bangladesh and Fossil Fuel

World energy consumption has been rapidly increasing with the global population and economic growth. According to global statistics of 2020, fossil fuels dominate the energy mix at 78.5% of the total production, whereas renewable energy is only at 12.6% (REN21, 2022).The global carbon emission, from the use of fossil fuel, was 36.6 billion tons in 2021 (IEA, 2022) and projected to be 37.5 billion tons in 2022. (Osaka, 2022). In addition, the increasing use of fossil fuels has contributed to climate change and environmental degradation, calling for a shift to renewable energy sources. To ensure sustainable energy usage in future, coordinated efforts among governments, industry, and communities to ensure access to affordable, reliable, and clean energy for all are required. (United Nations, 2022).

Although the production of electricity is increasing day by day, there is still a large number of people across the world living without access to electricity. This is particularly stark in under-developed and developing countries, where access to energy remains limited. This has also led to the issue of energy poverty, which affects almost one billion people worldwide. The use of renewable energy could be an alternative solution to meet energy demands.

Global oil and natural gas prices have surged since late 2020, due to COVID-19 restrictions followed by the Russian invasion of Ukraine in early 2022. Oil prices tripled, exceeding $100 per barrel, and price of liquefied natural gas (LNG) and liquefied petroleum gas (LPG) in Europe and Asia rose about six fold. Coal prices doubled, which created inflation in countries like Bangladesh. The Government of Bangladesh is paying a huge energy subsidy to the energy sector each year. Therefore, the government is trying to explore multiple sources to ensure reliable and affordable power for energy transition.

Bangladesh plans to achieve 30% renewable energy by 2030 under the Mujib Climate Prosperity Plan, considering the commitment to achieve the 40% renewable energy target by 2041, pledged at COP26 and the net zero target of the Paris Agreement by mid-century. However, the current renewable energy generation capacity is only about 4%. On the other hand, statistics show the contribution of carbon emissions of Bangladesh was 0.5 metric tons per capita (World Bank, 2020) and Bangladesh contributes only 0.3% to the World's Carbon emissions. Around 49% of the carbon in Bangladesh comes from the power sector, which is mostly fossil fuels like natural gas, coal, oil, etc.

According to the Sustainable Renewable Energy Development Authority (SREDA), the total power generation capacity in Bangladesh is 26,018 MW including the captive power plant's capacity of 2,800 MW, while the Bangladesh Power Development Board (BPDB) reports it to be 24,911 MW, For renewable energy production, SREDA's data suggests the capacity to be 1194.26 MW, which is equivalent to 4% of the total capacity. BPDB however mentioned 689 MW of renewable energy capacity, which is equivalent to 3% of the total capacity, details are mentioned in Table 1.

Fuel/Resource	Capacity in MW (BPDB)
Coal	4188
Gas	11592
HFO	6441
HSD	841
Imported	1160
Renewable	459 (Solar) and 230 (Hydro)
Total	24,911 MW Derated (24,171 MW)

Table 1: Power Generation Capacity of Bangladesh (BPDB, 2023)

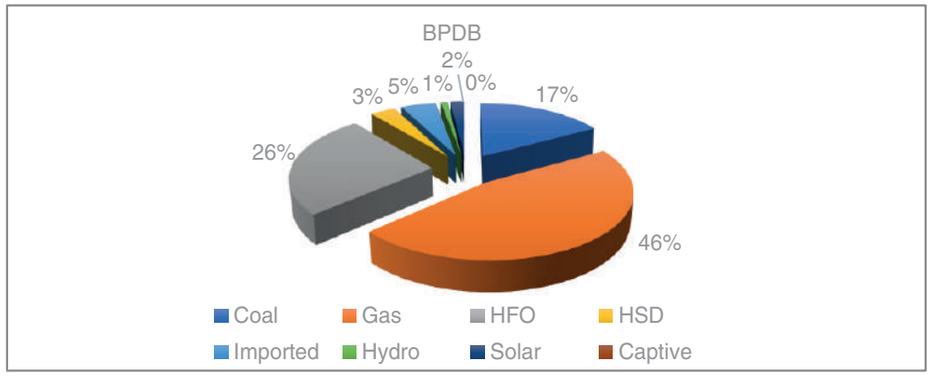

Figure 1: Power Generation Capacity of Bangladesh (BPDB, 2023)

According to BPDB, gas remains the primary fuel for the electricity generation in Bangladesh, contributing 46% of total electricity generation. Heavy Fuel Oil (HFO) is the second largest contributor at 26%, while coal contributes 17% to the sector, which has been increasing in recent years, and according to the IEPMP the number of the coal -based power plants will be increasing in future as well.

The government is also considering shifting towards coal-based electricity generation instead of HFO, HSD, and captive power plants. The renewable energy sector has received little attention from the government and has the lowest percentage of contribution (3-4%) to the energy industry of Bangladesh. On the other hand, the private sector of the country has come forward and has started to contribute to the growth of capacity for renewable energy.

The Bangladesh Power Development Board (BPDB) began its journey on May 1st, 1972, with an installed capacity of 200 MW. Since 1972, the capacity of electricity production has increased slowly compared to the demand. In 2010, the power generation capacity was 6,454 MW and the government introduced the Power System Master Plan, with the goal of meeting the projected demand of 33,708 MW by 2030. However, as of 2022, the current electricity demand in the country ranges between 12,000-14,000 MW (BPDP, 2023).Year-wise breakdown has been shown below.

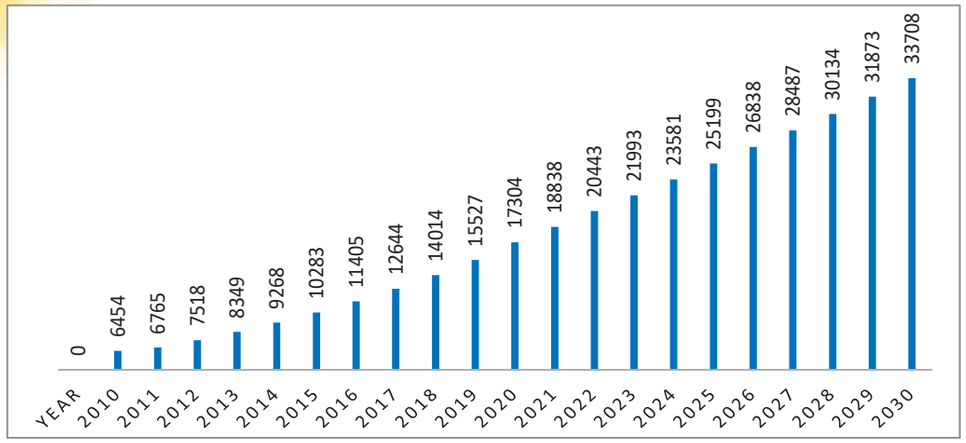

Figure 2: Peak Demand Forecast (BPDB, 2023)

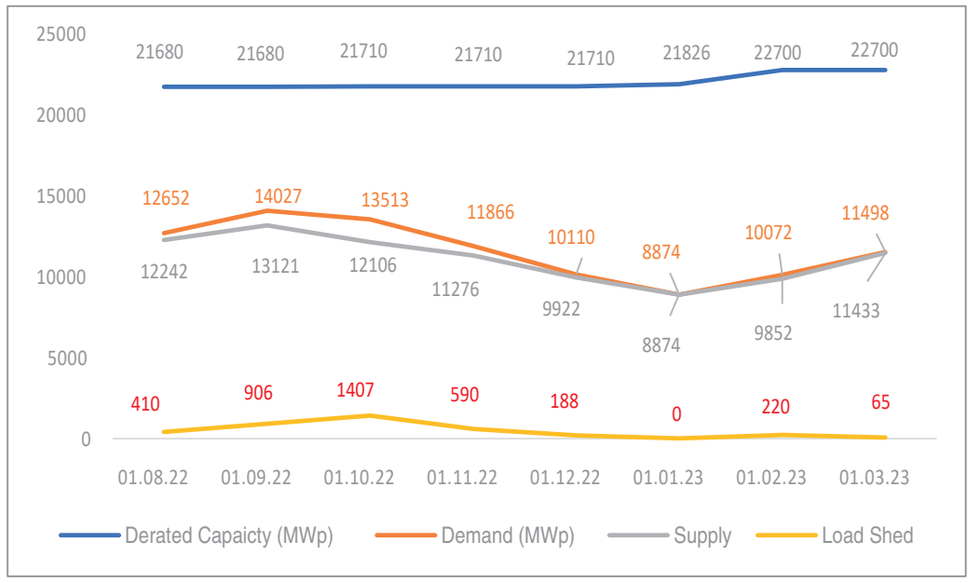

Figure 3: Derated Power Generation Capacity, Demand, Supply & Load Shedding (BPDB,2023)

The figure shows that from August 2022 to March 2023, the derated electricity generation capacity increased from 21,680 MW to 22,700 MW.The graph also shows the maximum amount of electricity generation and demand statistics on the first day of each month in 2022. The analysis of the data reveals that the demand superseded the generation since the middle of July 2022, resulting in frequent load shedding, despite the high electricity generation capacity, which were reported to be 410 MW in August, 906 MW in September, 1407 MW in October, 590 MW in November, and 188 MW in December. During this time, the load-shedding situation was worse during September and October 2022.

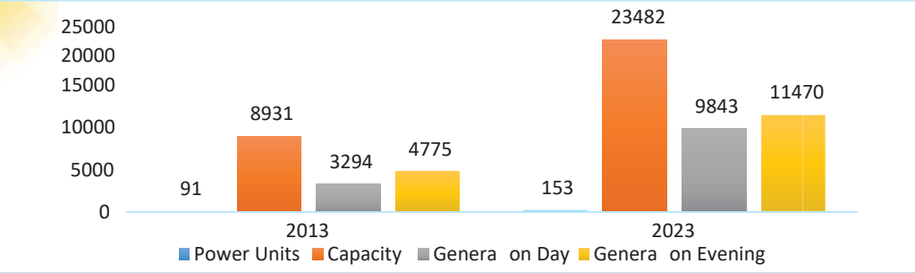

Figure 4: BPDB Power Generation, Units, and Capacity Data (1 March 2013 and 25 February 2023)

The unstable price of gas and oil in the international market, after the Russia-Ukraine war, has impacted the power generation scenario of Bangladesh. The government stopped power generation from quick rental power plants and reduced import of gas (especially LNG) and oil from the international market. This resulted in heavy load shedding and a price hike in electricity prices.

Bangladesh has 2,195 MW capacity of electricity, produced by three coal-based power plants at present. However, six more coal-based plants with the capacity of producing 8,080 MW are under construction, including the Adani Godda Coal with 1,600 MW capacity coal-based power plant. In addition, ten more coal-based power plants with the capacity of 11,447 MW have been proposed by the private companies of the country. However, the government has cancelled 8,856 MW worth coal-based power plants. Therefore, it seems that fossil fuel-based power plants are still getting priority instead of the renewable energy sector in Bangladesh.

3 Loss and Damage of Using Fossil Fuel

Several reports say that fossil fuel-based power plants cause multiple loss and damage in the form of adverse health impacts, ecological disasters, global warming social disruptions, and economic losses. Fossil fuel-based power plants pose various challenges and threats, particularly for countries vulnerable to climate change, such as, Bangladesh. These plants significantly contribute to the pollution of land, air, and water, and are responsible for global warming, rise in sea level, acid rain, and ocean acidification. They also pose health hazards and are the primary cause of extreme weather events, resulting in disasters like floods, hurricanes, wildfires etc. that cost billions of dollars in loss and damage.

3.1 Climate Change

Climate change refers to long-term shifting in temperature and weather patterns, which impact all the continents of the world (United Nations, 2022). Bangladesh has become one of the most climate vulnerable countries in the world and suffers from floods, cyclone, along with other climate change impacts (Buh, et al., 2018). Fossil fuel-based power plants are the primary source of such climate change impacts, jeopardising countries like Bangladesh with great intensity.

3.2 Polluting Earth Elements

Land, air, and water are the three core elements of the earth, and fossil-based power plants are significantly responsible for polluting these earth elements. Unearthing, processing, and moving the underground coal, gas, and oil are enormously impacting the landscape and ecosystem. Coal mining operations wash toxic runoff into lakes, rivers, and streams. Oil and gas spills and leaks during extraction and transportation also pollute water, including the drinking water source, which jeopardises the entire aquatic biodiversity (Denchak, 2022). Wastewater from the fracking well can contaminate the freshwater with substances like lead, arsenic, chlorine, and mercury. Furthermore, fossil fuels are polluting the air by releasing sulfur dioxide, nitrogen, carbon monoxide, mercury etc. which are harmful for the environment and life of the world (Bertrand, 2021).

3.3 Global Warming and Rising Sea Level

The fossil fuel sector is responsible for increasing global warming and rise in sea level as it emits harmful greenhouse gasses like carbon dioxide (United Nations, 2022). Earth's climate is changing because of the greenhouse effect and melting glaciers and land-based ice sheets which are causing the sea level to rise. Since late 1800, the sea levels have risen by about 9 inches (Lindsey, 2022). In addition, there has been a shift in agriculture and food consumption habits as a result of climate change, as it's threatening the food security of the world.

3.4 Acid Rain and Ocean Acidification

Acid rain and ocean acidification are the climate externalities of fossil fuels. Power plants that burn fossil fuels emit a huge amount of greenhouse gas and use a significant amount of freshwater to cool the power point system that impacts aquatic biodiversity. On the other hand, at least a quarter of CO_2 emitted from fossil fuels is absorbed by the ocean which is increasing the level of acidity and impacting the marine species. In fact, in the last 150 years, ocean acidity has increased by 30 percent (UCMP, 2022).

3.5 Health Hazards

Study says that around 70% of sulfur dioxide emissions are the result of coal-fired power plants. Burning conventional coal is causing a significant amount of nitrogen oxide and nitric oxide emissions. Burning oil, on the other hand, emits a high number of sulfur dioxide, nitrogen oxides, carbons, volatile organic compounds, and ash particles into the atmosphere (Shahsavari & Akbari, 2018). Benzene, toluene, xylene, and ethylbenzene are found in gasoline as additives that contain cancer-causing substances. The emitted toxic gas and elements of the fossil fuel-based industries are responsible for global health impacts, like asthma, cancer, heart disease, and premature death. Statistics show, fossil fuel pollution is responsible for one in five deaths in the world (Bertrand, 2021).

3.6 Extreme Weather Events

The National Oceanic and Atmospheric Administration identified that the burning of fossil fuels is the key cause of extreme weather events which lead to disasters like floods, hurricanes, drought, windstorms, wildfires etc. (Shahsavari & Akbari, 2018). Billions of dollars are spent on the loss and

damage of these extreme weather events across the world. The government of Bangladesh allocated Taka 9.836 crore for disaster management and relief in the financial year 2020-2021 (UNB, 2020) and received donations from national and international organisations for tackling the challenge. For example, recently World Bank approved $500 million credit to benefit over 1.25 million people of 14 inland flood affected districts of Bangladesh (The Daily Star, 2022).

4 Energy Transition and Bangladesh

Energy transition is a significant structural change in an energy system concerning supply and consumption (Jaccard, 2020). Thus, energy transition refers to changes in energy supply and demand patterns and is a roadmap for implementing a clean, green, and sustainable energy system. ActionAid believes in the 'principles for a just transition', where the transition must be addressed in a way that does not worsen existing inequalities; transform systems to benefit people, nature, and the climate; ensure inclusiveness and participation of all stakeholders; and implement comprehensive plans and policy frameworks.

The goal of the energy transition is to achieve a clean, green, and sustainable energy system that promotes energy justice. In order to achieve the targeted goals of transitioning to renewable energy from fossil fuels, governments should not continue to invest in fossil fuel-based power plants, or else the target will be unattainable. To achieve the targets of Mujib Climate Prosperity Plan, Vision 2041, sustainable development goals, and climate conferences, it is essential to increase investment in renewable energy and move away from the fossil fuel sector. This transition will promote sustainable and clean energy, and also ensure that energy is accessible and affordable to all.

4.1 Carbon Footprint of Energy Technologies

The carbon footprint of energy technologies is an important consideration when evaluating their environmental impact. The amount of carbon dioxide equivalent (CO2e) emitted per kilowatt-hour of electricity generated varies depending on several factors, such as the technology used and the fuel source. Coal-fired power plant emits around 900-1,100 grams for each kWh electricity, Natural gas-fired power plant emits around 500-600 grams of CO2 for each kWh electricity, Oil-fired power plant emits 700-800 grams of CO2 for each kWh electricity and nuclear power plant emits around 12-32 grams of CO2 for each kWh electricity (IEA, 2022).

However, renewable energy technologies generally have much lower carbon footprints than fossil fuel-based technologies. For example, solar photovoltaic systems have a carbon footprint of approximately 20-50 grams of CO2e per kWh, wind turbines have a carbon footprint of approximately 10-20 grams of CO2e per kWh (IEA, 2022). Tidal power systems have very low carbon footprints, with estimates ranging from 1-18 grams of CO2 per kWh (Carbon Trust, 2022). On the other hand, ammonia can be used as a carbon-free fuel in power plants, with a carbon footprint figure of zero, if produced using renewable electricity. On the other hand, the carbon footprint of ammonia produced using fossil fuels can be significant, with estimates ranging from 1.6-2.2 kilograms of CO_2e per kg of ammonia produced. Hydrogen can also be used as a carbon-free fuel in power plants, with a carbon footprint fugire of zero, if produced using renewable electricity whereas the carbon footprint of hydrogen produced using fossil fuels can be significant, with estimates ranging from 9-12 kilograms of CO_2e per kg of hydrogen produced (IEA, 2022).

It is important to consider that these estimates are approximate and can vary depending on various factors such as location, specific technology, and efficiency. It is also worth noting that some technologies, such as green ammonia and green hydrogen, have the potential to be carbon-free fuels when produced using renewable electricity.

5 Renewable Energy Sector of Bangladesh

Renewable energy is derived from natural sources that are replenished at a higher rate than they are consumed (UN, 2022). Bangladesh has significant potential of increasing renewable energy generation i.e., solar, wind, biogas, tidal wave, micro-hydro etc.

Currently, Bangladesh has around 4% of electricity generation capacity from renewable energy, which is 1,195.03 MW. According to the Mujib Climate Prosperity Plan the government has a target of achieving 30% of renewable energy by 2030, and 40% by 2041 (as agreed on COP-26). At present, different categories of renewable energy capacity are being used in limited ways in Bangladesh.

Technology	Off-grid (MW)	On-grid (MW)	Total (MW)
Solar	365.88	595.39	961.27
Wind	2	0.9	2.9
Hydro	0	230	230
Biogas to Electricity	0.69	0	0.69
Biomass to Electricity	0.4	0	0.4
Total	368.97	826.29	1,195.26

Table 2: Renewable Energy Generation Capacity (SREDA, 2023)

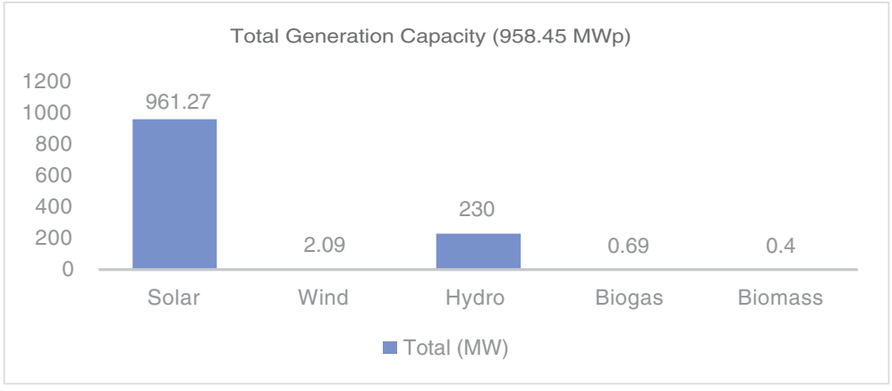

Figure 5: Renewable Energy Generation Capacity (SREDA, 2023)

The figure above shows that solar and hydro energy are the two main renewable energy sources for Bangladesh. The country has a solar energy capacity of 961.27 MW and a hydro energy capacity of 230 MW. In contrast, wind energy has an electricity generation capacity of 2.9 MW, biogas has a capacity of 0.69 MW, and biomass has a capacity of just 0.4 MW. However, it is unclear whether the 1,194.03 MW capacity is the actual amount of electricity that can be generated from renewable sources in Bangladesh. For now, solar and hydro energy appear to be the most promising renewable energy sources for Bangladesh. Further analysis is needed to determine the actual amount of electricity that can be harnessed from renewable sources.

5.1 Solar Energy

Solar energy is one of the potential sources of energy that can even be harnessed in cloudy weather. Earth is intercepting about 10,000 times greater energy than the rate at which we consume it (UN, 2022). Bangladesh is located between 20° 30" and 26° 45" north latitude and an average of 5 kWh/m^2 of solar radiation falls over 300 days per year, where minimum solar radiation is available from December to January and the maximum radiation is available from March to April. (Deb, Bhuiyan, & Nasir, 2013). According to the December 2020 report of the Bangladesh Meteorological Department, average bright sunshine hours were 6.25 per day (BMD, 2021) and 6.83 hours per day during March 2021 (BMD, 2021). Therefore, it is a fact that Bangladesh has the potential to harness solar energy and reduce its dependency on fossil fuels and as such should be able to meet the renewable energy target of the Government of Bangladesh.

5.2 Harnessed Solar Energy

Solar energy can be harnessed mainly in two ways.

i) Photovoltaic Cell (PV)

PV cell is a popular technology across the world and Bangladesh is no exception. PV Cell device is also known as a solar cell that directly converts solar light into electricity. PV cells are normally used for both off-grid and on-grid electricity harness. Polycrystalline solar panels and mono-crystalline solar panels are two types of solar panel which are available in Bangladesh. Môn crystalline solar panels are more efficient than polycrystalline solar panels due to their higher purity level and uniform crystalline structure.

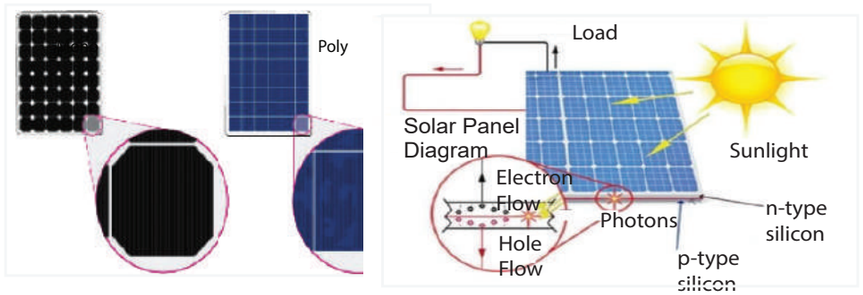

Figure 6: Photovoltaic Polycrystalline and Mono-crystalline Solar Panels

ii) Solar Thermal Energy (STE)

STE collects and concentrates sunlight to produce high-temperature heat for generating electricity. Reflectors or mirrors and receivers are two main components of STE. Reflectors capture sunlight and redirect it to the receiver to generate high-temperature heat.Using this technology, temperatures of more than 1000°C can be achieved (Cleveland & Morris, 2014).

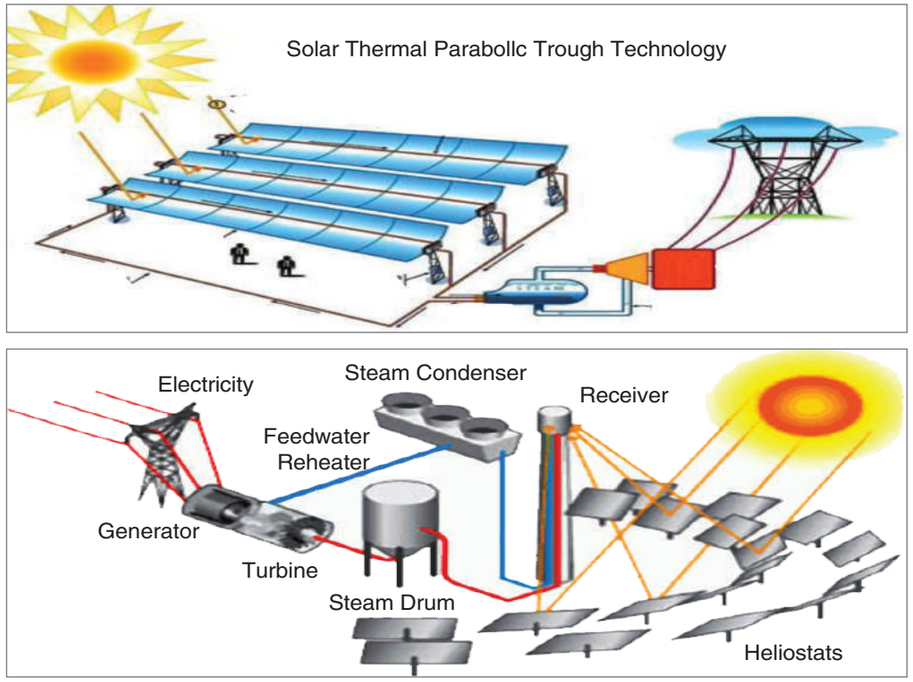

Figure 7: Solar Thermal Energy

The integral parts of a conventional solar photovoltaic system are: (a) Solar photovoltaic panel(s) (b) Battery charge controller (c) Inverter (d) Cables between the solar photovoltaic panel(s) and the battery charge controller (e) Cables between the battery and the battery charge controller (f) Cables between the inverter and the distribution board (DB/SDB/BDB) (g) Other cables and accessories.

5.3 Solar Technologies in Bangladesh

The current solar technologies available such as solar parks, rooftop solar systems, solar irrigation, solar home systems, and solar streetlights have made an impact in Bangladesh. A part of them, solar mini-grid, solar nano-grid, solar charging stations, solar-powered telecom BTS, and solar drinking water systems are also gaining popularity in Bangladesh. The table below shows the most recent data regarding electricity generation capacity from different solar technologies (See Table 3).

Technology	Quantity	Off-grid MWp	On-grid MWp	Total MWp
Solar Park	10	0	461	461
Rooftop Solar Except NEM	210	26.736	41.259	67.995
Net Metering Rooftop Solar	1930	0	84.96	84.96
Solar Irrigation	2865	49.83	2.349	52.179
Solar Home System	603789	263.793	0	263.793
Solar Minigrid	28	5.805	0	5.805
Solar Microgrid	0	0	0	0
Solar Nanogrid	2	0.001	0	0.001
Solar Charging Station	14	0.266	0.016	0.282
Solar Street Light	296861	17.065	0	17.065
Solar Powered Telecom BTS	1933	8.06	0	8.06
Solar Drinking Water System	82	0.095	0	0.095
Total		371.69	589.584	961.74

Table 3: All Technologies of Solar Energy in Bangladesh (SREDA, 2023)

These figures illustrate renewable energy capacity under different technologies, divided into off-grid and on-grid generation. In Bangladesh, the total solar energy generation capacity is 961.74 MW, with 371.69 MW from off-grid and 589.584 MW from on-grid technologies.

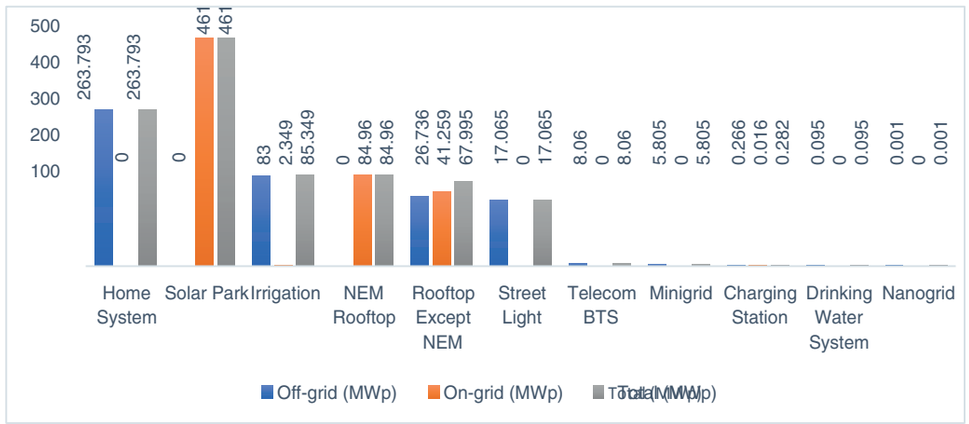

Figure 8: Technology -Wise Capacity of Solar Energy (SREDA, 2023)

Off-grid systems include solar home systems with 263.739 MW, solar irrigation with 52.179 MW, rooftop solar excluding NEM with 26.736 MW, solar streetlights with 17.065 MW, solar mini-grid with 5.805 MW, solar nano-grid with 0 .001 MW, solar charging station with 0.266 MW, solar-powered telecom BTS with 8.06 MW, and solar drinking water systems with 0.095 MW. Meanwhile, on-grid technology includes solar parks with 461 MW, rooftop solar excluding NEM with 41.259 MW, net metering rooftop solar with 84.96 MW, solar irrigation with 2.349 MW, and solar charging stations with 0.016 MW capacity. Considering this data, solar home systems and solar parks have made the most significant contributions to solar energy technology in Bangladesh , as mentioned below.

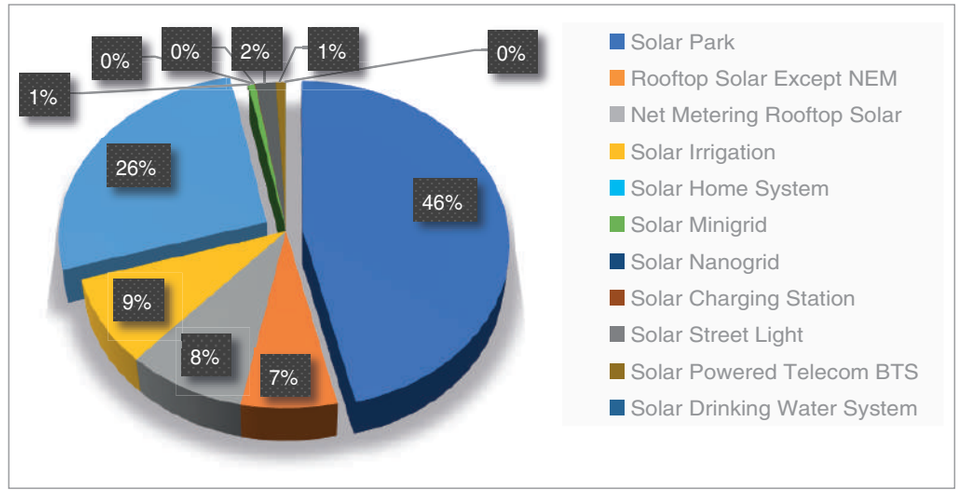

Figure 9: Share of Solar Technologies, Bangladesh

5.4 Rooftop Solar System

The rooftop solar system is a popular technology used in Bangladesh to harness electricity. The country has a total capacity of 192.955 MW for generating electricity from rooftop solar systems (SREDA, 2023). Most rooftop solar systems are installed in commercial and residential buildings in Bangladesh, and photovoltaic (PV) is the only system used in existing rooftop solar projects. The Government of Bangladesh is now encouraging industries to install rooftop solar systems to offset a certain portion of their electricity demand from renewable energy. Three types of rooftop solar systems exist in the country, which are;

i) On - Grid Solar System

On- grid Solar systems are connected to the national electricity grid and consumers can utilise electricity from both the solar system and the national grid.

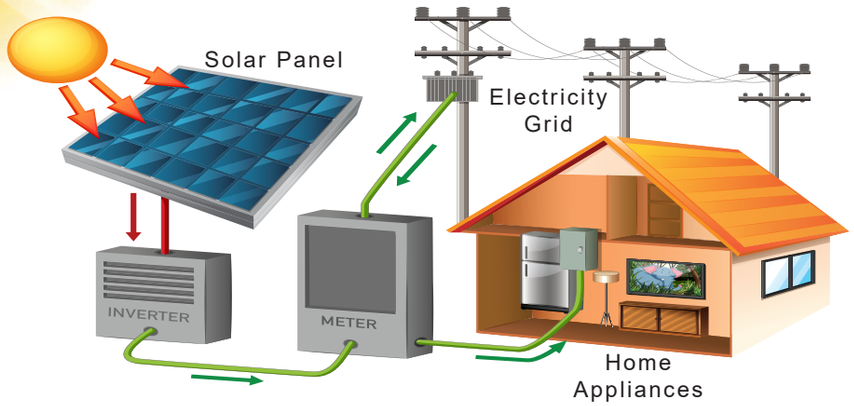

Figure 10: On -Grid Solar System

ii) Off-Grid Solar System

Off-grid solar systems are not connected to the national grid and consumers need to use a battery to store the electricity during daytime foruse at night.

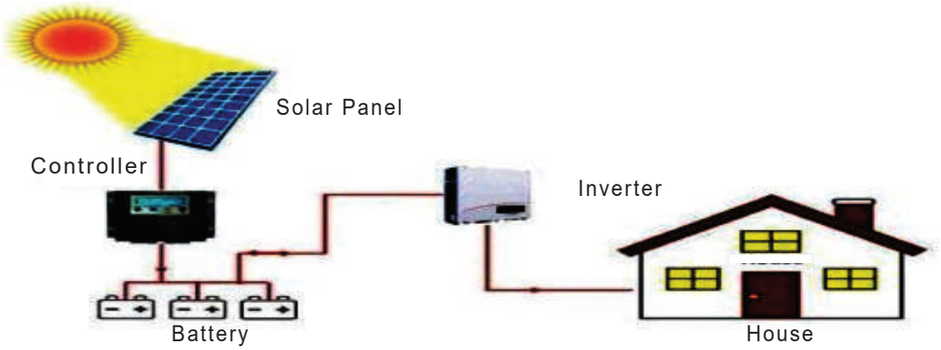

Figure 11: Off -Grid Solar System

iii) Hybrid Solar System

Hybrid solar system is more like an on-grid solar system. It has a battery storage system, which continues the electricity supply during a power cut or/and for night-time use.

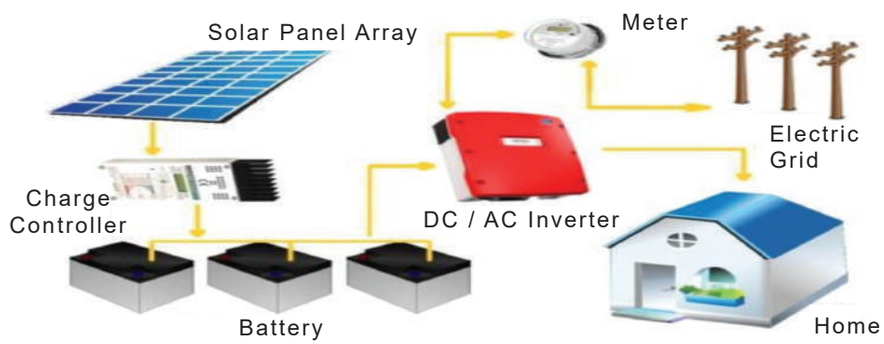

Figure 12: Hybrid Solar System

Bangladesh has both off-grid and on-grid rooftop solar systems, with the majority being on-grid systems. There are currently 1930 net metering rooftop solar systems with a capacity of 84.96 MW and 210 rooftop solar systems excluding net metering with a capacity of 67.995 MW. The figure below shows the number and capacity of rooftop solar systems in Bangladesh.

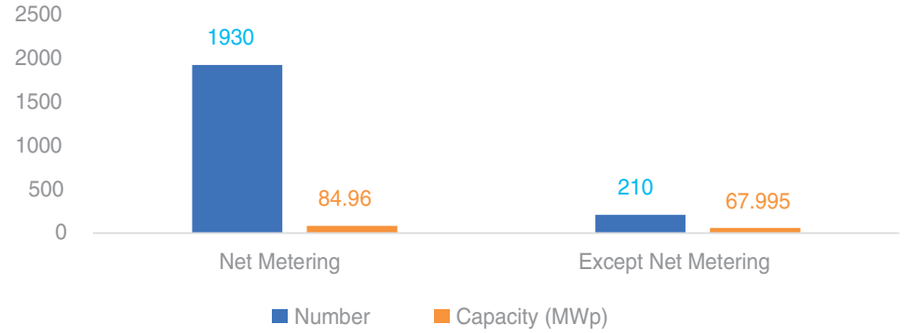

Figure 13: Rooftop Solar Systems (SREDA, 2022)

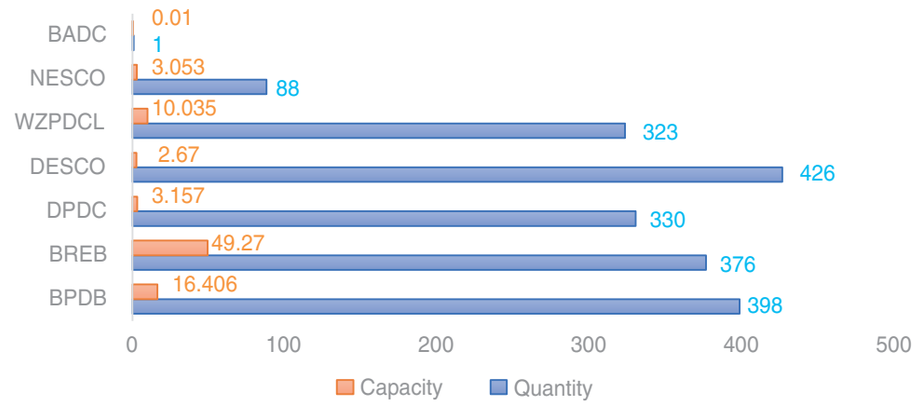

Figure 14: Net Metering Solar Installation by Utility Companies of Bangladesh (SREDA, 2023)

NESCO, WZPDCL, DESCO, DPDC, BREB, BPDB, and BADC are the utility companies that have installed a total of 1942 net metering rooftop solar systems in Bangladesh. Among them, DESCO has installed the highest number of systems, which is 426, but with a low-capacity output of 2.67 MW. WZPDCL has installed 323 systems with the capacity output of 10.035 MW. NESCO installed 88 systems with a capacity of 3.053 MW. On the other

hand, BREB has installed 376 systems with the highest capacity output of 49.27 MW among other utility companies. BPDB installed 398 systems with a capacity of 16.406 MW. Lastly, BADC has recently installed a 10 KWp net metering rooftop solar system.

5.5 Solar Home System

The Solar Home system is one of the most popular and effective technologies in the world including Bangladesh. Currently, there are around 60,37,689 solar home systems installed by different organisations with a total capacity of 263 MW. IDCOL and MODMR are two key organisations for installing solar home systems. However, all of them are off-grid systems. There are ten organi sations that are working to install solar home systems, particularly in remote places of the country, where it is difficult for the national grid to supply electricity. Apart from the remote places of the country, many buildings in cities have installed solar home systems in their residences.

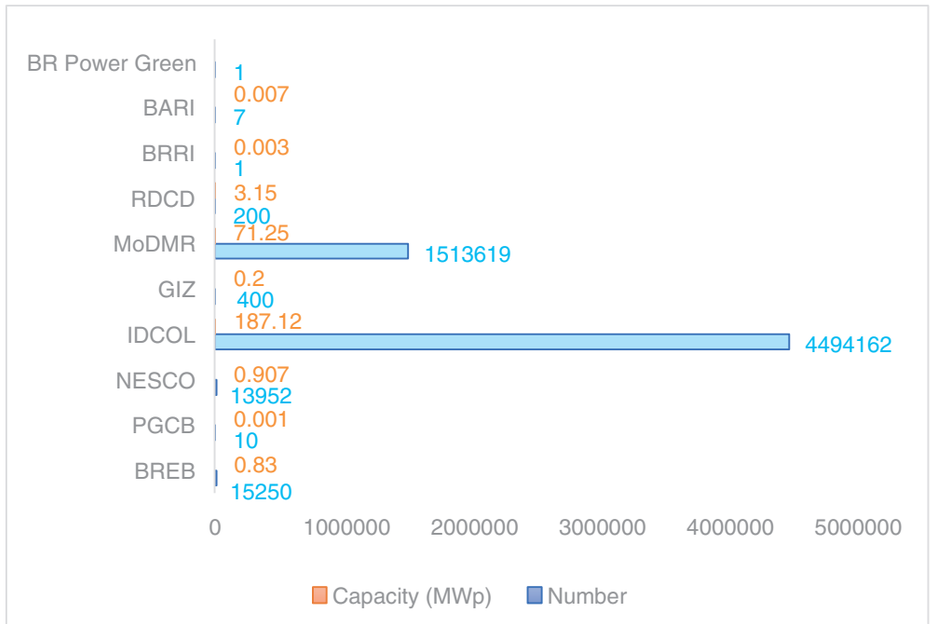

Figure 15: Installation Agencies of Solar Home System (SREDA, 2023)

According to the SREDA, IDCOL has installed 44,94,162 solar home systems with a capacity of 187.12 MW in 64 districts in Bangladesh, which is the largest among all other organisations. Among them, 41,15,593 solar home systems were installed by August 2022.

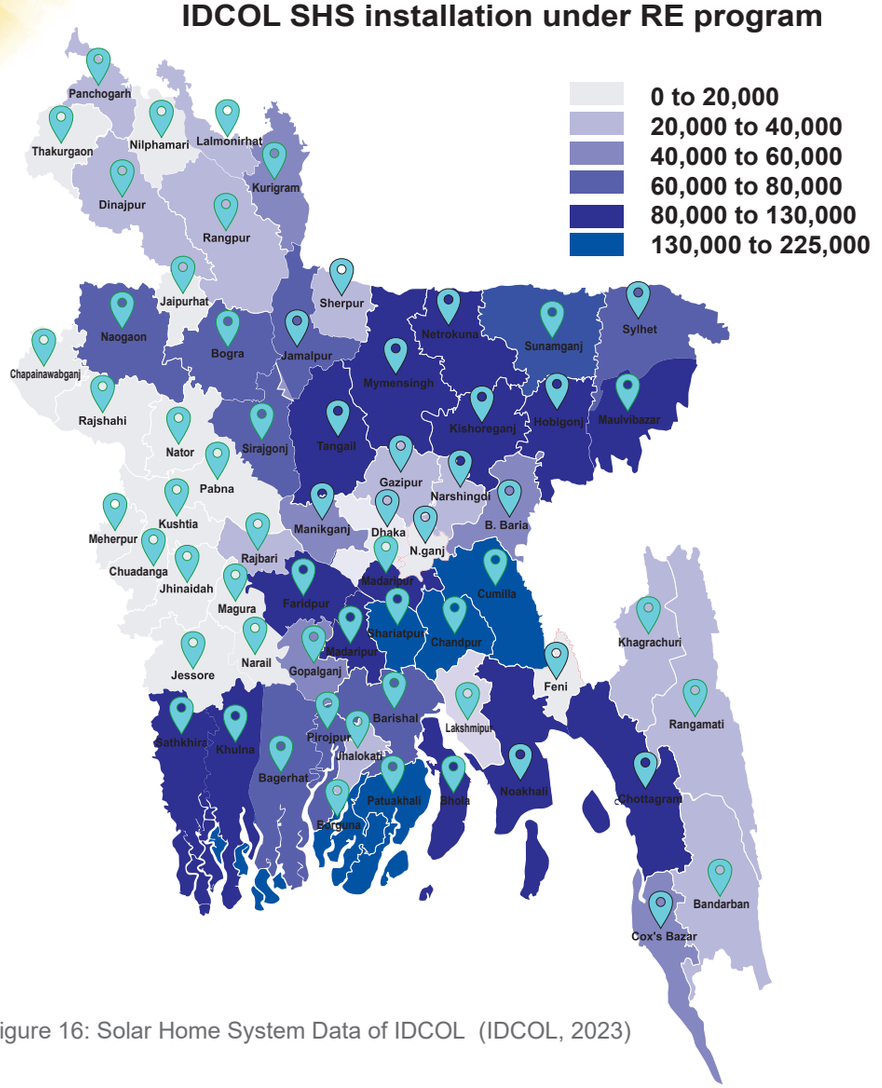

Figure 16: Solar Home System Data of IDCOL (IDCOL, 2023)

MoDDMR, on the other hand, installed a total of 15,13,619 solar home systems with a capacity of 71.25 MW. BARI, BRRI, RDCD, GIZ, NESCO, PGCB, and BREB also installed 29,820 solar home systems in total, with a capacity of 5.098 MW worth solar energy in Bangladesh. BR Power Green has one SHS with a capacity of 0.02 MW Thus, itis evident that the IDCOL and MoDDMR have installed majority of the solar home system in Bangladesh.

5.6 Solar Irrigation System

Agriculture is one of the major driving forces of the economic development in Bangladesh, as it ensures the food security of the country. Agriculture's contribution to GDP in the Fiscal year 2021-2022 was about 11.50 percent (Bangladesh Economic Review, 2022). Irrigation is a key factor in agricultural production. Currently, around 1.34 diesel-based irrigation pumps

are operating in Bangladesh which covers a land of 3.4 million hectares. The Government of Bangladesh has a target to install 150 MW worth of solar irrigation pumps by 2030 to meet the renewable energy target. Around 3,36,00 irrigation pumps are used during the dry season and 50% of these are using diesel generator pumps, which creates a huge scope of solar irrigation pumps (hereinafter SIP) (SREDA, 2023). To promote renewable energy in this sector, the government has introduced the 'Guideline for the Grid Integrated of Solar Irrigation 2020'.

Figure 17: SolarIrrigation Project at Rangpur Division, Bangladesh

IDCOL, BMDA, BADC, and BREB mostly install the solar irrigation system in Bangladesh. Apart from these organisations BRRI, BARI, BARD, and RDA also installed a few solar irrigation pumps across the country.

Figure 18: Solar Irrigation with household use of solar energy at Kalapara, Patuakhali

Farmers are using solar irrigation systems for household use in addition for the purpose of cultivation. The above picture, shows a solar panel apparatus which a woman farmer, Julekha Begum, uses for both agriculture and household work at Kalapara Upazila, Patuakhali District in Bangladesh.There are

eight organisations that have installed a total of 2,865 solar irrigation pumps across the country with a capacity of 52.179 MW as of 2023. IDCOL is one of the largest organisations in terms of installation of solar irrigation pumps in the country, having installed 1523 solar irrigation pumps with a capacity of 42.08MW. BMDA has installed 792 solar irrigation pumps with a capacity of 4.37 MW, BADC has installed 237 solar irrigation pumps with a capacity of 3.13 MW,and BREB has installed 191 solar irrigation pumps with a capacity of 1.69 MW.Additionally, RDA, BARD, BARI, and BRRI have installed a total 80 solar irrigation pumps, respectively, with a combined capacity of 0.468 MW.

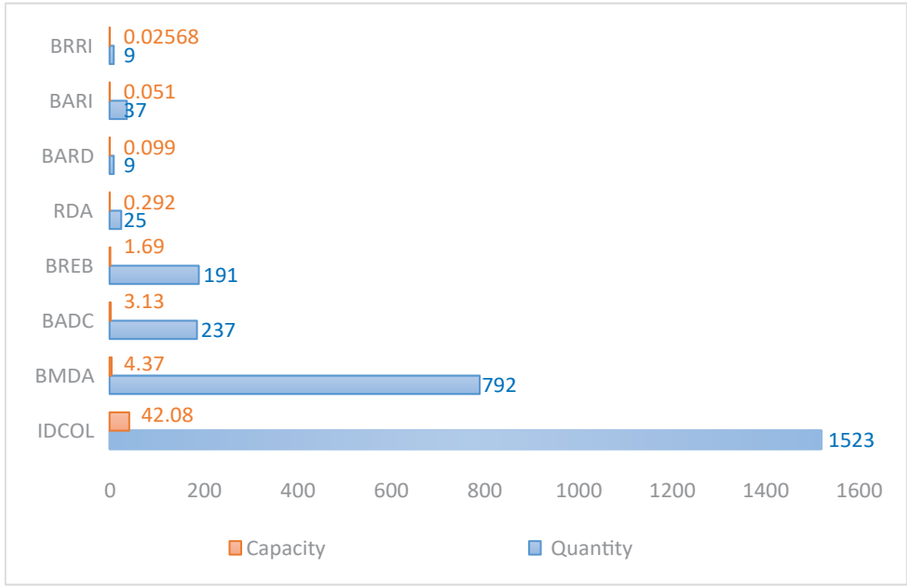

Figure 19: Solar Irrigation Pump (SREDA & Bangladesh Economic Review, 2023)

IDCOL has installed its solar irrigation pumps in eighteen districts of five divisions of the country. In the Dhaka division, IDCOL installed 5 systems with a capacity of 0.028 MW, and in the Chattogram division, 2 solar irrigation pumps were installed with a capacity of 0.015 MW.

A total number of 936 solar irrigation pumps were installed in 6 districts of Rangpur with a capacity of 24.588 MW, a total number of 217 solar irrigation pumps were installed in 3 districts of Rajshahi division with a capacity of 3.256 MW, a total number of 453 solar irrigation pumps were installed in 6 districts of Khulna with a capacity of 14.194 MW (IDCOL, Solar Irrigation Program, 2022).

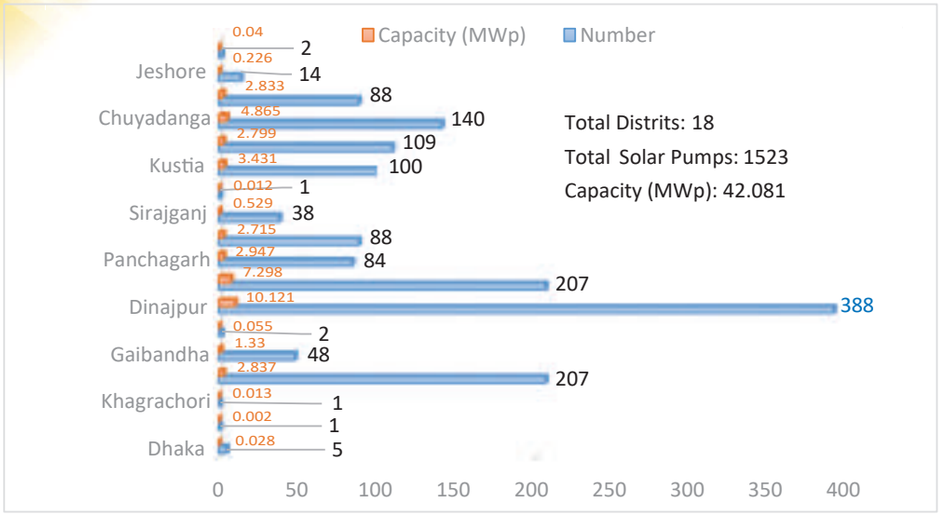

Figure 20: Solar Irrigation System installed by IDCOL (IDCOL, 2022)

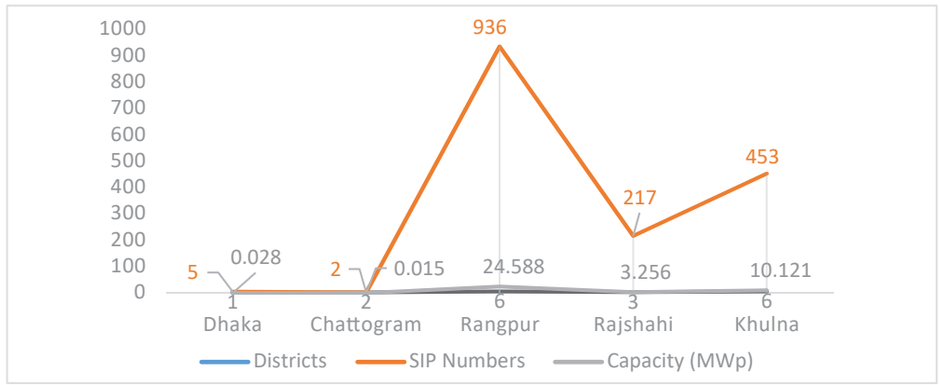

Figure 21: Division Figure of Installed Solar Irrigation Pumps (IDCOL, 2022)

Most of the solar irrigation pumps were installed in the Rangpur division and Dinajpur, with the highest number of 388 systems with a capacity of 10.121 MW. On the other hand, Chattogram has the lowest number of the 2 systems with a capacity of 0.015 MW.

Thus, the data highlights the growing adoption of solar irrigation pumps in Bangladesh, with multiple organisations working to install them across the country. This shift towards renewable energy can have positive impacts on the environment and contribute to more sustainable agriculture practices.

5.6.1 Solar Dug Wells

A dug well can serve the dual purpose of increasing groundwater recharge while conserving rainwater. It is a method of harnessing and storing rainwater to replenish the groundwater table. Furthermore, a solar pump is employed to draw water from the dug well for various purposes, including

irrigation (over a limited area), drinking water, and also domestic use. Apart from the solar irrigation pump, BMDA has installed about 578 solar dug wells with a capacity of 2.3 MW that covers a total of 1150 hectares of land for cultivation of low irrigation crops, food, and household purposes in Rajshahi Division. Another 101 solar-powered dug wells have been installed by BADC in different districts of Bangladesh (Bangladesh Economic Review, 2022).

5.6.2 Agrovoltaics

Agrovoltaics or agrophotovoltaics, combines solar panels with agriculture, optimizing land use and offering income opportunities for Bangladeshi farmers (Alam, 2022). This sustainable practice enhances food security and energy production, protecting crops from heat and UV radiation with solar panel shade, potentially boosting yields (Rahman, 2022). Agrovoltaics reduce water consumption by minimizing soil evaporation, supporting improved agricultural productivity in Bangladesh. However, combines solar panels with agriculture, optimizing land use and offering income opportunities for Bangladeshi farmers.

5.7 Solar Mini-grid

Solar mini-grid is installed in remote places where it is difficult for the national grid to provide the power supply. In Bangladesh, there are 28 solar mini-grid systems installed with a capacity of 5.805 MW. The first Solar mini-grid was established in 2010 at Sandip Upazila, Chittagong with a capacity of 100 kWp. In 2014, another solar mini-grid was installed with a capacity of 104 kWp at Raipura Upazila, Narsingdi. In 2015, five solar mini-grids were operating. Recent research found that the existing 21 solar mini-grid projects in Bangladesh are cost-effective in installation and many of the mini-grids have excess generation capacity compared to the local needs (Aziz & Chowdhury, 2021).

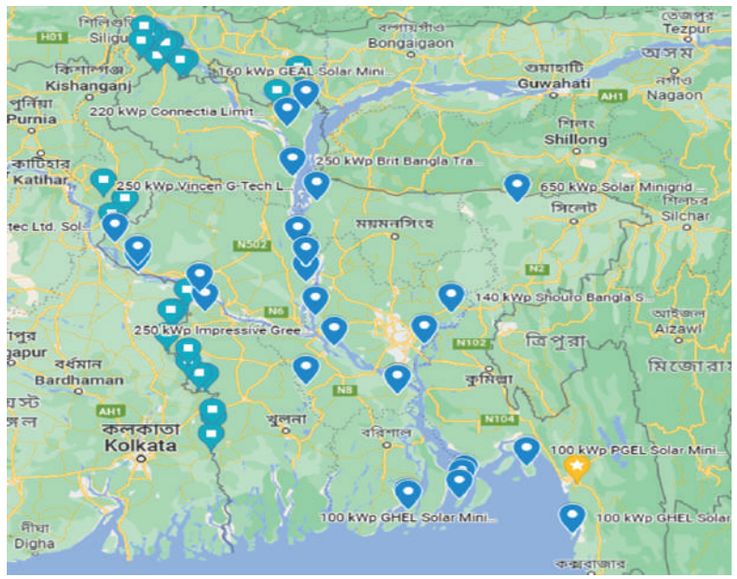

Figure 22: Figure: Map of 28 Solar Mini- Grids in Bangladesh

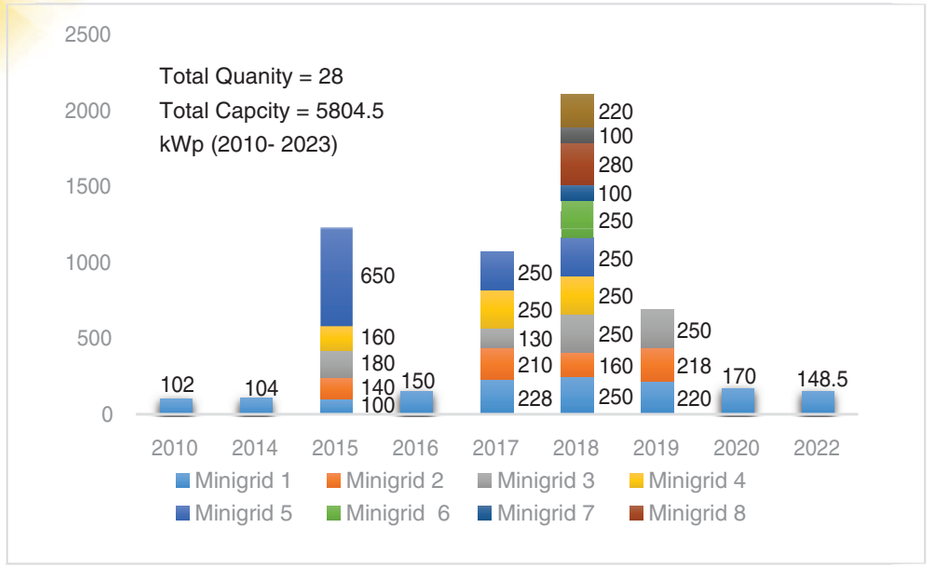

Figure 23: Solar Mini-Grids by Year

IDCOL, NESCO, and BPDB are three key organisations involved in installing 28 solar mini-grids in Bangladesh. Among them, IDCOL has installed 26 solar mini-grids in seven divisions with a total capacity of 5006 kWp.All of these mini-grids are currently in operation and providing power to around 16,000 families. They are also reducing carbon emission of 29,300 tons annually. Financial institutions such as the World Bank, KfW, GPOBA, JIKA, USAID, ADB, and DFID have provided funding for these projects (IDCOL Annual Report, 2021). Additionally, another mini-grid has recently been approved for financing by IDCOL. NESCO has installed one solar mini-grid in Godagari, Rajshahi with a capacity of 148.5 kWp, and BPDB has installed another at Sullah, Sunamganj with a capacity of 650 kWp.

5.8 Solar Nano-grid

There are only two nano-grids installed in Bangladesh by GIZ. One with a capacity of 0.25 kWp at Chandpur and another with a capacity of 0.75 kWp at Dharampasha, Sunamganj, in 2015.

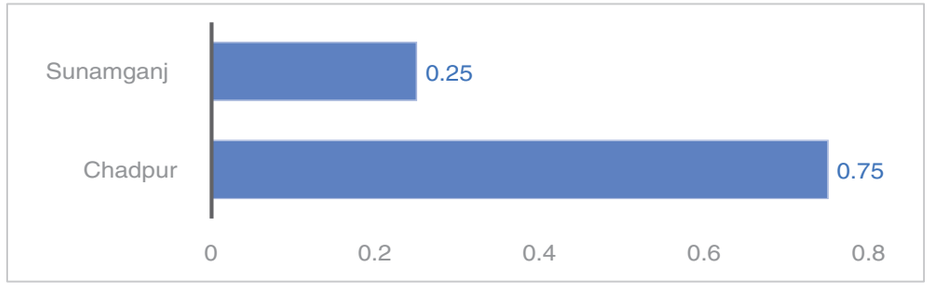

Figure 24: Two Solar Nanogrid's Capacity (2022)

5.9 Solar Street Light

The government of Bangladesh initiated the installation of solar streetlights in different districts of the country. Currently, there are 296,861 solar street lights installed with a total capacity of around 17.065 MW. Among them, 295,798 were installed by MoDMR with a capacity of 17.7 MWp.

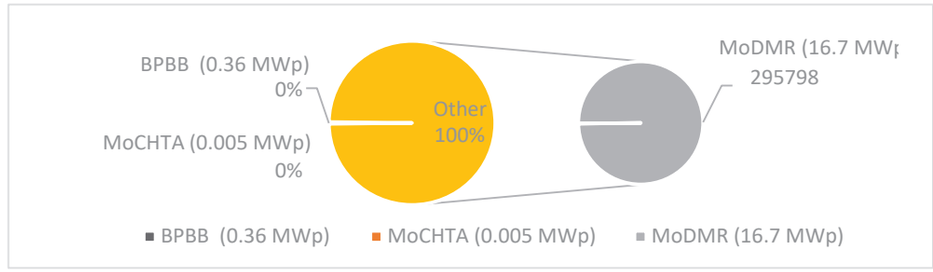

Figure 25: Solar Street Light (SREDA, 2023)

BPDB has installed 800 street lights with a capacity of 0.36 MW and MoCHTA installed 263 street lights with a capacity of 0.005 MW.

5.10 Solar Park

To promote renewable energy, the Government of Bangladesh has introduced ten solar parks with a capacity of 461 MW. 9 solar systems in the park were installed by BPDB with a capacity of 453.4 MW. NWPGCL has installed one with a capacity of 7.6 MW , and Beximco Power Co. Ltd. has installed one with a capacity of 200 MW, (See Table 4).

Organization	Quantity	Capacity (MWp)
BPDB	9	453.4
NWPGCL	1	7.6
Total	10	461

Table 4: Installed Capacity of 10 Solar Parks (2023)

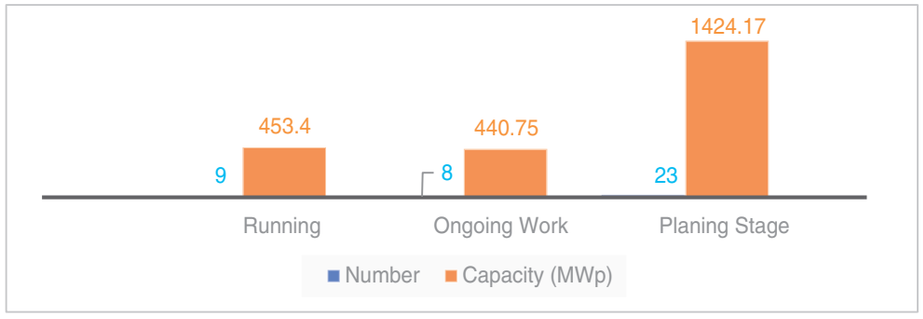

Figure 26: Solar Parks (SREDA, 2023)

The above figure shows that the government has the plan to install another 9 solar parks in different districts of the country with a capacity of 440.75 MW. An additional 23 solar parks are under planning with a capacity of 1424.17 MW. This implies that the government is committed to further increasing the capacity of renewable energy in the country and is actively exploring new opportunities to achieve this goal. These initiatives have the potential to contribute towards sustainable development and reduce carbon emissions in the country.

5.11 Solar Charging Station

Bangladesh has a total of 14 solar charging stations with a total capacity of around 2.82 MW. BREB, BPDB, WZPDCL, DPDC, DESCO, BMDA, and IDCOL are the installing agencies of solar charging stations in different districts of Bangladesh. The following figure indicates the current state of solar charging stations in Bangladesh.

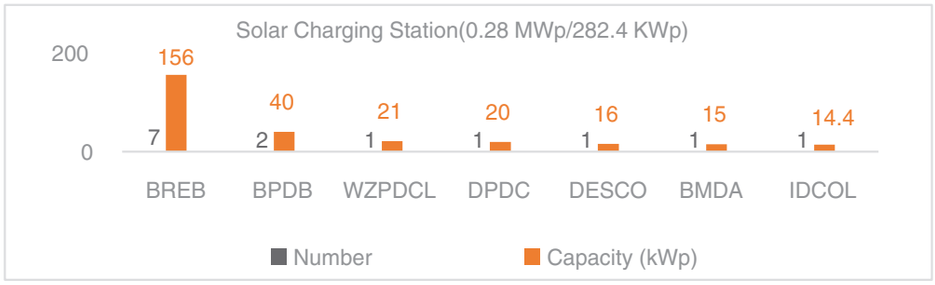

Figure 27: 14 Solar Charging Stations (2023)

The figure shows that BREB has installed seven solar power stations with a total capacity of 156 kWp. Additionally, BPDB, WZPDCL, DPDC, DESCO, BMDA, and IDCOL have each installed one solar charging station with capacities ranging from 14.5 kWp to 40 kWp. However, the data also reflects that the growth of solar charging stations in the country is not as promising as the adoption of solar charging stations has been slow, and there may be challenges that are hindering the growth of this technology.

5.12 Solar Drinking Water System

The Solar drinking water system is one of the most useful technologies which Bangladesh started to install form 2012, particularly in saline-prone areas.

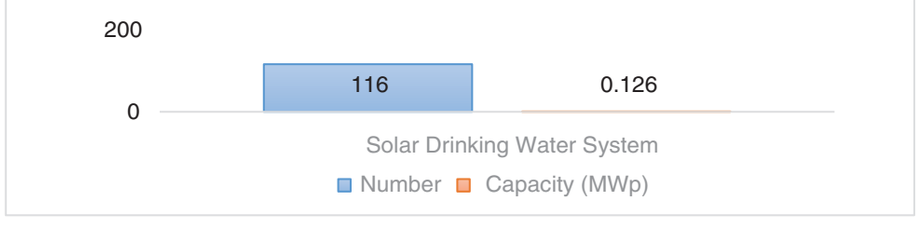

Figure 28: Solar Water System (2023)

The figure describes, currently 116 solar drinking water systems with a total capacity of 0.126 MW have been installed. All of these solar drinking water systems were installed and financed by GIZ between 2012 to 2014. Most of these systems were installed in the Khulna division.

5.13 Solar Powered Telecom BTS

The Base transceiver stations (BTS) are related to the infrastructure of the telecom industry which provides wireless communication between the telecom operator networks and the subscribers. The solar technology in the Telecom BTS service is new to the country.

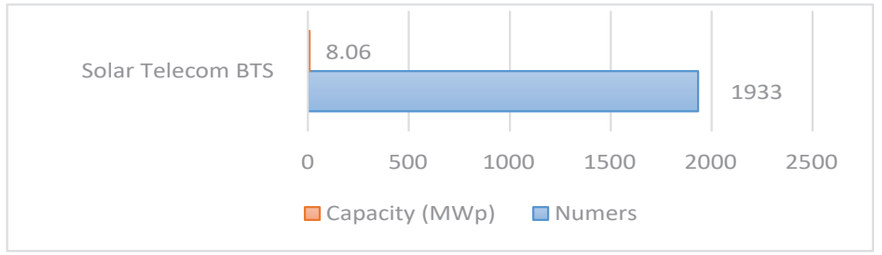

Figure 29: Solar Powered Telecom BTS Data (SREDA, 2022)

This figure shows that Bangladesh has 1,933 off-grid solar power telecom BTS operating with a capacity of 8.06 MW. However, the Solar Powered Telecom BTS is yet to become popular in Bangladesh.

5.14 Challenges of Solar Energy in Bangladesh

Even though there are many prospects for solar energy in Bangladesh, challenges also exist in this arena, which are;

5.14.1 High Installation Cost

The initial installation cost of solar modules is higher in Bangladesh due to absence of manufacturing plants. Most of the solar modules, like panels, inverters, converters etc. are imported from different countries. There are high customs duties, VAT, and tax on solar modules which is impacting the price of the solar modules and other parts.

5.14.2 Off-grid System

Many rooftops solar systems and solar home systems have been installed as part of off-grid systems. The government does not have sufficient information about the capacity and output of off-grid renewable energy, which causes lack of accurate information related to electricity generation and thereby impacting the monitoring process of the government.

5.14.3 Energy Storage and Recycling Solar Residues

Energy storage has always been a challenge for scientists. However, tubular or lead-acid batteries are commonly used to store electricity with an

output ratio of only 50-60%. The use of advanced lithium-ion batteries could reduce these storage limitations with a high output ratio and less environmental concern, but the price of these batteries remains a challenge.

Another issue is that of recycling solar residues including batteries which is largely ignored in policies. This poses a threat to environmental safety in Bangladesh.

5.14.4 Capacity of the Local Distributors

The local electricity distributors of the country do not have the infrastructure to accommodate net metering with their system, and to receive excess electricity, which is generated from the consumer's solar system.

5.14.5 Implementation Problem and Legal Barrier

The Net Metering Guideline 2018 imposes few restrictions Consumers are not allowed to have more than 70% of their sanctioned load, and the maximum output of AC capacity cannot exceed 10 MW. The long installation period of net metering, as mentioned in the guidelines, is also a challenge for expansion of the rooftop solar system. Moreover, only three -phase consumers are eligible for the net metering system, which further limits its reach.

5.14.6 Research, Technological Advancement, and Technical Expatriates

The imported solar panels available in Bangladesh market have an efficiency level of about 20-23%, which poses a challenge to the expansion of solar energy in the country. Additionally, there is a lack of availability of spare parts for solar modules across the country. The shortage of technical experts in rural areas parts of the country regarding solar energy is also a challenge. In rural areas, the unavailability of technical equipment is a key challenge for solar technologies too.

5.14.7 Subsidy and Soft loan

Limited subsidies for solar equipment and accessories are a challenge for the solar system. Not having enough soft loans opportunity and financial incentives for renewable energy projects can hinder the expansion.

6 Hydro Energy in Bangladesh

Hydro energy is the most popular source of renewable energy in the world. Hydropower plants harness the energy of water moving from higher to lower elevations and can be generated from reservoirs and rivers. Hydropower reservoirs are used for providing drinking water, irrigation, flood and drought control, energy supply etc (UN, 2022). In Bangladesh, there is one hydro-power plant in Kaptai, Rangamati district, with a capacity of 230 MW which started operation in 1962. Kaptai Hydropower Plant has 5 units that generate miximum 144 MW of electricity.

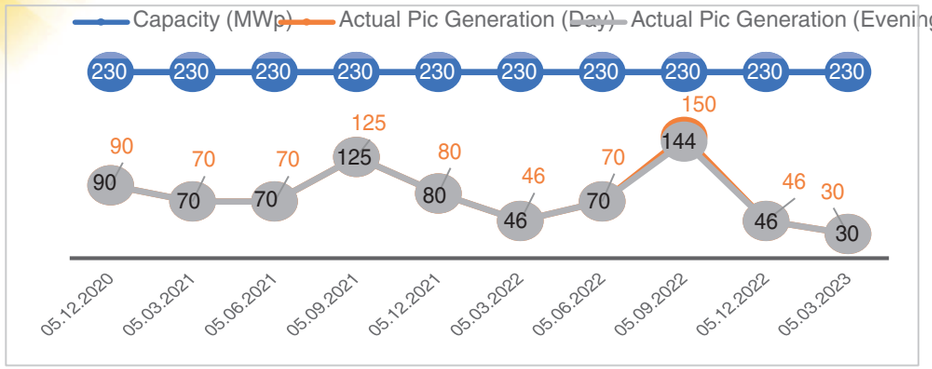

Figure 30: Daily Generation Data of Kaptai Hydro Power Plant (BPDB, 2023)

The graph shows that the plant's electricity generation fluctuates over months, with the lowest point being in March and December 2022 and the highest point being in June, where it generates between 146-150 MW.

Figure 31: Kaptai Hydro Power Plant of Bangladesh

6.1 Challenges of Kaptai Hydropower

Kaptail hydropower has been producing less amount of electricity than its capacity over the years due to fluctuations in water flow and use of old technology.

7 Wind Energy in Bangladesh

Wind power is a form of renewable energy that harnesses the kinetic energy of moving air by using wind turbines located on land, onshore and offshore. For power generation from the wind, the required wind speeds is 5.75–7.75 m/s. There is more than 20,000 km2 of land with a gross wind potential of over 30,000 MW of electricity in Bangladesh (Jacobson, Capozzola, & Lee, 2018).

Currently, there are three wind power plants operating in Bangladesh, two of which are off-grid systems with a capacity of 1 MW each and another one is an on-grid system of 0.90 MW. Until August 2022, a total of 910,609 kWp of

electricity was generated from two off-grid wind power plants, and 285,746 kWp was generated from the on-grid wind power plant (BPDB, 2022).

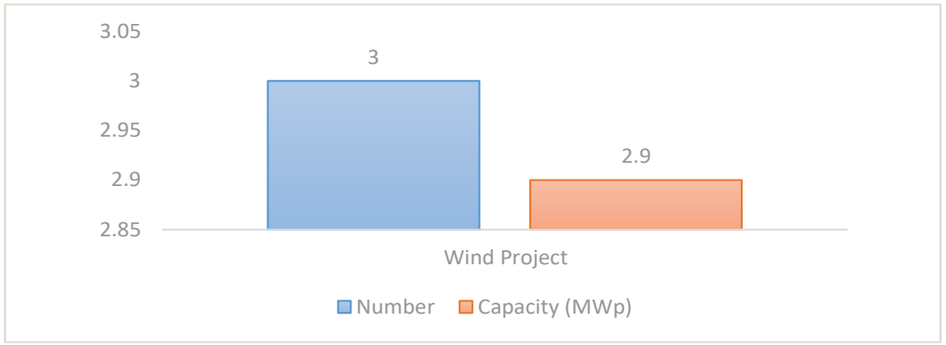

Figure 32: Active Wind Power Plants of Bangladesh (2023)

There are two on-grid wind power plants under the installation stage under BPDB, one with a 2 MW capacity at Sirajganj Sadar Upazila and another with a 60 MW capacity at Chakaria Upazila, Cox's Bazar. Additional seven power plants are in the planning stage with a combined capacity of 355 MW.

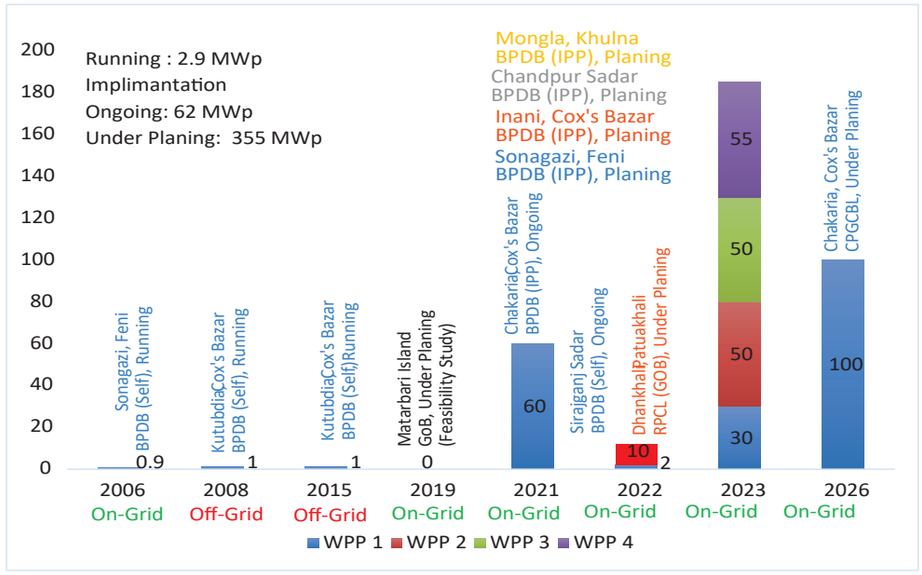

Figure 33: Wind Power Plants of Bangladesh (2023)

The government has already initiated to install seven new wind power plants, and the largest one will have a capacity of 100 MW and will be built in Chakaria, Cox's Bazar within 2026 by CPGCBL. The smallest new wind power plant will have a capacity of 2 MW and is planned to be built in Sirajganj Sadar by 2022 under BPDB. Currently, there are three wind power plants in operation with a total capacity of 2.9 MW. By 2022, three more wind power plants were expected to be built with a total capacity of 72 MW.

However, there are still two power plants under construction by BPDB, one with a capacity of 60 MW in Chakaria and another with a capacity of two MW in Sirajganj. Construction for another ten MW wind power plant at Dhankhali has not yet started. BPDB is planning to establish a total of six wind power plants, with five wind power plants having a total capacity of 185 MW by 2023 and another 100 MW wind power plant by 2026. US- DK Green Energy Ltd. is setting up the largest wind power plant with a capacity of 60 MW at Khurushkul in Cox's Bazar by June 2023.

7.1 Challenges of Wind Power Plants

Insufficient investment, and technical expertise are the key challenges for the wind power sector of the country. Moreover, the delay in the completion of wind power projects also creates challenges to the expansion of wind power plants in Bangladesh.

Another challenge is installing wind power plants in many coastal areas of the country, but installed, the country will be able to mitigate disaster risk by using modern technology.

8 Biogas to Electricity in Bangladesh

Biogas is a mixture of methane and carbon dioxide and is produced from the fermentation of organic materials, which is suitable for cooking, heating, electricity generation, and transportation fuel (Muth, Aalto, Mylläri, Rönkkö, & Harsia, 2021). Generating electricity from biogas is not a new technology and is widely used all over the world. Bangladesh is no exception. One study found that six major cities, such as, Dhaka, Chattogram, Rajshahi, Sylhet, Barisal, and Khulna generate about 8,000 tons of solid waste every day, which creates a huge scope for biogas technology to generate electricity. Among them, Dhaka city contributes 70% of this solid waste (Abedin & M, 2015).Currently, there are 87,536 biogas plants installed in different districts of Bangladesh. Most of the biogas plants are off-grid systems therefore, there is no actual data regarding the capacity of the biogas. IDCOL and BCSIR are two major organisations that installed most of the biogas plants across the country. Apart from them, GIZ and MoDMR also installed a few biogas plants in Bangladesh.

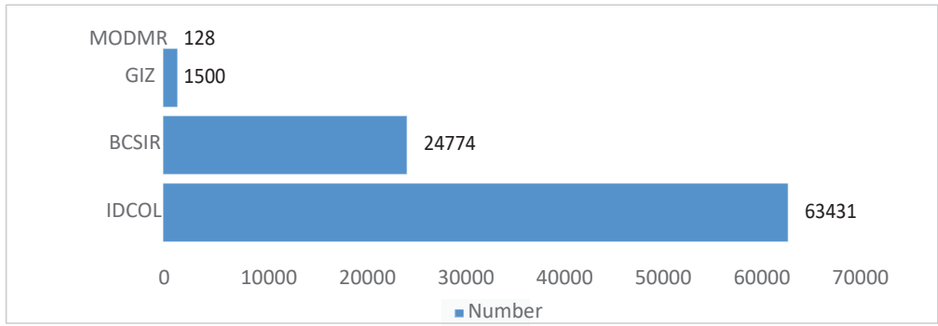

Figure 34: Number of Bigas Plants Bangladesh (2023)

The breakdown suggests, IDCOL alone installed 63431 biogas plants in Bangladesh, BCSIR installed 24774 biogas plants, GIZ installed 1500 biogas plants, and MoDMR installed 128 (the lowest number.) The key challenges faced in the implementation of biogas technology are mentioned below;

8.1 Challenges of Biogas Technology

8.1.1 Collection and Supply

The collection and supply of biogas fuels is a significant issue in the adoption and expansion of biogas technology in Bangladesh. There is currently no organisation responsible for the collection or publication of data on the supply and consumption of biogas fuels in the country, which makes it difficult to develop a sustainable system for biogas technology.

The lack of a proper supply chain for biogas fuels is another significant challenge. The supply of organic waste is highly dependent on the location of the biogas plant, and transportation of waste to the plant can be expensive.

8.1.2 Lack of Technical Suppliers

The lack of technical suppliers is also a major challenge for the development of biogas technology in Bangladesh. There are only a limited number of organisations and technicians available to provide technical support and maintenance services to the biogas plants. This is especially true for rural areas where the majority of biogas plants are installed.

8.1.3 Support of Government

Another challenge in the implementation of biogas technology is the price of the technical equipment. To make biogas technology more financially viable, the government needs to be more supportive of the manufacturers, and suppliers by reducing tax, and VAT on biogas equipment. Moreover, the government needs to develop local production of the necessary equipment and train people to achieve the latest technical expertise in their field. Without a sustainable policy, it will not be possible to promote biogas technology in Bangladesh.

9 Biomass to Electricity in Bangladesh

In modern biomass systems, electricity can be generated from organic materials like wood, crops, or trees, residues from agriculture and forestry, and other organic wastes (UN, 2022). Generating electricity from biomass technology has a lot of potential worldwide but it is not popular in Bangladesh. There is only one off-grid biomass system operating with a capacity of 400 kWp at Thakurgaon, installed by IDCOL.

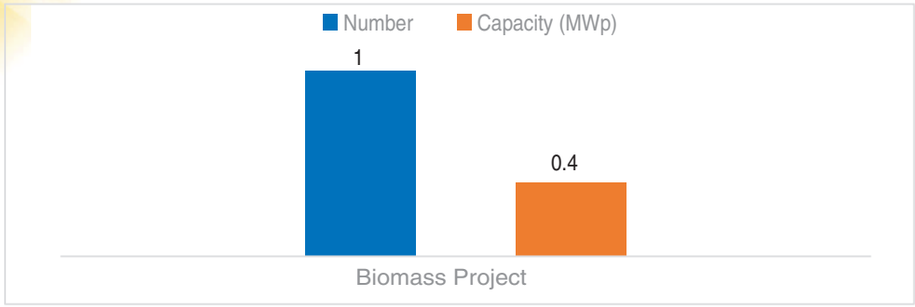

Figure 35 : Biomass based Power Plant and Capacity (SREDA,2023)

9.1 Challenges of Biomass Technology

The government is not motivated enough to promote biomass technology in Bangladesh due to operational challenges such as costly transportation cost, technology and equipment shortage and land use issues. However, few organisations are installing biomass plants, but they lack the drive due to constraints of excessive investment and high risk operating costs, which scattered farmers and small scale fuel companies may not be able to afford.

10 Tidal Wave Energy

The main idea of tidal wave technology is to utilise the ocean wave and generate energy by using turbine and paddles. The tidal wave is becoming popular in a few countries as a great source of renewable energy. The following picture shows the tidal wave power plant in Jaffa, Israel.

Figure 36: Israil's 60 kwh Tidal Power Plant in Jaffa

Many countries have started to generate energy from tidal wave technology like China, France, Israel etc. Bangladesh does not have any tidal wave power plant at present; however, it could be a potential source of renewable energy for the country as it has 47,201 square kilometres of coastal area.

10.1 Challenges of Tidal Wave Energy in Bangladesh

10.1.1 Availability of Technology

The challenge of tidal wave energy in Bangladesh can be attributed to the lack of availability of technology. Therefore, there is a need to collaborate with international organisations and other countries to develop the necessary technology and expertise for harnessing tidal wave energy.

10.1.2 Research and Innovation

There is a need to create an opportunity for research and innovation for the development of tidal wave energy in Bangladesh. It would require allocation of proper funds.

10.2 Hydrogen Energy

In recent days, hydrogen energy is becoming a popular source of renewable energy across the world, particularly in Australia, China, France, Germany, Italy, Japan, Poland, South Korea, Spain, the USA, United Kingdom etc. Moreover, our neighbouring country, India, launched its National Hydrogen Mission in 2021 and targeted to be energy independent by 2047,also in line with using green hydrogen energy. This hydrogen energy can be a good source for generating electricity. Chittagong University of Engineering and Technology (CUET) has been experimenting to produce hydrogen fuel and successfully used it in a hydrogen car in Chattogram. However, there are three main types of hydrogen energy technology available in the world, which are;

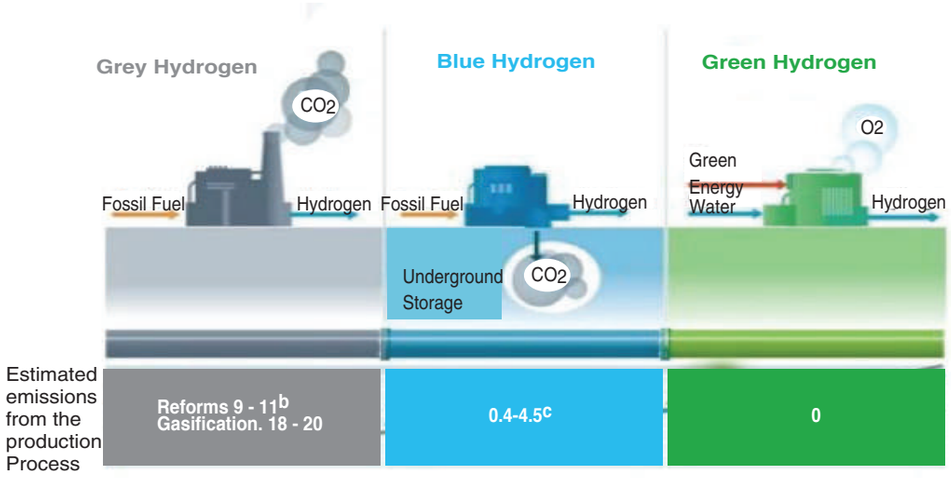

Figure 37: Hydrogen Energy Technologies

10.2.1 Grey Hydrogen

Gray hydrogen is produced by splitting the natural gas into hydrogen and CO2 by using Steam Methane Reforming (SMR) or Auto Thermal Reforming (ATR) technology and CO2 is released into the atmosphere.

10.2.2 Blue Hydrogen

Steam Methane Reforming (SMR) or Auto Thermal Reforming (ATR) technology normally produces blue hydrogen by splicing natural gas into hydrogen and CO2 and capturing CO2 and storing it (called as Carbon Capture Usage and Storage).

10.2.3 Green Hydrogen

Green hydrogen is produced by using electrolysis technology which splits water into hydrogen and oxygen and oxygen can be released into the atmosphere without impacting the environment.

10.3 Challenges of Hydrogen Energy

10.3.1 Technology and Expertise

The technology of hydrogen energy generation is not available in Bangladesh as Bangladesh does not have the adequate expertise to operate and provide technical assistance to solve any problem relating to hydrogen production and storage.

10.3.2 Storage

Hydrogen energy has the potential to be a clean and renewable energy source for Bangladesh, but there are big challenges in storing it. The lack of storage facilities makes it difficult to transport and distribute hydrogen to different parts of the country. The high costs of setting up and maintaining the necessary infrastructure for hydrogen energy are also a significant barrier.

10.3.3 Safety and Security

Hydrogen is a highly flammable gas, and there are concerns about ensuring safety and security in production and storage. It is required to develop new safety standards and regulations to ensure hydrogen use, production, storage, and distribution.

10.4 Ammonia

Ammonia is one of the known global commodities which is used for nitrogen fertiliser and may also be used as zero-carbon fuel for power generation. In recent times, ammonia is produced mainly from fossil fuels that cause around 1% of the total greenhouse gas emissions of the world (IRENA, 2022). In a joint study of the University of Oxford and Cardiff University, it

was found that a system using water electrolysis to provide a hydrogen supply and extract nitrogen from the air under the Haber-Bosch process can produce green ammonia without emitting Carbon dioxide (Siemens Energy, 2022). The Haber-Bosch process is a chemical process for producing ammonia by combining hydrogen and nitrogen gases under high pressure and temperature. Ammonia can then be used as a source of energy in fuel cells, providing electricity and heat through electrochemical reactions. However, in the recent Integrated Energy and Power Master Plan, the government is planning to increase the target gradually up to 5% by 2050 and reduce to 1% after this period. The objective is to increase the use of green energy, including gas and hydrogen, for generating electricity (JICA, 2022).

10.5 Challenges Usage of Ammonia for Producing Energy

10.5.1 Technological Advancement

Generating electricity from ammonia is a new idea for Bangladesh and there is a lack of expertise in this field.

10.5.2 Pollution and Health Hazards

The key challenge is the possibility of pollution and health hazards. Ammonia production involves the use of fossil fuels or renewable energy sources, and the production process can result in emissions of greenhouse gases, which can pollute the environment.

10.6 Waste to Energy

Waste-to-energy (WTE) is the process of converting municipal solid waste (MSW) into energy. This can be done through a variety of technologies, including incineration, gasification, and anaerobic digestion (EPA, 2023). WTE is a process that involves converting solid waste into usable energy, such as electricity, heat, or fuel. The primary goal of WET is to reduce the volume of waste going to landfills while simultaneously producing a sustainable energy source. In the specific context of Bangladesh, a country grappling with limited land availability, the WTE approach presents a dual solution by mitigating waste accumulation and harnessing energy from the approximately 23,688 tons of solid waste generated in urban areas, of which around 70% is organic (Mostakim, Arefin, Islam, Shifullah, & Islam, 2021). The government of Bangladesh is currently promoting WTE as a way to improve waste management and reduce greenhouse gas emissions. A significant step was taken in 2022 when the government partnered with WTE Power Plant North Dhaka Private Limited, an enterprise established in collaboration with China Machinery Engineering Corporation (CMEC). Their joint effort aims to construct a 42.5 MW WTE facility in Aminbazar, Dhaka by the year 2024 (TBS, 2021). This initiative not only tackles the urgent waste disposal challenges but also makes a substantial contribution to the national energy grid.

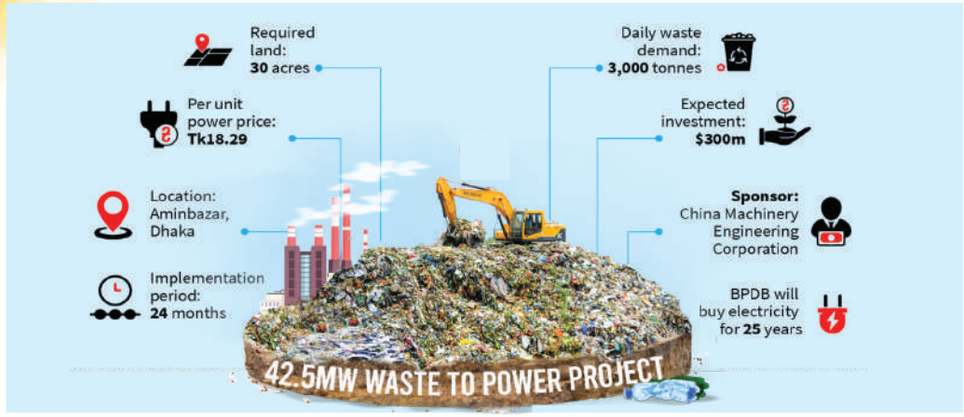

Figure 38: Waste to Energy Plant (TBS, 2023)

10.7 Challenges of Waste to Energy

10.7.1 Long-Term Contracts and Rate Fluctuations

The contract to purchase electricity for 25 years at a fixed rate of Tk18.29 per unit might become problematic if energy prices fluctuate significantly over the contract period (TBS, 2021). The fixed-rate could lead to financial strains or losses for either party depending on market conditions.

10.7.1 Environmental Impact of Incineration

Incineration, the technology chosen for waste-to-energy conversion in this project, raises environmental concerns. The process emits greenhouse gases and air pollutants, potentially contributing to air quality degradation and climate change. Additionally, the ash residue from incineration can contain toxic substances that require proper disposal (Khan, Mubeen, & Yan, 2022).

10.8 Nuclear Energy

Nuclear energy is the energy in the nucleus or core of the atom. Electricity is generated through the process of nuclear fusion by generating heat (Galindo, 2022). Nuclear energy is one of the most popular technologies to generate electricity world wide. In keeping with this strength Bangladesh has begun to construct its first nuclear power plant at Rooppur, Pabna; next to the river Padma with a capacity of 2.4 GW. The construction of the first unit begunin November 2017 and is expected to start its operation in 2023 and the construction of the second unit was started in July 2018. Rosatom, a subsidiary of Russia's State Atomic Energy Corporation is constructing the power plant, consisting of two water-cooled and moderated power reactors (Fisher, 2021). Uranium-235 (235U or U-235) is used as one of the fuel sources in the Rooppur Nuclear Power Plant in Bangladesh. Uranium-235 is a radioactive isotope of uranium that can undergo fission, which releases a tremendous amount of energy. Uranium-235 (235U or U-235) has a half-life of approximately 703.8 million years (WNA, 2021). The fission process occurs inside the reactor, where uranium-235 is bombarded by neutrons,

commitment period, parties committed to reducing GHG emissions by at least 18% below 1990 levels, with a different composition of parties compared to the first commitment period. The amendment entered into force on December 31, 2020, with 147 parties depositing their instrument of acceptance.

11.1.3 The Paris Agreement

The Paris Agreement is an internationally binding agreement on climate change that was adopted by 194 parties at the 21st Climate Conference in Paris on December 12, 2015, and came into force in 2016 (United Nations, 2022). Bangladesh signed the agreement on April 22, 2016, and ratified it on September 21, 2016. The goal of the agreement is to reduce greenhouse gas emissions and provide zero-carbon solutions by 2030, with a key target of limiting global warming to below 2 degrees Celsius, preferably below 1.5 degrees Celsius (UNFCC, 2022). As a signatory of the agreement, Bangladesh is obligated to reduce its carbon emissions as well.

The government of Bangladesh has submitted its update on energy industries, industrial processes and product use, agriculture, forestry, and other land and waste sectors under the Nationally Determined Contributions (NDCs) of the Paris Agreement (Zahir, 2021). However, the increasing use of fossil fuel-based energy sectors instead of renewable energy is jeopardising the achievement of the agreement's goals.

11.1.4 The 26th UN Climate Change Conference (COP 26)

The 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26) took place in Glasgow, UK in November 2021. The conference established four goals: i) securing global zero carbon emissions by mid-century and the ultimate target of global warming below1.5 degrees celcius within reach, ii) adapting to protect communities and natural habitats, iii) mobilising finance of at least $100 billion every year, and iv) working together to deliver. To achieve the first goal, certain plan of action have to be put into execution, including accelerating the phase-out of coal, curtailing deforestation, speeding up the transition to electric vehicles, and encouraging investment in renewable. However, Bangladesh is increasingly investing in coal-based power plants, and the investment in renewable is inadequate to meet the target of achieving 40% of renewable energy by 2041 (Hasina, 2021). Although the number of electric vehicles in the country has increased, and the government has taken some initiatives to curtail deforestation and plant trees, Bangladesh, (being one of the most climate-affected countries), is yet to receive the promised $100 million climate fund (United Nations, 2022). To meet the conference's targets, it is essential to work together and increase investment in renewable instead of fossil fuels and more importantly distribute the promised climate fund among vulnerable countries.

11.1.5 *Sharm el-Sheikh* Climate Change Conference (COP 27)

The COP 27 took place in Egypt in November 2022 and the key focus was the “loss and damage” funding for vulnerable countries. A transitional committee was established to monitor the climate funds. The Sharm el-

Sheikh Implementation Plan focused on the global transformation to a low-carbon economy. The conference expressed deep concern regarding the $100 billion climate fund for developing and underdeveloped countries, which has not been delivered (United Nations, 2022). Climate-vulnerable countries like Bangladesh face immense challenges due to climate change impacts, including loss and damage. In many cases, these impacts violate basic human rights and have significant social, economic, and environmental consequences. Therefore, it is important to provide compensation for the loss and damage caused by climate change and to ensure that the affected communities are supported in their efforts to adapt to the changing climate. It is critical that the international community comes together to address this issue and provide necessary funding, resources, and technology to support countries in need.

11.2 Domestic Instruments

11.2.1 Electricity Act, 2018

The Electricity Act, 2018 has been enacted in Bangladesh with the aim of reforming and developing the power generation, transmission, supply, and distribution sectors by modifying and replacing the previous Electricity Act, 1910. Significant reforms have been made to the electricity regulatory framework in Bangladesh to shift from public to private service, reduce regulation, establish a regulatory commission, and move towards corporate governance.

11.2.2 Bangladesh Energy Regulatory Commission Act, 2003

The Bangladesh Energy Regulatory Commission (BERC) was established in 2004 to promote transparency, competition, and consumer protection in the energy sector of Bangladesh. BERC is responsible for determining prices for electricity, gas, and petroleum, granting licenses, implementing standards for quality services, and collecting and publishing statistical data. Private companies with agreements executed before the Act came into force are treated as licensees for energy-related activities. However, the government amended section 34A of this Act by an ordinance in 2022 to adjust gas and electricity tariffs, without public hearings. This ordinance was validated by the parliament on 31 January 2023.

11.2.3 Quick Enhancement of Electricity and Energy Supply (Special Provisions) Act, 2010 and its amendments

The Quick Enhancement of Electricity and Energy Supply Act 2010 and later on its amendments enable special provisions for improving electricity and energy supply to meet demands in various sectors and allow for quick implementation of plans for importing energy from abroad and extraction of minerals related to energy. However, the Act does not include provisions for renewable energy sources.

11.2.4 Private Sector Power Generation Policy of Bangladesh, 2008

The Private Sector Power Generation Policy of Bangladesh was introduced to address the increasing demand for electricity in the country. This policy enables private investors to build, own and operate power plants with the government allocating project sites and fuel supplies. The government will set tariffs for purchasing power and provide fiscal incentives such as tax exemptions and import duty exemptions to private power generating companies. The Power Cell will be responsible for evaluating proposals and negotiating contracts.

11.2.5 The Sustainable and Renewable Energy Development Authority Act,2012

The Bangladesh government has established an authority on sustainable and renewable energy by enacting The Sustainable and Renewable Energy Development Authority Act, 2012 with the aim of promoting renewable energy and energy efficiency, to ensure energy security and mitigate risks associated with natural calamities from global warming. SREDA's responsibilities include coordinating government efforts, standardising and labelling products, piloting new technologies, creating an investor-friendly environment, conducting research and development, and creating awareness of renewable energy and energy efficiency. The Act also established the Sustainable and Renewable Energy Development Authority Fund.

11.2.6 Renewable Energy Policy of Bangladesh

The Renewable Energy Policy 2008 of Bangladesh aims to promote the use of renewable energy resources such as solar, wind, biomass, hydro, geo-thermal, and tidal wave. The policy prioritises promoting efficient and environmentally friendly use of renewable energy, developing sustainable energy supplies, and creating an enabling environment. Tax exemptions and subsidies are also provided to encourage public and private sector investment in renewable energy projects. The policy sets a target to meet 5% of the country's total power demand by 2015 and 10% by 2020.

11.2.7 Onshore Wind Power Projects Installation Guideline 2021

The Sustainable and Renewable Energy Development Authority (SREDA) has introduced the Onshore Wind Power Projects Installation Guideline 2021 to promote the development of efficient, cost-effective, and environmentally friendly land-based wind energy projects. These guidelines cover a range of issues, including site selection and feasibility, quality assurance, micro-siting, grid code, monitoring, energy storage, decommissioning, community awareness, grievance redress, and implementation. The guidelines provide project developers with best practices in the wind sector, ensuring the availability of resources, proper land use, required transport logistics, quality power dispatch, and a risk-free business environment. However, despite having 2.9 MW of wind power capacity and a few set-ups under construction, wind power does not currently contribute to the national grid of Bangladesh (BPDP, February 2023).

11.2.8 Guidelines for the Grid Integration of Solar Irrigation Pumps 2020

The Guidelines for the Grid Integration of Solar Irrigation Pumps in Bangladesh was adopted by SREDA under the ministry of power energy and mineral resources in 2020. The ministry aims to prioritise the use of renewable energy and the appropriate utilisation of excess electricity. They provide technical specifications for solar irrigation pumps and guidelines for their installation, commissioning, and power conditioning units. The guidelines define the roles and responsibilities of stakeholders involved in the installation and maintenance of solar pumps, and they specify safety standards to be followed. The guidelines also address net metering policies for excess power generated by solar pumps and provide recommendations for their implementation, billing, and settlement. These guidelines promote renewable energy in the agriculture sector of Bangladesh and provide a framework for the integration of solar pumps into the national power grid while ensuring safety, efficiency, and sustainability.

11.2.9 Bangladesh Energy and Power Research Council Act, 2015

The Bangladesh government has established a council for research on power and energy, including renewable energy, by the Bangladesh Energy and Power Research Council Act, 2015. BEPRC aims to fund applied research projects that develop technologies, tools, and strategies to overcome technological and economic barriers to increasing the use of renewable energy in Bangladesh.

11.2.10 Net Metering Guideline 2018

In 2018, the Bangladesh government introduced the Net Metering Guidelines to promote renewable energy by encouraging the installation of rooftop solar systems at the consumer level by connecting with the national grid. The government is currently emphasising the installation of net metering systems in industries and individuals to track the electricity generation from rooftop solar systems.

To install a net metering system, a consumer needs to apply to the local power distribution unit and fulfill the requirements specified in the guideline. These requirements include having a three-phase connection and the maximum output capacity of the renewable energy system on the AC side of inverters not exceeding 70% of the consumer's sanctioned load. Additionally, the maximum output AC capacity of the renewable energy system is limited to 3 MW (Power Division, 2018). The guideline discourages the OPEX model, in which an investor or project developer invests in a solar project for a consumer and signs a long-term purchase agreement for tenure and tariff. On the other hand, in the CAPEX model, all installation costs of the solar system are borne by the consumer, and the maintenance service is provided by a hired Engineering, Procurement, and Construction company.

Figure 39: Rooppur Nuclear Power Plant, Bangladesh

leading to the release of energy that is harnessed for generating electricity (BAEC, 2022). Moreover, the government is also looking to install another nuclear power plant soon

10.9 Challenges of Nuclear Energy

10.9.1 Safety and Security

Safety and security are always a pressing issue for nuclear power plants, especially after nuclear disaster history, such as, the Chernobyl Nuclear Disaster (INES Level 7), Ukraine in 1986; Fukushima Nuclear Disaster (INES Level 7), Japan in 2011; Kyshtym Nuclear Disaster (INES level 6), Russia in 1957; Wind scale Fire Nuclear (INES level 5), UK in 1957; Three Mile Land Nuclear Accident (INES level 5), USA in 1979 etc. Academics and environmental activists have also expressed their concerns about the threats and risks of the Rooppur nuclear power plant in Bangladesh, which is considered the biggest challenge. However, the government has assured that it has taken all types of advanced safety and security measures.

10.9.2 Consumption of Water

For generating 2 GW of electricity, the nuclear power plant will consume approximately 1,04,000 gallons of freshwater per minute (Rahman, 2022), which may impact the water flow of the river Padma thereby affecting fisheries and as such the livelihood of the people, who are dependent on the river. Moreover, the ecosystem could also be endangered because of the massive water consumption of the Rooppur nuclear plant. Considering the facts, the government has established cooling treatment plants to reuse and recycle water.

10.9.3 Nuclear Waste Management

During the nuclear fuel cycle, nuclear power plants produce high-level radioactive waste, which is generated from the used fuel rods that have become highly radioactive due to the fission process. One of the main waste

management challenges is associated with Uranium-235 (235U or U-235), as it can take several thousands of years for the fuel to decay completely (NEI, 2022). However, with the help of new technology, this timeline could be reduced to 300 years (WNA).

The disposal of nuclear waste poses a significant challenge due to its long half-life and potential environmental and health risks. Therefore, proper storage and disposal methods must be implemented to minimise the risk of radiation exposure to humans and environment. Several waste management strategies have been proposed for nuclear waste, including deep geological repositories, and spent fuel reprocessing. Deep geological repositories involve the placement of nuclear waste in deep geological formations, while spent fuel reprocessing involves the separation of nuclear waste into reusable and non-reusable components (IAEC, 2016).

11 Domestic and International Instruments of Climate Change and Renewable Energy Commitments

Climate change is a global challenge that requires collective action to mitigate its impacts. There are several international and national legal instruments that have been enacted in the last two and half decades which are mentioned below.

11.1 International Instruments

11.1.1 Sustainable Development Goal (SDG)

The Sustainable Development Goals (SDGs) were introduced by the UN after the successful implementation of the Millennium Development Goals. The SDGs aim to create a better future for everyone by addressing global challenges such as poverty, inequality, and climate change. To effectively measure progress, 17 goals have been set across a range of areas, including health, education, economic growth, and climate action.

Goal 7 is the most relevant one for renewable energy, as it intends to ensure access to affordable, reliable, sustainable, and modern energy for all (United Nations, 2022). The countries that are using renewable energy more than non-renewable energy sources are making more progress to achieve SDG goals by 2030 (Güney, 2019). To achieve goal 7, all members of the UN need to reduce the use of fossil fuels and increase the production of renewable energy.

11.1.2 Kyoto Protocol and Doha Amendment

The Kyoto Protocol, which was adopted in 1997 and came into force in 2005, commits industrialised countries would limit and reduce greenhouse gas emissions in accordance with agreed individual targets. Bangladesh ratified the convention on October 22, 2001. The Protocol only binds developed countries and sets binding emission reduction targets for 37 countries and the EU, aiming for a 5% reduction (compared to 1990 levels)from2008-2012.

In 2012, the Doha Amendment was adopted for a second commitment period from 2013-2020. The amendment includes a revised list of GHG to be reported, and amendments to articles of the protocol. During the second

11.2.11 The Building Construction Act 1952 and the Building Code

The Bangladesh National Building Code, 2020 was introduced under section 18A of the Building Construction Act, 1952. The code requires buildings to obtain 3% of their energy load from renewable sources for residential buildings and 5% for non-residential buildings. The use of renewable energy should follow a priority list that includes lighting for basements or underground areas, dark corridors, supplementary lighting, fans, emergency lighting such as fire stairs and egress path lighting, and more. Additionally, both residential and commercial buildings are required to install solar water heaters on their rooftops instead of electric or gas water heaters (Bangladesh National Building Code, 2020). The code also specifies the installation of solar PV systems on the roof and outlines safety measures for such systems. Violating the code can result in punishment under section 18A of the Building Construction Act, 1952, which may include up to 7 years imprisonment, a fine of up to 50 thousand takes, or both (The Building Construction Act, 1952).

11.2.12 Vision 2041 and Mujib Climate Prosperity Plan

To meet the goals of the SDGs and climate conferences the government adopted vision 2041, a national strategic plan, focusing on resilience to climate change and other environmental challenges. Reduction in the share of fossil fuel consumption and increased reliance on clean technology and renewable energy (Ministry of Planning, GOB), 2020).

Mujib Climate Prosperity Plan was adopted by the government of Bangladesh in 2021 considering the resilience and low carbon socio-economic growth of the country. It also includes the losses and damages by equipping vulnerable communities, industry, and the government, with a new risk management model for resilience and stability (Government of Bangladesh, 2020). The plan intends to achieve 30% renewable energy by 2030 and implement the goals of SDGs and explore green opportunities (Centre for Research and Information, 2021).

11.2.13 The Integrated Energy and Power Master Plan Project

The government of Bangladesh introduced the power sector master plan in 2016, addressing achieving Sustainable Development Goal 7 to ensure affordable and clean energy. Now, the government took initiative to introduce the Integrated Energy and Power Master Plan by fixing the goal to establish a low or zero-carbon energy demand or supply system based on the promise of ensuring security and economic viability. Japan International Cooperation Agency (JICA) is the organisation that is consulting the government to prepare the IEPMP. However, the key activities under the project are; i) review of the current status of policies, ii) energy data management, iii) balance of primary energy supply and final consumption, iv) development of power system plan, v) LNG legal framework, and vi) environmental and social considerations. In this master plan project, the government is planning to use ammonia, hydrogen energy, and nuclear energy as clean energy.

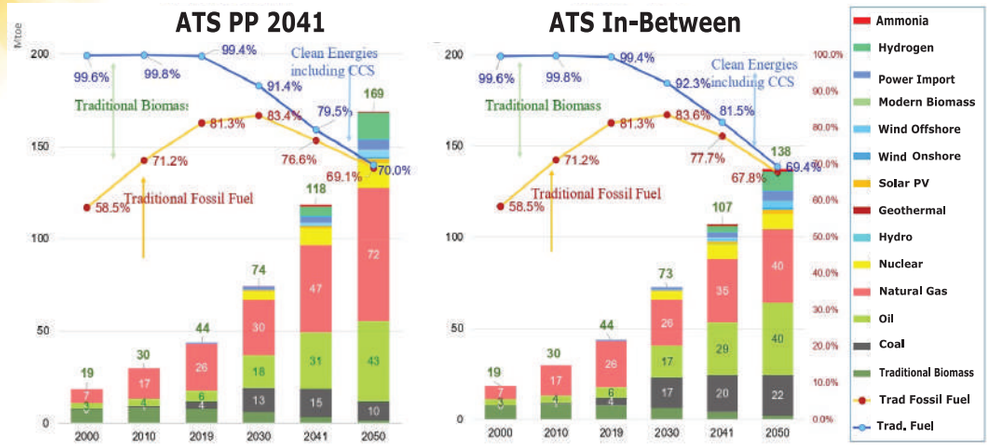

Figure 39: IEPMP, Ver.4, JICA (December 2022)

The fourth version of the "Integrated Energy and Power Master Plan of Bangladesh," released in December 2022, outlined the goal of achieving 20% clean energy sources, such as ammonia, hydrogen energy, and nuclear energy, by 2041 and 30% by 2050, which raises additional concerns.

12 Recommendation and Energy Framework

The recommendations outlined below focus on encouraging the use of renewable energy sources in Bangladesh to reduce the country's dependency on fossil fuels and promote sustainable development.

12.1 Accelerate the Phase-Out of the Fossil-Based Power Plant and Increase Investment on Renewable Energy

Bangladesh has opportunities to accelerate the phase-out of fossil fuel-based power plants, such as coal, gas, and oil, and invest in cleaner alternatives considering the availability of solar, wind, tidal wave and other renewable energy sources. As such, the government should review its policy and move away from coal-based power plants. Not only because it has these opportunities but also because of the hazardous environmental and social impacts.

To further promote renewable technology, the Government of Bangladesh needs to create an action plan to collect and utilise available local raw materials to generate electricity. The government should allocate funds to support biomass technology and encourage private investors to invest in this sector. Furthermore, the government should create policies and provide incentives to encourage private investors to invest in hydrogen energy storage infrastructure. Bangladesh should also partner with international organisations to develop hydrogen storage technology in the country. By doing so, Bangladesh can significantly reduce its reliance on fossil fuels and transition towards a cleaner, more sustainable energy future.

12.2 Encourage the Use of Renewable Energy Products

The Government of Bangladesh should encourage the use of renewable energy products, such as electric vehicles, to reduce carbon emissions from transportation. As transportation is a significant contributor to greenhouse gas emissions, shifting to renewable energy-powered electric vehicles can help reduce the country's carbon footprint.

To encourage the use of renewable energy products, the government can provide incentives for the purchase of electric vehicles and invest in electric vehicle charging infrastructure. This will make electric vehicles more accessible and affordable for the public, which will lead to a reduction in the use of conventional vehicles powered by fossil fuels. In addition, the government can also encourage the use of renewable energy-powered products in other areas of daily life, such as solar-powered home appliances and lighting systems. By promoting the use of renewable energy products, Bangladesh can reduce its dependence on fossil fuels, mitigate the impacts of climate change, and create a more sustainable future.

12.3 Encouraging Domestic Manufacturing Industries

Bangladesh should encourage the development of domestic renewable energy by providing incentives, subsidies, soft loans, and other structural support to the manufacturing industries, which will help to reduce the cost of installation and import dependency.

12.4 Energy Storage Facility

The energy generated from renewable sources like solar and wind can fluctuate depending on weather conditions, time of day, and season. Hence, energy storage systems are essential to store the excess energy generated and supplied during the time of low or no production. Lithium-ion batteries are one such energy storage solution that can store a large amount of energy with a high output ratio, meaning they can discharge energy quickly. Additionally, lithium-ion batteries are relatively eco-friendly compared to other old battery technologies.

The government should also invest in the recycling of these batteries to ensure environmental safety. The recycling process can recover valuable metals like lithium, cobalt, nickel etc. used in batteries, reduce waste, and limit environmental pollution.

12.5 Capacity of Local Distributors

The government of Bangladesh should focus on improving the capacity of local utility distributors to accommodate net metering with their system and receive excess consumer electricity generated from solar systems. This will require investments in infrastructure development, such as upgrading transmission lines and distribution systems, to ensure that the grid can handle the influx of solar energy. Additionally, the government can consider providing incentives to local utility distributors to encourage them to invest in renewable energy infrastructure.

12.6 Ammedment of Legal Instruments

To improve the renewable energy industries and infrastructure, the government needs to update policies and legal instruments. i.e. Net Metering Guidelines, 2018; the National Building Code, 2020; The Electricity Act, 2018; Bangladesh Energy Regulatory Commission Act, 2003; Sustainable and Renewable Energy Development Authority Act, 2012; the Quick Enhancement of Electricity and Energy Supply Act, 2010; the Bangladesh Energy and Power Research Council Act, 2015; the Renewable Energy Policy 2008; the Private Sector Power Generation Policy, 2008. The government also needs to enact laws relating to renewable energy industries including import duties on renewable energy equipment, anti-dumping laws, green tax policy, pollution control law, Safety Standards laws on the manufacturing and distribution of ammonia, hydrogen, nuclear energy, Disaster Management Law, etc.

12.7 Technological Advancement, Research, and Innovation

The Government of Bangladesh should accelerate the scope of renewable energy research and innovation by engaging all public and private universities. The public and private institutions need to work jointly to promote research and innovation to develop the renewable energy industry of the country.

12.8 Pollution and Health Hazards Management

The government needs to introduce a green tax policy against any type of pollution and health insurance for people living around the industrial areas.

12.9 Increase Public Awareness

The government needs to create mass awareness in order to promote and encourage the use of renewable energy technologies through education programs, and community engagement initiatives in Bangladesh. The government also needs to build public-private partnerships.

12.10 Waste Management

The government should have a national waste management plan for both fossil fuel and renewable energy industries considering the loss and damage to the environment and ecosystem of the country. The government strictly needs to follow the polluters pay principle for waste management costs. Additionally, the government also needs to develop a national plan for recycling domestic waste and using them to generate electricity and organic fertilisers.

13 Conclusion

Only one world is habitable for humans and other living beings. It is therefore our responsibility to keep the world habitable by conserving the key elements of nature. Global warming which is now one of the main challenges (due to climate change.) To deal with this situation we need to curb greenhouse gas emissions by reducing fossil fuel consumption. To combat the threat of

greenhouse gasses, the world has agreed to reduce the use of fossil fuels and increase the use of renewable fuels to reduce the global temperature.

In recent times, the demand and consumption of electricity have increased for industrialisation and the GDP-centric economic growth of a country. The fossil-fuel based power generation capacity has been increasing the risk of greenhouse gas emissions which accelerate the global temperature. Alternatives are now being explored to reduce the dependency on fossil fuel use by generating energy from renewable sources.

Considering the high production cost, environmental, and ecological damages, the Government of Bangladesh has taken an initiative to reduce fossil fuel dependency. In line with other countries of the world, Bangladesh is also inclined towards the use of renewable energy. We hope to reach global targets close to net zero by the middle of this decade by ensuring the use of 30% renewable energy by 2030 (MCPP) and 40% by 2041 (COP-26) as per the current commitment of the Bangladesh Government.

A coordinated effort among governments, public and private institutions, and communities is necessary to ensure a just and green transition to achieve a sustainable energy future, calling for a reduction in the use of fossil fuels, which has contributed to climate change and environmental degradation. It is crucial to balance energy needs with environmental sustainability to achieve climate justice and ensure a better future for all.

References

Abedin, M., & M, J. (2015). Waste generation and management in Bangladesh: An overview. Asian Journal of Medical and Biological Research, 1(1), 114-120.

Alam, M. S. (2022). A dual-use solar energy technology for Bangladesh. in the journal Renew able and Sustainable Energy Reviews.

Aziz, S., & Chowdhury, S. (2021). Performance evaluation of solar mini-grids in Bangladesh: A two-stage Data Envelopment Analysis. Cleaner Environmental Systems, 2, 1-12. doi:https://doi.org/10.1016/j.cesys.2020.100003

BAEC. (2022). Rooppur Nuclear Power Plant. Bangladesh Atomic Energy Commission. Retrieved from https://baec.go .bd/site/page/6ed90c6d-8e98-45f2-9fa9-9a53aa1f0667 /Rooppur-Nuclear-Power-Plant

Bangladesh Economic Review. (2022, June 9). Dhaka, Bangladesh: Ministry of Finance.

Bangladesh National Building Code. (2020). Dhaka, Bangladesh: Ministry of Housing and Public Works.

Bertrand, S. (2021). Climate, Environmental, and Health Impacts of Fossil Fuels. Environmental and Energy Study Institute .

BMD. (2021). Forecast for the period: 22.03.2021 to 31.03.2021. Dhaka: Bangladesh Meteoro logical Department. Retrieved from http://live.bmd.gov.bd/file/2021/03/22/pdf/111560.pdf

BMD. (2021). Forecast for the period: 22.12.2020 to 02.01.2021. Dhaka: Bangladesh Meteoro logical Department.

BPDB. (2023). Bangladesh Power Development Board. Dhaka, Bangladesh: BPDB.

BPDP. (2023). Bangladesh Power Development Board . Retrieved from http://119.40.95.168/b pdb/area_wise_demand

Buh, B., Volz, U., Donovan, C., Kling, G., Lo, Y., Murinde, V., & Pullin, N. (2018). Climate change and the cost of capital in developing countries. London: Imperial College Business School and SOAS University iof London.

CAB. (2022). Proposed Bangladesh Energy Transition Policy, 2022. Dhaka: Consumer Assosciation of Bangladesh.

Carbon Trust. (2022). Carbon Trust. Retrieved from https://www.carbontrust.com/

Centre for Research and Information. (2021). All you need to know about Bangladesh's climate prosperity plan. Retrieved fromhttps://cri.org.bd/2021/11/01/all-you-need-to-know-about -bangladeshs-climate-prosperity-plan/

Cleveland, C. J., & Morris, C. (2014). Dictionary of Energy. Elsevier.

Deb, A., Bhuiyan, M., & Nasir, A. (2013). Prospects of Solar Energy in Bangladesh. IOSR Journal of Electrical and Electronics Engineering, 46-57.

Denchak, M. (2022). Fossil Fuels: The Dirty Facts. NRDC. Retrieved from https://www.nrdc.org /stories/fossil-fuels-dirty-facts

EPA. (2023). Energy Recovery from the Combustion of Municipal Solid Waste (MSW). United States Environmental Protection Agency. Retrieved from https://www.epa.gov/smm/en ergy-recovery-combustion-municipal-solid-waste-msw

Fisher, M. (2021, December). Bangladesh nuclear reactor construction progresses ahead of planned 2023 start-up. Retrieved from IAEA: https://www.iaea.org/bulletin/bangla desh-nuclear-reactor-construction-progresses-ahead-of-planned-2023-start-up

Galindo, A. (2022). What is Nuclear Energy? The Science of Nuclear Power. Retrieved from IAEA: https://www.iaea.org/newscenter/news/what-is-nuclear-energy-the-science-of -nuclear-power#:~:text=Nuclear%20energy%20is%20a%20form,fu sion%20%E2%80%93%20when%20nuclei%20fuse%20together.

GOB. (2020). Mujib Climate Prosperity Plan-Decade 2030. Retrieved from https://mujib plan.com/wp-content/uploads/2021/09/Mujib-Climate-Prosperity-Plan_26Sept2021.pdf

Grubler, A. (2015). In 2nd (Ed.), Dictory of Energy (pp. 177-216). Elsevier. doi:https:// doi.org/10.1016/B978-0-08-096811-7.50008-1

Güney, T. (2019). Renewable energy, non-renewable energy and sustainable development. International Journal of Sustainable Development & Word Ecology, 26(5), 389-397.

Hasina, S. (2021, November 01). 26th Session of the Conference of the Parties (COP26). Retrieved from United Nations Framework Convention on Climate Change (UNFCCC):

https://unfccc.int/sites/default/files/resource/BANGLA DESH_cop26cmp16cma3 _HLS_EN.pdf
Holick, M. F. (2004). Sunlight and vitamin D for bone health and prevention of autoimmune diseases, cancers, and cardiovascular disease. The American Journal of Clinical Nutrition, 80(6). doi:https://doi.org/10.1093/ajcn/80.6.1678S
IAEC. (2016). Management of Radioactive Waste from the Mining and Milling of Ores: Safety Standards Series No. WS-G-1.2. IAEA. International Atomic Energy Agency. Retrieved from https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1710_web.pdf
IDCOL. (2021). IDCOL Annual Report. Dhaka: Infrastructure Development Company Limited.
IDCOL. (2022). Solar Irrigation Program. Dhaka, Bangladesh: Infrastructure Development Company Limited.
IEA. (2022). International Energy Agency. Retrieved from https://www.iea.org/
IEA. (2022). World Eenergy Outlook 2022. Paris: International Energy Agency. Retrieved from https://www.iea.org/reports/world-energy-outlook-2022/key-findings
IRENA. (2022, May 19). The Role of Renewable Ammonia in the Energy Transition. Retrieved from The International Renewable Energy Agency: https://www.ire na.org/events/2022/May/The-role-of-Renewable-Ammonia-in-the-Energy-Transition
Jaccard, M. (2020). Renewables Have Won- The Citizen's Guide to Climate Success: Over coming Myths that Hinder Progress. Cambridge University Press.
Jacobson, M., Capozzola, T., & Lee, J. A. (2018). Assessing the Wind Energy Poten tial In bangladesh. Dhaka: USAID-NREL.
JICA. (2022). IEPMP 3rd Stakeholder's Meeting. JICA.
JICA. (2022). IEPMP Ver 4. JICA.
Khan, M. S., Mubeen, I., & Yan, M. (2022). Waste to energy incineration technology: Recent development under climate change scenarios. Waste Management & Research, 40(12). doi:https://doi.org/10.1177/0734242X221105411
LINDSEY, R. (2022). Climate Change: Global Sea Level. Retrieved from NOAA Climate.gov: https://www.climate.gov/news-features/understanding-climate/c limate-change-global-sea-level
McPherson, S. S. (2012). War of the Currents: Thomas Edison vs Nikola Tesla. Minneapolis, USA: Rwebty-First Century Books.
MEFCC (2022). Air Pollution (Control) Rules. Ministry of Environment, Forest and Climate Change.
Ministry of Planning (GOB). (2020). Making Vision 2041 a Reality- Perspective Plan of Bangldesh 2021-2041. Banladesh: Ministry of Planning.
Mostakim, K., Arefin, M., Islam, M., Shifullah, K., & Islam, M. (2021). Harnessing energy from the waste produced in Bangladesh: evaluating potential technologies. Heliyon, 7(10), 1-14. doi:https://doi.org/10.1016/j.heliyon.2021.e08221
Muth, C. J., Aalto, P., Mylläri, F., Rönkkö, T., & Harsia, P. (2021). Globally and locally applicable technologies to accelerate electrification. In Electrification-Accelerating the Energy Transition (pp. 25-55). Academic Press.
NEI. (2022). Nuclear energy and the environment. Nuclear Energy Institute. Retrieved from https://www.nei.org/resources/fact-sheets/nuclear-energy-and-the-environment
Orrok, G. A. (2014). Pearl Street Station The First Central Station in the World. Transactions of the Newcomen Society, 98-108. doi:https://doi.org/10.1179/tns.1930.008
Osaka, S. (2022, December 5). Scientists thought carbon emissions had peaked. They've never been higher. The Washington Post. Retrieved from https://www.washington post.com/climate-environment/2022/12/05/carbon-emissions-peak-record-2022/
Power Division, M. o. (2018). Net Metering Guidelines 2018. Capacity and Energy Export Limits. ` Dhaka, Bangladesh: Power Division, Ministry of Power, Energy and Mineral Resources.
Rahman, K. M. (2022, December 10). Cooling water requirement for Rooppur nuclear power plant. Retrieved from The Daily Star: https://www.thedailystar.net/cooling-water-re quirement-for-rooppur-nuclear-power-plant-42883
Rahman, M. M. (2022). A potential solution for Bangladesh's energy and food security challenges. Journal Energy for Sustainable Development.
REN21. (2022). RENEWABLES 2022: GLOBAL STATUS REPORT. Paris: REN21.

Shahsavari, A., & Akbari, M. (2018). Potential of solarenergy in developing countries for reducing energy -related emissions. Renewable and Sustainable Energy Reviews(90), 275-291.
Siemens Energy. (2022). 'Green' ammonia is the key to meeting the twin challenges of the 21st century. Retrieved from Siemens Energy: https://www.siemens-energy.com/uk/en/offer ings-uk/green-ammonia.html
SREDA. (2023). Solar Irrigation. Retrieved from Sustainable and Renewable Energy Develop ment Authority: http://www.sreda.gov.bd/site/page/c0de9d40-9013-452c-9d99-c5fd458dd2c6/-
TBS. (2021, December 01). Country to get power from waste in 2024. Retrieved from The Business Standard : https://www.tbsnews.net/bangladesh/energy/country-get-pow er-waste-2024-337453
The Building Construction Act, 1952. (1952). Power to make Bangladesh National Building Code.
The Daily Star. (2022). World Bank's $500 million financing for Bangladesh's disaster prepared ness. Retrieved from The Daily Star: https://www.thedailystar.net/busi ness/news/world -banks-500-million-financing-bangladeshs-disaster-preparedness-3071576
UCMP. (2022). UNDERSTANDING GLOBAL CHANGE. Retrieved from University of California Museum of Paleontology : https://ugc.berkeley.edu/background-content/burning-of-fossil-fuels/
UN. (2022). Climate Action. Retrieved from United Nation: https://www.un.org/en/climat echange/what-is-renewable-energy
UNB. (2020). Disaster Management Ministry gets reduced allocation. Retrieved from United New of Bangladesh: https://unb.com.bd/category/bangladesh/disaster-manag ment-minis try-gets-reduced-allocation/52897
UNFCCC. (2022). The Paris Agreement. Retrieved from https://unfccc.int/process-and-meet ings/the-paris-agreement/the-paris-agreement
United Nations. (2022). Affordable and Clean Energy. Retrieved from UN Sustainable Develop ment Goals: https://www.un.org/sustainabledevelopment/energy/
United Nations. (2022). COP26: Together for our planet. Retrieved from Climate Action: https://www.un.org/en/climatechange/cop26
United Nations. (2022). The Paris Agreement. Retrieved from https://www.un.org/en/climat echange/paris-agreement
United Nations. (2022). The Sustainable Development Goals in Bangldesh . Retrieved from United Nations Banladesh: https://bangladesh.un.org/en/sdgs/7
United Nations. (2022). United Nations. Retrieved from Climate Action: https://www.un.org/en/cli matechange/what-is-climate-change
United Nations. (2022, Novemebr 20). COP27 Reaches Breakthrough Agreement on New "Loss and Damage" Fund for Vulnerable Countries. Retrieved from United Nations Climate Change: https://unfccc.int/news/cop27-reaches-breakthrough-agreement-on-new-loss-and -damage-fund-for-vulnerable-countries#:~:text=UN%20Climate%20 Change%20News%2C%2020,UN%20Climate%20Change%20Executive%20Secretary.
Williams, M. W. (2012). What creates static electricity?. American Scientist, 100(4), 316-323.
WNA. (2021). Uranium-235. World Nuclear Association. Retrieved from https://www.world-nucle ar.org/information-library/nuclear-fuel-cycle/fuel-recycling/used-fuel-management.aspx
World Bank. (2019). CO2 emissions (metric tons per capita)- Bangladesh. Retrieved from The World Bank: https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?end=2019& locations=BD&start=2019&view=bar
World Bank. (2020). Access to electricity (% of population) - Bangladesh. Retrieved from The World Bank: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=BD
Zahir, A. (2021). Overview of Bangladesh's NDC at COP26. Retrieved from Center for Gover nance Studies: https://cgs-bd.com/article/4795/Overview-of-Bangla desh%E2%80%99s-NDC-at-COP26