An Overview of Solar Energy In Bangladesh and a Comparative Analysis with Traditional Energy Sources.

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Degree Thesis

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Abstract:

This thesis compares solar power with more conventional energy sources like biomass and fossil fuels to assess its present and future possibilities in Bangladesh. This study compares solar energy to traditional energy sources in Bangladesh and tries to shed insight on the environmental, social and economic effects of energy consumption habits in the country. There has been a noticeable uptick in the demand for energy in Bangladesh driven by both economic development and population growth. Solar power offers a promising solution to this problem. As it can reduce reliance on foreign fuels and lessen the environmental damage caused by burning fossil fuels. In order to assess the efficacy, affordability and scalability of solar power systems the study uses a mixed-method strategy that combines quantitative and qualitative data.This thesis look at the upfront costs of solar energy infrastructure, the savings on operations over time and the positive impact on the environment from lower emissions of greenhouse gases. The thesis also evaluates the difficulties and roadblocks to broad use of solar energy including budgetary restraints, regulatory impediments and technical limits. Although solar technology requires a larger initial investment than conventional energy sources it offers substantial long-term benefits like energy independence, environmental friendliness and financial savings. In addition to being a greener and more long-term energy choice solar power has the ability to make countries more self-sufficient and less susceptible to swings in energy prices throughout the world according to the study.

Keywords: Solar Energy, Conventional Energy Sources, Bangladesh Energy Sector, Patterns of Energy Consumption, Benefit-Cost Analysis, Technological Developments Social and Economic Effect, Adoption of Solar Energy and Renewable Energy Incentive.

Acknowledgement

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Contents

List of figures

List of tables

Abbreviations

ADB	Asian Development Bank
BPC	Bangladesh Petroleum Corporation
BPDB	Bangladesh Power Development Board
CCGP	Cabinet Committee on Government Purchase ().
GEF	Global Environment Facility
IDCOL	Infrastructure Development Company Limited
LNG	Liquefied natural gas
MENA	Middle East and North Africa
PERC	Passivated emitter and rear contact
SHS	Solar home systems
UNDP	United Nations Development Programme
WWF	World Wildlife Fund

1 Introduction

1.1 Background

Bangladesh, a nation experiencing tremendous urbanization and population growth, is at a turning point in its energy environment. The energy demand is currently on the rise due to the expanding population, economic growth and technological advancements. The development and production of many contemporary technologies would yield substantial energy security and economic advantages in Bangladesh. Energy in the nation is mostly supplied by conventional sources such as coal, oil, biomass and natural gas. Since its inception, natural gas has been an integral part of Bangladesh's energy infrastructure powering most of the country's electrical generating and industrial processes. Liquefied natural gas (LNG) imports are becoming more important as domestic gas stocks dwindle. Although natural gas is more common, coal and oil are still essential for transportation and power generation. Biomass is extensively used for heating and cooking in rural areas, although it is inefficient and harmful to the environment. Problems with these conventional energy sources include their impact on the environment, their release of greenhouse gases and their susceptibility to changes in the global energy market. Regular power outages and an urgent need for renewable energy sources are results of the energy infrastructure's inability to meet growing demand.

Energy that does not deplete over time is known as renewable energy. They often leave little to no carbon footprint and occur naturally. In the fight against climate change, one of the world's most critical problems, renewable energy plays a key role. Renewable energy sources, including solar, wind, hydro and geothermal release negligible ammount of greenhouse gases when they generate electricity, in contrast to fossil fuels. In keeping with international climate accords such as the Paris Agreement, this considerably lessens the impact on the environment and contributes to limiting the increase in global temperatures.

Diversifying the energy supply and decreasing reliance on imported fuels are two ways in which renewable energy improves energy security. Instead of relying on fossil fuels, which are subject to supply disruptions, price volatility and geopolitical tensions, countries can generate energy from renewable resources in their own regions. Countries that rely largely on imported energy sources such as Bangladesh find this particularly crucial. One of the main forces propelling sustainable growth is renewable energy. It boosts the economy, makes people employed and makes people healthier. Manufacturing, installation and maintenance jobs abound in the renewable energy sector, which helps the economy grow. In addition, renewable energy projects can bring much-needed electricity to unserved and rural areas, which improves people's quality of life and opens doors to better economic and educational opportunities. The environmental effect of renewable energy sources is less severe than that of conventional energy sources. Air and water pollution, habitat devastation and biodiversity loss are all consequences of fossil fuel extraction, transportation and burning. On the other hand, renewable energy sources such as solar and wind power, leave far less of an impact on the environment. By doing so, we can keep biodiversity high and natural habitats intact. The economy stands to gain a lot from renewable energy investments. Renewable energy technologies may have a higher upfront cost but they usually have lower running expenses and last longer than systems that rely on fossil fuels. Saving money and a more stable economy are the long-term results of this. At the same time, renewable technologies are becoming more competitive with conventional energy sources as their prices dip. Energy access and social fairness can be improved by renewable energy. Communities in rural areas or those without access to the main power grid can still get the electricity they need through decentralized renewable energy systems like solar home systems or mini-grids. This promotes economic and social growth by increasing access to basic amenities including healthcare, schools and water.Innovation and technical progress are propelled by the renewable energy sector. Better, more dependable and less expensive solutions are the result of ongoing research and development in renewable energy technology. This technical improvement is good for the economy as a whole, not just the energy industry because it encourages innovation in other areas. Solar power is unique among renewable energy sources because of its scalability and abundance.

Being close to the equator means that Bangladesh gets plenty of sunshine all year round, which makes it a great place to use solar power. Financial restrictions, technological hurdles, and regulatory hurdles have all contributed to the sluggish adoption of solar energy, notwithstanding its potential. However, numerous pilot projects and initiatives have been launched as a result of the government and other stakeholders' growing recognition of solar energy's advantages. An example of this is the work that Infrastructure Development Company Limited (IDCOL) has done to improve access to power in rural regions through the installation of solar household systems. Aiming to promote sustainable agriculture practices, the Solar Irrigation Pump Project seeks to switch out diesel-powered pumps for solar-powered ones. Solar energy has the ability to solve Bangladesh's energy problems and these attempts show that it is both practical and advantageous. A comparative examination of solar energy and traditional energy sources is required to determine their relative benefits and drawbacks. This research gives useful insights into the economic, environmental, and social implications of various energy sources which can help guide policy decisions and investment strategies. By weighing cost-effectiveness, efficiency, environmental sustainability and scalability, we can find Bangladesh's most viable and sustainable energy alternatives. Such a study serves to emphasize the long-term benefits of switching to renewable energy, informing politicians and the general public about the vital need for a deliberate energy transition.

1.2 Aims of Thesis

The main goal of this thesis is to look into the present and potential state of solar energy in Bangladesh and see how it stacks up against other types of energy in terms of viability and sustainability. The goal of this study is to look at the economic, environmental and social effects of using solar energy and to list the difficulties and possibilities that come with it. The goal of this thesis is to tell lawmakers, stakeholders and the public about the pros and cons of switching to renewable energy sources in Bangladesh.

1.3 Structure of Thesis

This thesis is organized into six primary chapters: Introduction, Literature Review, Methodology, comparative Analysis with Traditional Energy Sources, Discussion, Conclusion and Recommendations. The Introduction chapter Presents an overview of the energy situation in Bangladesh, emphasizing the significance of renewable energy and clearly states the research goals. The Literature Review chapter provides an overview of the current studies on solar energy and traditional energy sources in Bangladesh and worldwide. Additionally, it encompasses the theoretical framework and prior research that is pertinent to the subject matter. The Methodology chapter Provides a detailed account of the research methodologies and procedures employed for the purpose of gathering and analyzing data. This chapter presents the methods used to collect and analyze data both qualitatively and quantitatively. The comparative Analysis with Traditional Energy Sources chapter presents the results of a comparison analysis conducted between solar energy and traditional energy sources. The information encompasses metrics related to efficiency, cost-effectiveness, environmental impact and socio-economic advantages. The Discussion chapter provides an interpretation of the results, explores their ramifications and addresses the research questions. This chapter examines the capacity of solar energy in Bangladesh and contrasts it with conventional energy sources. Conclusion and Recommendations chapter presents a concise overview of the main discoveries, offers suggestions for policy actions and proposes potential directions for future investigation. This chapter highlights the importance of implementing strategic interventions to encourage the use of renewable energy in Bangladesh.

2 Literature Review

2.1 Solar power

Solar power refers to the utilization of the sun's energy, which is transformed into either thermal or electrical energy. The sun is an extraordinary and inexhaustible source that possesses the ability to maintain life on earth and offer environmentally friendly, enduring energy to all living beings. Solar photovoltaic (PV) modules convert solar energy into electricity. Solar energy refers to the radiant light and heat emitted by the Sun, which is captured and utilized by various technologies such as solar power, to produce electricity. Solar energy refers to the radiant energy emitted by the Sun, which has the ability to generate heat, induce chemical reactions or produce electricity. The solar energy that reaches Earth is significantly greater than the current and expected energy needs of the planet. If effectively utilized, this widely spread supply has the capacity to meet all forthcoming energy requirements. In the 21st century, solar energy has gained significant appeal as a renewable energy source due to its abundant availability and environmentally friendly nature. Solar energy principles center on the acquisition of sunlight and its conversion into practical energy using diverse methods. Solar energy is plentiful, sustainable and has low ecological consequences in comparison to fossil fuels. Current advancements in solar technology are primarily centered around enhancing efficiency and decreasing expenses. Notable advancements encompass the creation of superior photovoltaic (PV) materials such as perovskite solar cells, that possess the capacity to surpass the efficiency of conventional silicon cells. Bifacial solar panels, which are capable of capturing sunlight on both sides are experiencing increased popularity due to their superior energy output.

Solar energy is a powerful and influential factor that carries great significance for society. Solar technologies utilize sunlight to provide an environmentally-friendly, economically viable and socially inclusive energy source that effectively tackles urgent environmental, economic and social issues. Solar energy is a significant form of renewable energy that has the capacity to address numerous global concerns. There are numerous justifications for advocating for an increase in its market share within the energy industry. The versatility and numerous benefits of this power source have led to its growing appeal among people and its positive impact on the environment. Solar power provides a secure and viable alternative to present fossil fuels such as coal and gas for energy generation, without the harmful air, water and land pollution they cause. The World Wide Fund For Nature, also referred to as the World Wildlife Fund (WWF), acknowledges that the production of energy from fossil fuels results in air pollution, which in turn leads to acid rain, degradation of forest regions and negative impacts on agricultural productivity, resulting in significant global economic losses amounting to billions of dollars. Conventional power plants, particularly those utilizing coal, oil or natural gas, release significant amounts of carbon dioxide (CO_2) and other detrimental pollutants into the atmosphere. On the other hand, solar power systems provide electricity without emitting CO_2, thereby aiding in the battle against climate change.Solar power generation is devoid of air pollutants such as sulfur dioxide and nitrogen oxides, that are responsible for the formation of smog and acid rain. The utilization of solar energy will eradicate the hazardous and unsanitary repercussions associated with the use of traditional fossil fuels.The solar sector generates a multitude of employment opportunities in production, installation, maintenance and research and development. The U.S. Department of Energy says that the solar business employs more workers than the coal or natural gas industries in the United States. Investing in solar energy infrastructure promotes economic growth by cultivating new enterprises and sectors. Despite the high upfront cost, solar panels offer significant long-term savings through the reduction of electricity expenses. After installation, solar panels produce electricity without any further expenses, resulting in significant savings during their lifespan of 25-30 years. Solar energy systems, particularly rooftop installations, facilitate the generation of power in a decentralized manner. This minimizes the requirement for extensive and costly transmission infrastructure and reduces transmission losses. Decentralized solutions improve the resilience and reliability of the grid by minimizing the effects of breakdowns in centralized power plants. Solar energy improves public health by mitigating air and water pollution. Fossil fuel power plants are significant contributors of noxious emissions that can lead to respiratory ailments, cardiovascular complications and other health concerns. Adopting solar energy can reduce the occurrence of certain health issues, resulting in reduced healthcare expenses and enhanced quality of life.Solar energy has the capability to supply electricity to isolated and disadvantaged communities that lack access to the main power network. Solar household systems, mini-grids and portable solar gadgets provide dependable and cost-effective energy solutions, enhancing quality of life and facilitating economic operations in these regions. This is especially pertinent in rural areas of Bangladesh, where there is little availability of electricity.

2.2 Solar PV

Photovoltaics (PV) is the process of converting light into energy by utilizing semiconducting materials that demonstrate the photovoltaic effect, which is a phenomenon extensively investigated in the fields of physics, photochemistry and electrochemistry. Photovoltaic (PV) systems utilize the photovoltaic effect to directly convert sunlight into power. This process entails the assimilation of photons (individual units of light) by a semiconductor substance, which subsequently emits electrons, resulting in the production of an electric current. The photovoltaic effect is utilized commercially for the purpose of generating power and as photosensors. Photovoltaics, sometimes known as PV, derives its name from the phenomenon of turning light, specifically photons, into electricity or voltage, known as the photovoltaic effect. In 1954, scientists at Bell Laboratories were the first to utilize this phenomenon by developing a functional solar cell composed of silicon. This solar cell was capable of producing an electric current upon exposure to sunlight. Solar cells quickly found application in powering space spacecraft as well as smaller devices like calculators and watches. Currently, solar cells are economically viable in various areas and large-scale photovoltaic systems are being implemented to contribute to the electricity supply of the grid. Photovoltaic (PV) systems are a flexible and expandable technology employed for various purposes, ranging from tiny residential installations to large-scale power plants utilized by utility companies.

2.3 Solar PV system

A photovoltaic (PV) system consists of one or more solar panels along with an inverter and other electrical and mechanical components. These components harness energy from the Sun and convert it into electricity. Photovoltaic (PV) systems exhibit significant variation in size, ranging from compact rooftop or portable systems to massive utility-scale production plants. Solar panels harness the energy of photons, which are discrete units of light emitted by the Sun, to generate an electric current using the photovoltaic effect. Individually, each panel generates a modest amount of energy but when connected with other panels, they form a solar array that can generate larger amounts of electricity. The electricity generated by a solar panel (or array) is in the form of direct current (DC). While electronic gadgets such as phones and laptops utilize DC electricity, they are specifically engineered to function with the electrical utility system, which operates on alternating current (AC) and necessitates its use. Hence, in order to make the solar electricity practical, it is necessary to convert it from direct current (DC) to alternating current (AC) by means of an inverter. The AC electricity generated by the inverter can be utilized to power local devices or transmitted to the electrical grid for external usage.

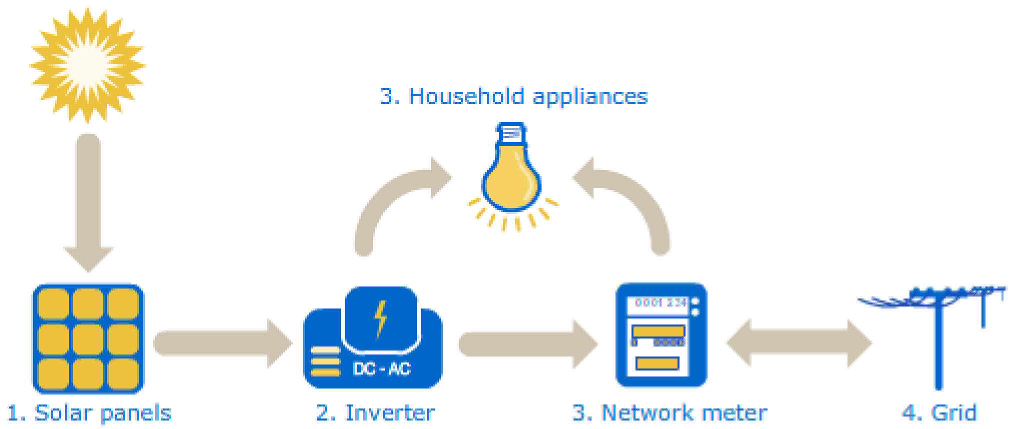


Figure 1 :Residential grid-tied solar PV system Diagram (Wikimedia Commons, 2018)

Photovoltaic cells also known as PV cells can be produced using various manufacturing techniques and a wide range of materials. Notwithstanding this distinction, all of them carry out the identical function of collecting solar energy and transforming it into practical power. Silicon with its semiconducting qualities is the most prevalent material used in the fabrication of solar panels. A solar panel requires several solar cells, and a photovoltaic array consists of numerous panels. The world market is primarily dominated by three PV cell technologies: monocrystalline silicon, polycrystalline silicon, and thin film.Various varieties of solar panels cater to distinct requirements and objectives. The varying utilization of sunlight on Earth versus in space highlights the importance of location in determining the optimal solar panel angle and direction. Consequently, the choice between different types of solar panels is heavily influenced by this factor. To differentiate between various types of solar panels, one must distinguish between single-junction and multi-junction solar panels, sometimes known as first, second or third generation panels. The distinction between single-junction and multi-junction solar panels is in the number of layers that are exposed to sunlight. On the other hand, the categorization based on generation focuses on the materials used and the efficiency of various solar panel types.

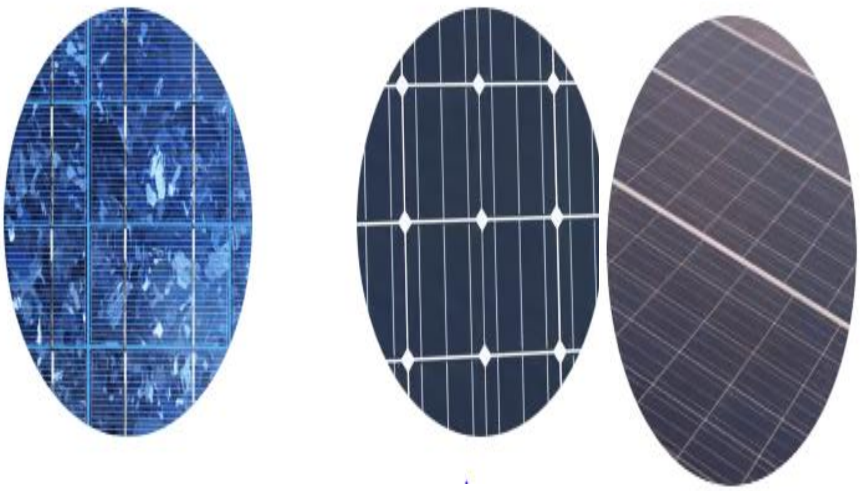


Figure 2: Monocrystalline, Polycrystalline amd Thin film Solar Panels (GreenMatch,2024)

Monocrystalline solar panels, often known as mono panels are manufactured using a solitary silicon crystal. Initially, the solar cells that were available for purchase were fabricated using

monocrystalline silicon, a highly refined variant of silicon. The most prevalent type of solar panels for residential systems are chosen due to their superior efficiency and suitability for roofs with limited space. The monocrystalline silicon solar panels are the most pure form available. Monocrystalline panels have superior power output, occupy a smaller footprint, and boast the longest lifespan. Perfect for installations in constrained spaces such as residential rooftops. Naturally, this implies that they are the priciest among the group.
There are two types of Monocrystalline solar panels Passivated emitter and rear contact (PERC) panels are mostly utilized for rooftop installations. To enhance energy absorption, they incorporate an additional conductive layer on the rear side of their photovoltaic cells. Bifacial panels have the ability to capture light on both sides and they do so at a greater efficiency compared to PERC panels. These panels are usually used for ground-mounted systems where both sides of the panels are exposed. Bifacial panels are additionally employed on awnings, canopies and highly reflective white business roofs.

Polycrystalline panels are manufactured using older solar technology, which makes them less expensive compared to the more recent monocrystalline type. Nevertheless, due to their outdated technology, polycrystalline panels exhibit lower efficiency compared to their contemporary equivalent. Polycrystalline cells consist of several minute grains of crystals. Monocrystalline panels are produced using a slower and more expensive technique compared to the faster and cheaper method of melting raw silicon to create these panels. These cells are composed of fused silicon crystals and have a granular, polycrystalline form. Marginally less efficient and necessitate a larger amount of room for a same power output. Designed for huge installations when spatial limitations are minimal.

Comparatively, the efficiency of monocrystalline and polycrystalline solar cells is higher than that of thin-film solar cells. Created by covering a substance (glass, plastic, metal, etc.) with a thin coating of photovoltaic material. Therefore, they are more commonly found in expansive industrial solar arrays where floor space is not an issue. Small solar projects, like powering a boat or small commercial buildings with thin metal roofs like a warehouse, can also benefit from thin-film panels. Many varieties of thin film solar cells are available. Telluride, that is, cadmium: The use of Cadmium Telluride in this photovoltaic technology allows for the production of solar cells at a comparatively low cost, resulting in a shorter payback time (less than a year) compared to other types of solar panels. It uses the least quantity of water to produce solar energy compared to all other technologies. Using CdTe solar cells will minimize your impact on the environment because of their fast energy payback period. Cadmium telluride's toxicity when breathed or swallowed is the sole drawback of utilizing it. Of the many varieties of solar panels, the one most commonly seen in portable electronic devices like these calculators is the amorphous silicon solar cell. A triple-layer design, the gold standard of thin-film solar panels, goes into these panels.

Bifacial PV Cells the panel can soak up sunlight from both directions and More energy is produced because light is absorbed on both sides. Enhanced power generation, particularly in mirror-like systems. More complicated installation and higher starting cost. Perfect for installations on rooftops or on the ground with surfaces that have a high albedo.

2.4 Solar Energy Trends Around the World

In recent years, the worldwide solar energy industry has undergone significant expansion propelled by technological developments, favorable policies and a growing recognition of the importance of sustainable energy alternatives. This section offers a comprehensive summary of the most recent patterns, notable advancements and forecasts in the solar energy industry. After peaking at 1.2 TW in 2022, the world's solar photovoltaic (PV) capacity increased to almost 1.6 TW by the end of 2023. Record installations in key countries including the US, EU and China are mainly responsible for this expansion. (Energy tracker Asia,2023)
In 2023, the fastest growth rate in renewable capacity additions over the last 20 years was recorded with an increase of about 50% to nearly 510 gigawatts (GW). For the 22nd year running, renewable capacity increases have broken records. While the renewable capacity additions in Brazil, Europe and the US all reached record highs, China's acceleration was truly remarkable. As of 2023, China has installed more solar PV than the entire world in 2022, while its wind installations increased by 66% compared to the previous year. Three fourth of the renewable capacity additions globally were attributed to solar PV alone. (Energy tracker Asia,2023)
The graphic depicts the increase in renewable electricity capacity in different countries and regions across different time intervals, spanning from 2005 to 2028. The y-axis indicates the capacity in gigawatts (GW), while the x-axis displays various regions and countries. The data is divided into four distinct time periods, each represented by a different color. The graphic

demonstrates the notable growth in renewable electricity capacity in various areas and timeframes. Notable observations consist of The European Union and the United States exhibit the most significant growth in renewable capacity, which is a result of robust legislative backing and substantial investments in renewable technologies. Countries like India and regions like ASEAN and Latin America, which are considered emerging economies are seeing significant growth. This growth suggests a worldwide transition towards renewable energy. The Middle East and North Africa (MENA) and Sub-Saharan Africa, although beginning from a lower starting point are expected to see significant expansion in the upcoming years. Furthermore, numerous countries across different geographical areas are experiencing consistent growth, which underscores the widespread acceptance of renewable energy on a global scale. (International Energy Agency 2023)

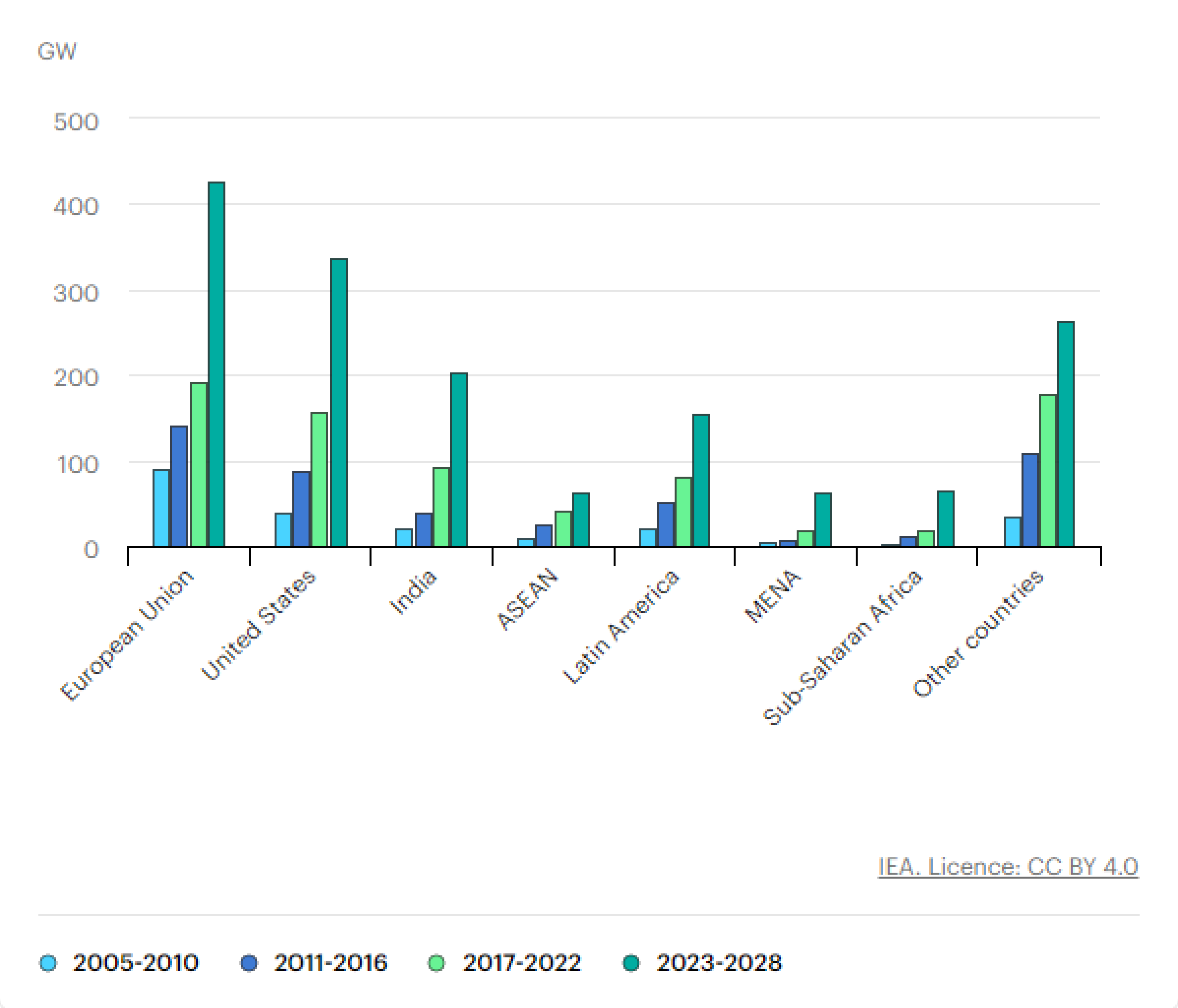


Figure 3:Growth in the amount of renewable electricity that a country or region can produce (2005–2028)

This category exhibits the most notable surge in capacity among the technologies listed. The significant increase indicates significant expenditures and efforts to enhance renewable energy sources, specifically wind and solar photovoltaic (PV) systems, in order to achieve sustainability and climate objectives.

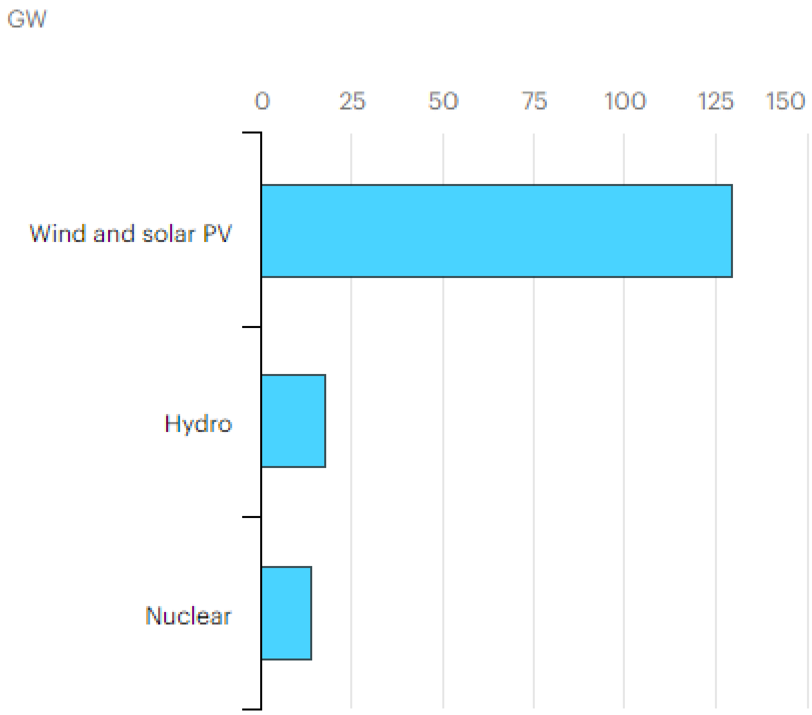


Figure 4: Average annual increase in capacity in the power sector as a result of the sustainable recovery plan, 2021-2023(IEA 2023)

The Chinese market continues to dominate both new and cumulative capacity, adding 106 GW DC or 44% of new capacity to reach 414.5 GW of cumulative capacity. This figure is more than double that of Europe.Spain (8.1 GW), Germany (7.5 GW), Poland (4.9 GW) and the Netherlands (3.9 GW) continue to exhibit robust growth in Europe with a total of 39 GW installed. Brazil installed a high 9,9 GW virtually, while the American market contracted to

18,6 GW due to the combined influence of trade issues and grid connection backlogs. The previous year's new capacity was doubled and India once again demonstrated robust growth with 18.1 GW, primarily in centralized systems and a PV penetration of nearly 10%.

More than 1 GW was deployed in 23 countries in 2022. Currently, sixteen nations (excluding the EU) have a total cumulative capacity of 10 GW or more and five of those have capacities of 40 GW or more. China accounted for 414.5 GW, the European Union (as EU27) for 209 GW, the United States for 142 GW and Japan for 85 GW; the EU27 had previously dominated the rankings but is currently in second place. With more than 45 percent of the region's new capacity coming from China in 2022, the country will continue to dominate the market. (IEA, 2023)

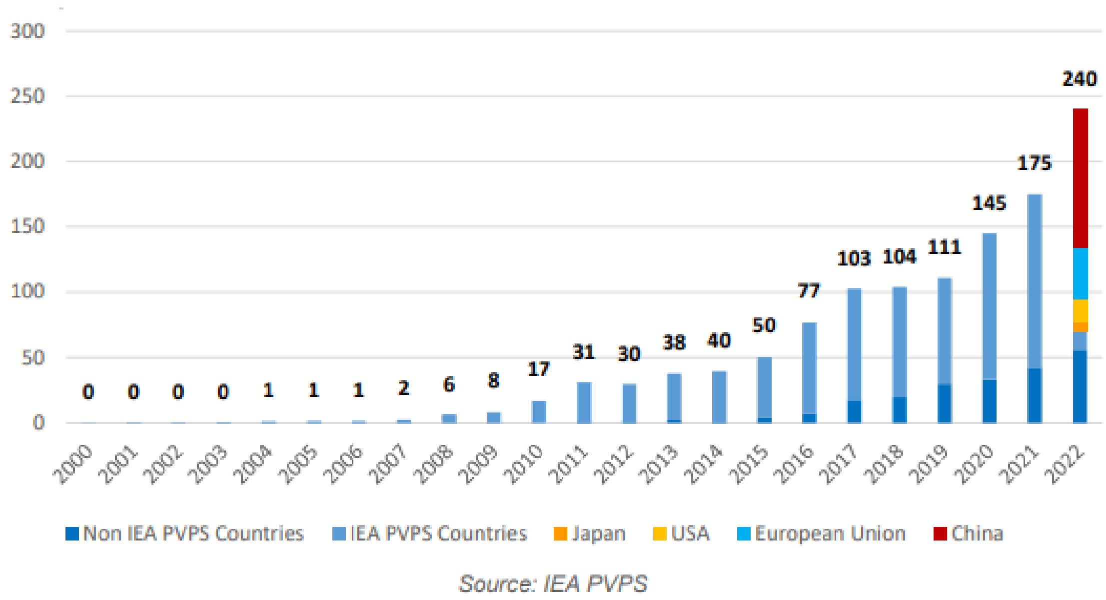


Figure 5: Evolution of Annual Installations(IEA PVPS)

This chart shows how the worldwide PV market is evolving with particular emphasis on China's market share and the rapid expansion of developing nations like India. While other markets have experienced acceleration, Japan which was previously a primary market, continues to maintain a constant rhythm of new projects.

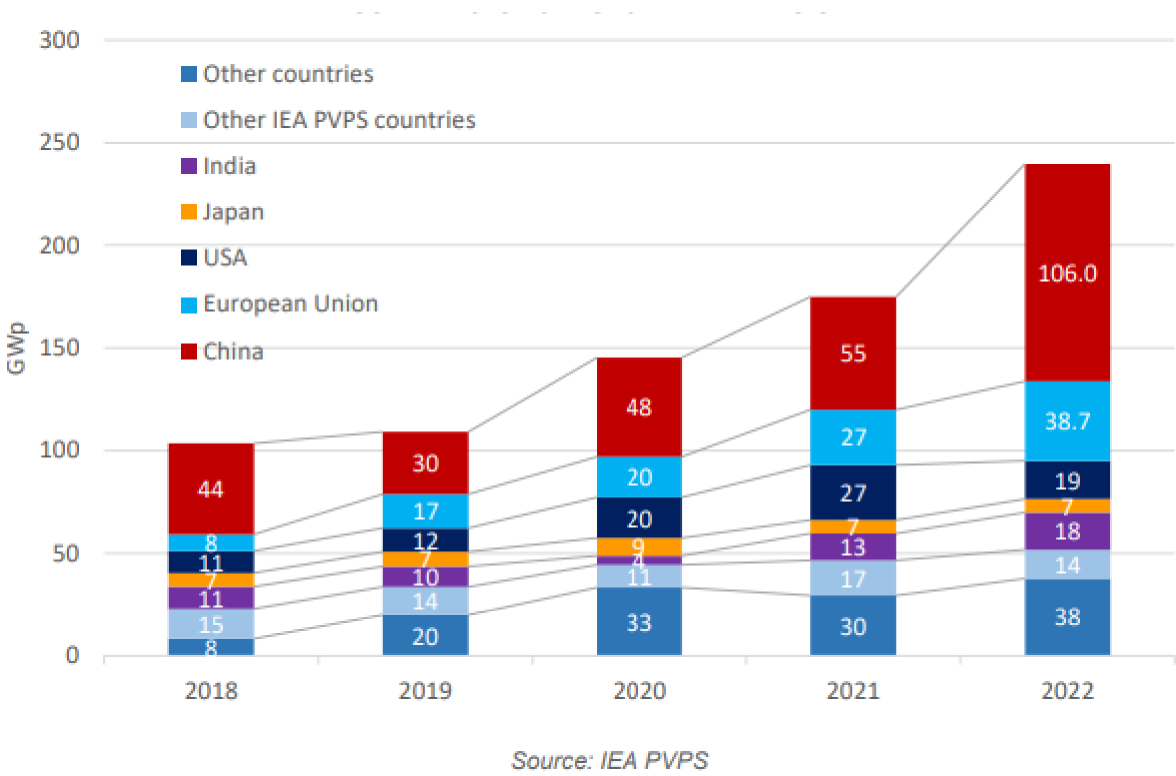


Figure 6: 2018-2022 Growth per Region(IEA PVPS)

2.5 Annual Global PV Deployment

According to analysts, around 350 GWdc of photovoltaic (PV) systems were deployed worldwide in 2023, representing a 50% increase compared to 2022. During the initial three quarters of 2023, there was a substantial year-on-year rise in photovoltaic (PV) installations in China (145%), Germany (102%) and the United States (42%). In 2023, China deployed approximately 260 gigawatts of photovoltaic panels. In 2023, Germany implemented a total of 14.3 gigawatts of direct current (GWdc). These projections were calculated before to China's announcement of 2023 photovoltaic installations, which have the potential to increase worldwide installations in 2023 to approximately 440 GWdc. During the indicated timeframe, China is expected to have the highest installation rate of PV, accounting for 39% of the total. Europe is forecast to have a 12% installation rate, followed by the United States with 9% and India with 6%. (National Renewable Energy Laboratory, 2024)

This bar chart depicts the anticipated yearly global installations of photovoltaic (PV) systems from 2021 to 2027. The y-axis indicates the annual installations of photovoltaic (PV) systems in gigawatts (GW), while the x-axis displays the years from 2021 to 2027. The figure employs distinct hues to depict diverse regions that contribute to the worldwide photovoltaic (PV) deployment

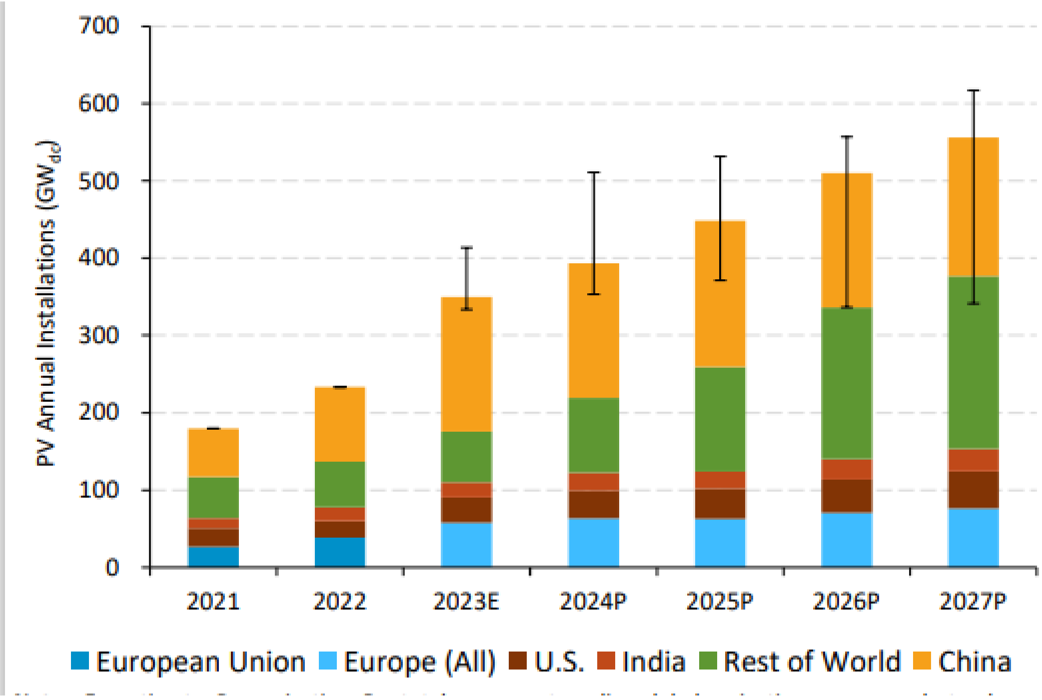


Figure 7: Annual Global PV Deployment (NREL, 2024)

Strong worldwide commitment to increasing solar energy capacity is shown in the graphic, which indicates a substantial growth in PV installations worldwide from 2021 to 2027. In terms of total PV installations worldwide, China ranks first, followed by the EU, the US and other areas. This shows a lot of money and government backing for these areas. Future installations may vary depending on policy shifts, market circumstances and technology developments, as shown by the error bars in the forecasts (2023E to 2027P).

2.6 Traditional Energy sources in Bangladesh

The energy sector in Bangladesh mostly depends on conventional energy sources such as natural gas, coal and biomass. Natural gas is the predominant energy source responsible for the majority of electricity production. Nevertheless, the available supply of domestic gas is diminishing, which requires the importation of liquefied natural gas (LNG). Bangladesh encounters substantial obstacles related to its conventional energy sources encompassing environmental deterioration, economic fragility and health repercussions. Adopting renewable energy sources such as solar and wind is essential for achieving sustainable development, minimizing environmental impacts and guaranteeing long-term energy stability. Nevertheless, attaining this shift necessitates significant capital infusion, breakthroughs in technology and robust policy backing. About 25% of the primary energy comes from biomass, while the remaining 75% comes from commercial sources. Commercial energy is primarily derived from natural gas with a small percentage coming from imported LNG (13%). (NREL, 2024)

Table 1: Energy calculation for 2021-22 in MTOE (BPC, 2023)

Total Primary Energy 57.20 MTOE, FY 2021-22			
Name	**Unit**	**Amount**	**Mtoe**
Oil (Crude + Refined)	K ton	10509.167	10.51
LPG	K ton	1543	1.54
Natural Gas	Bcf	842.01	19.52
LNG	Bcf	240.56	5.58
Coal (Imported)	K ton	6140	3.88
Coal (Local)	K ton	488.724	0.31
RE (Hydro)	MW	230	0.17
RE (Solar+ wind)	MW	717.5	0.53
Electricity (Imported)	MW	1160	0.86
Total Commercial			42.90
Biomass			14.30
Total primary			57.20

[Source: HCU Data Bank]

The table shows the whole primary energy consumption of Bangladesh in Mtoe (million tons of oil equivalent) for the fiscal year 2021-22. The table classifies the energy sources according to their type, gives the quantity consumed, and the Mtoe equivalent of that amount.

The overall energy usage is estimated to be approximately 57.20 MTOE in the end. The typical annual growth rate of energy use is around 6%. When compared to its South Asian neighbors, Bangladesh's energy consumption per capita is lower at 346 kgoe (Kilogram Oil Equivalent) and its per capita generation of electricity is 608.76 kWh with 100% access to power.

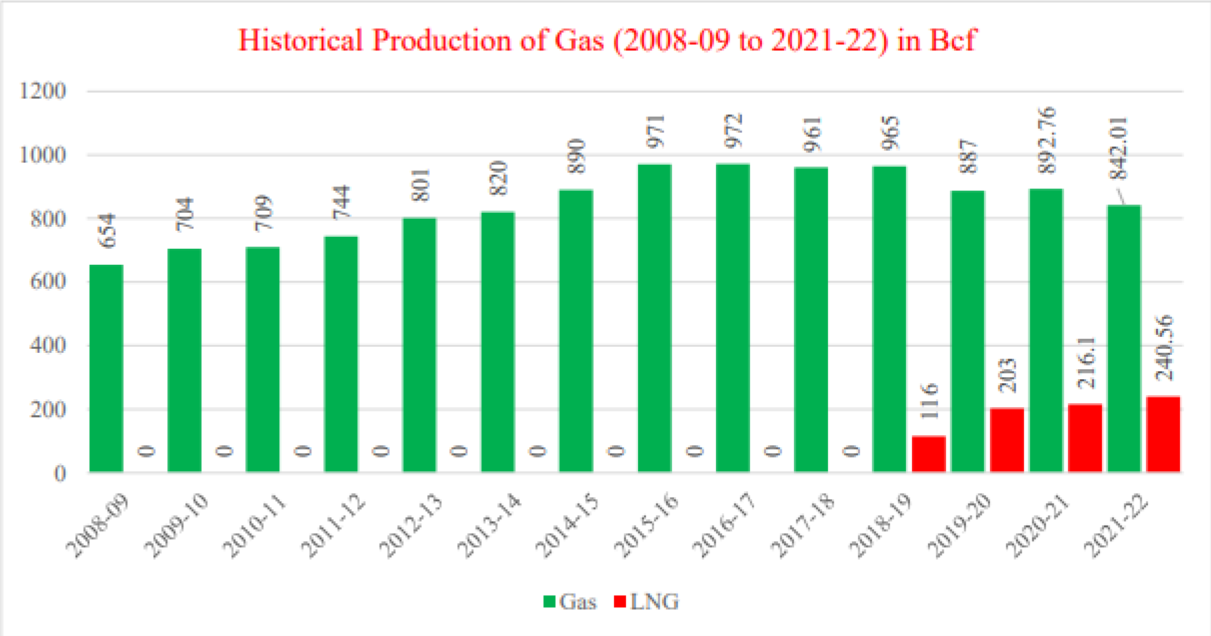
2.6.1 Natural Gas

In Bangladesh, the Energy and Mineral Resources Division of the Ministry of Power, Energy and Mineral Resources (Petrobangla) is in charge of oil and gas exploration, production, transmission and marketing. Petrobangla is short for Bangladesh Oil, Gas and Mineral Corporation. There have been a total of 26 gas fields found in the nation since their discovery in 1955; 24 are onshore and 2 are offshore. One offshore gas field depleted after 14 years of production, while another offshore field has not been economically viable to produce owing to its limited resource; twenty gas fields are currently producing gas. A total of 40.09 Tcf were considered to be the proven plus probable recoverable resource. There is just 10.42 TCF of recoverable reserve in the proved plus probable category as of June 2020, after 19.51 Tcf of gas has already been produced. (NREL, 2024)

Table 2: Natural Gas Sector at a Glance

Description	Amount
Total number of gas fields	26
Number of gas fields in production	20
Number of producing wells	112
Present gas production capacity	2750 MMcfd
Avg. gas production rate	1744-2750 MMcfd
Avg. Gas Production/day	2978 MMcfd
Highest Production (6th May, 2015)	2785.80 MMcfd
Total recoverable (Proven + Probable) reserve	40.09 Tcf
Cumulative Production (June,2021)	19.51 Tcf
Annual Production by NOC	308.17 (37%)
Annual Production by IOC	533.82 Bcf (63%)
Remaining Reserve (Recoverable)	10.42 Tcf
Present Demand	3508 MMcfd
Present Deficit	530 MMcfd (along with LNG)
Number of Customer	43 Lakh (Appx.)

[Source: Petrobangla MIS Report and HCU Data Bank]



[Source: Petrobangla, HCU Data Bank]

Figure 8: Historical Gas Production in Bangladesh (2008 – 2022)

2.6.2 Oil

Central to the petroleum industry in Bangladesh is the Bangladesh Petroleum Corporation (BPC), which operates under the Energy and Mineral Resources Division of the government. BPC is responsible for importing crude oil and petroleum products, refining oil and marketing refined petroleum products. While four oil marketing businesses are in charge of marketing completed products across the country, one refining company with one crude oil refinery in Chittagong is involved in refining crude oil. One private company began fractionating gas condensate extracted from gas sources in 1997, breaking the government monopoly on the oil business. There are currently small-scale fractionation operations run by Petrobangla, BPC and private individuals that separate gas condensates. The private sector also has two petrochemical facilities that use imported condensate as a feedstock. Worldwide almost 20% of commercial energy comes from petroleum products like diesel, gasoline, octane furnace oil and so on. Bangladesh relies heavily on imported liquid gasoline. Every year, refined petroleum products and crude oil totaling roughly 4.3 million metric tons are imported into Bangladesh. The sole domestic supply of liquid fuel is around 0.35 million metric tons per annum of domestically generated gas condensate, primarily fractionated into gasoline, diesel, and kerosene. The transportation sector is the largest user of liquid fuel with the power sector, agriculture, industry and commerce following closely after. Among the many uses of petroleum products, 62% go toward transportation, 13% to electricity, 17% to agriculture, 5% to industry, 1% to households and 2% to other uses. (BPC, 2023)

Table 3: Petroleum Sector at a Glance (BPC website and annual report2021-2022)

Product	FY 2021-22 (in Metric Ton)
Import of refined oil	4,809,131.00
Import of furnace oil	3,741,511.90
Import of crude oil	1,611,930.79
Production of Condensate	346,593.60
Total Import & Production	**10,509,167.28**
Production of Naptha	101,861.14
Storage Capacity of BPC	1,358,000.00
Refining Capacity of ERL	1,570,000.00
LPG Production from ERL	11,938.00
LPG Production from Kailashtila Frac. Plant	423.00
LPG import (private)	1,531,230.18

Table 4 : Sale of Petroleum Products by BPC during last 10 Year in Metric Tons (MT)

Prod-ucts	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
Octane	110850	117452	126114	147557	186911	230280	266988	262943	303917	**395,602.00**
Petrol	169710	178674	166823	137360	232359	284668	318593	321940	378846	**446,647.00**
Diesel	2962872	3242554	3396061	3606404	4000044	4835712	4593486	4015633	4597585	**4,850,700.00**
Kero-sene	314450	289871	263029	213685	170993	138403	121497	106195	101783	**86,117.00**
Furnace Oil	1070096	1202505	906771	711889	806440	925150	683725	362713	559032	**571,586.00**
Jet A-1	318423	323327	338829	347323	376700	408272	429951	350605	237894	**428,024.00**
Others	131591	130583	123796	91802	115283	125851	129982	68639	120673	**136,334.00**
Total	**5077992**	**5484966**	**5321423**	**5256020**	**5888730**	**6948336**	**6544222**	**5488668**	**6299730**	**6,915,010.00**

[Source: BPC Website and Annual Report 2021-22]

2.6.3 Coal

One of the most important infrastructure inputs to socioeconomic development is energy, which is also the primary predictor of a country's economic progress. For the time being, natural gas is Bangladesh's principal energy source. Multiple studies have shown that natural gas production in the United States is going to run out very soon. The nation must diversify its primary energy sources due to the unpredictability of its major energy supply.

Under such circumstances, local coal has the potential to become a significant alternative energy source bolstering the nation's energy security. Coal, both domestic and imported, accounts for 6.24 percent of the power generated so far. In all five coal fields Barapukuria, Khalaspir, Phulbari, Jamalganj and Dighipara have been found thus far. Additional coal mines could be found if nationwide exploring efforts were to be launched. Coal can currently be extracted from four of the mines that have been found with depths ranging from 118 to 509 meters. Due to the depth of the deposits, production from Jamalganj may not be feasible with present-day technology. Table uses the following units of measurement: meter for depth, sq. km for area, million tons for reserves and BTU/lb for calorific value.

Table 5: Coal Fields of Bangladesh(BPC website and annual report 2021-2022)

Place/Field (Discovery Year)	Depth (Meter)	Area (Sq. Km)	Reserve (Million Ton)	Depth (Meter)	Calorific Value (BTU/lb)
Barapukuria, Dinajpur (1985)	119-506	6.68	390	119-506	11,040
Khalaspir, Rangpur (1995)	257-483	12.00	523	257-483	12,700
Phulbari, Dinajpur (1997)	150-240	30.00	572	150-240	11,900
Jamalganj, Jaipurhat (1965)	900-1000	16.00	1,054	900-1000	11,000
Dighipara, Dinajpur (1995)	327	15.00	600	327	13,090
			Total = 3139		

Table 6: Coal Fields of Bangladesh(BPC website and annual report2021-2022)

Year	Public Sector Production	Import (Private)	Total (Metric Ton)
2016-17	1,160,657.81	2,801,407.00	3,962,065.00
2017-18	923,276.00	3,394,534.24.00	4,317,810.00
2018-19	803,315.00	5,754,025.00	6,557,339.00
2019-20	808,358.00	6,828,032.00	7,636,390.00
2020-21	753,973.00	6,751,000.00	7,504,973.00
2021-22	488,724.19	6,140,305.60	6,629,029.79

3 Method

This thesis makes use of a mixed-methods strategy. By using this method, this research able to examine the present state, difficulties and potential of solar power in Bangladesh in comparison to more conventional forms of energy, drawing on both quantitative and qualitative data.It has been verified. A comprehensive literature analysis on renewable energy policies in Bangladesh, solar power and conventional energy sources. Case studies, scholarly articles, official reports and trade journals all fall within this category. In order to gather data on user satisfaction, cost savings and performance of solar systems as well as to gain a better understanding of the practical aspects and challenges of solar energy adoption in Bangladesh, I have conducted interviews with key stakeholders. These stakeholders include government officials, energy experts, project developers and community leaders.

3.1 Data collection

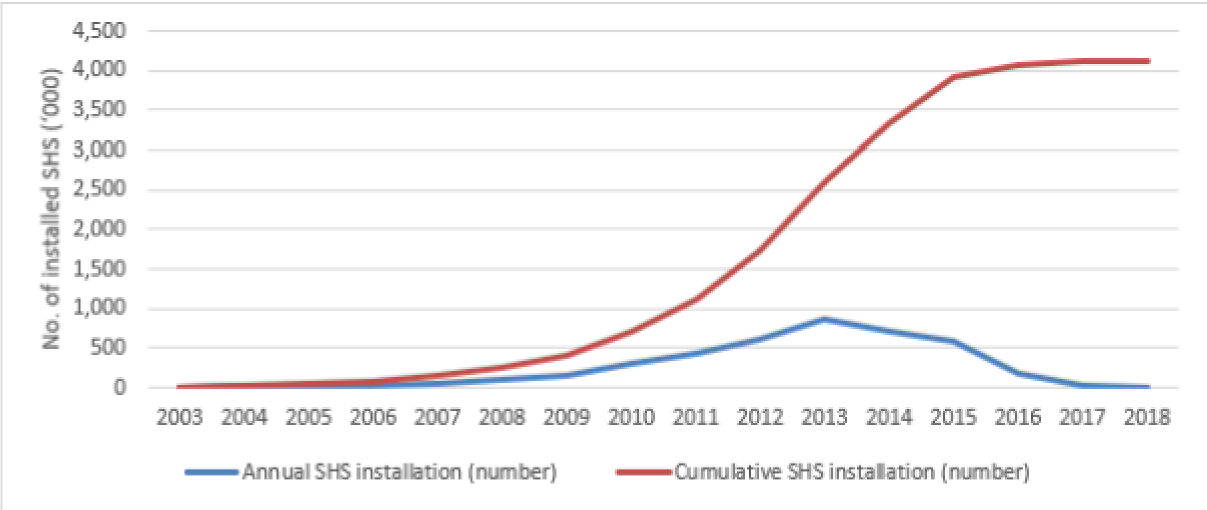
Using web databases, industry papers, scholarly articles and government publications to compile data. Making use of information gathered from sources including the IEA, the World Bank and the BPDB (Bangladesh Power Development Board). The process of creating and sending out surveys to people who use solar energy in order to get information about things like installation expenses, savings, user happiness and system efficiency. Interviewing solar energy stakeholders such as community leaders, industry experts and lawmakers, using a semi-structured format. Going to solar power sites such as SHSs, mini-grids and utility-scale projects, to collect data about how the systems work and what people think about them.

3.2 Data Analysis

Extracting meaningful patterns and themes from qualitative data collected through interviews and books by use of coding and categorization. Making sense of the conversation surrounding solar power and its implementation in Bangladesh by analyzing textual data from interviews, reports and policy papers. Using central tendency and dispersion indices to summarize survey data. Analyzing the performance of solar and conventional energy sources in comparison by using methods like hypothesis testing, correlation analysis and regression analysis to discover correlations between variables.

4 Solar Energy in Bangladesh

A large amount of renewable energy in Bangladesh is generated via solar panels. The coastal parts of Bangladesh get a period of bright sunshine hours ranging from 3 to 11 hours each day, according to the long term average sunshine data. Marketed to the 350,000 home loan clients of Grameen Bank and upper-income households in the villages, the first solar mass-scale program 'Grameen Shakti' was founded in 1996 to promote SHS. Their efforts to reach out to rural areas laid the groundwork for a SHS electrification initiative. Later on, other groups like BRAC also began selling solar systems. Infrastructure Development Company Limited administered a nationwide SHS program that the government established in 2003 with assistance from the World Bank and other donors. More than 14% of the population of Bangladesh gained access to electricity with the sale of over 4.1 million SHSs between 2003 and 2018.



No. = number, SHS = solar home system.
Source: Infrastructure Development Company Limited.

Figure 9:Solar System Installation by Infrastructure Development Company Limited(IDCOL)

In Bangladesh, solar mini-grids, grid-tied solar PV power plants and SHSs are the main methods for converting solar energy into electricity. In addition to prioritizing solar as an off-grid solution, the government has lately invested heavily in power generation. Nearly half of all solar energy solutions are either off-grid or on-grid, according to the Sustainable and

Renewable Energy Development Authority (SREDA). Solar irrigation, rooftop solar systems that do not use net metering and solar house systems have all contributed to the current uptick in off-grid alternatives.

4.1 Solar Home system

A large percentage of Bangladeshis still reside in rural and outlying highland regions without access to the country's electrical infrastructure. Solar home systems (SHSs) have gained appeal as an affordable and easy way to meet these people's electricity demands. IDCOL initiated the SHS program in 2003 with the goal of meeting the basic electricity demand of Bangladesh's electricity-deprived rural population and achieving the government's objective of providing access to electricity for all citizens by 2021. The company is currently the most influential player in this sector. By utilizing over 6.8 million SHSs across various regions of the nation, a total capacity of around 220 MW could be deployed by 2018. The SHS initiative would not have been possible without the support of IDCOL and other private groups like Grameen Shakti. Various private enterprises including IDCOL installed SHSs from 2003 to 2018, as shown in figure.

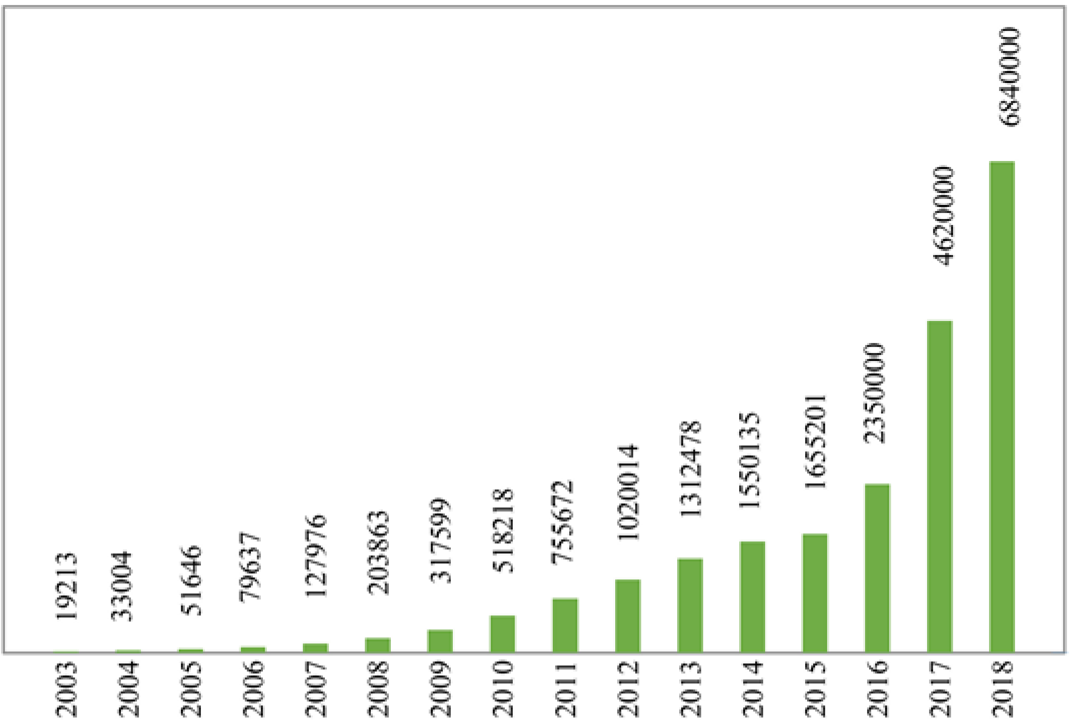


Figure 10:Total number of installed solar home systems in Bangladesh from 2003 to 2018.(IDCOL)

4.2 Solar Mini Grid

Installing mini-grids powered by solar PV is a common practice in outlying regions where grid expansion is unlikely to happen very soon. Commercial activity is encouraged in the project regions since these projects supply grid-quality energy to homes and small businesses.As a result of a collaborative effort between the UNDP, the GEF and the Sustainable and Renewable Energy Development Authority (SREDA) within the Ministry of Power, Energy and Mineral Resource, 1,199 homes on the island of Monpura in Bangladesh now have access to electricity via two solar mini-grids. The 26 solar mini-grids that IDCOL has funded have a combined generating capacity of 5 MW. In rural Bangladesh, some 16,000 people have gained access to low-emission power thanks to the mini-grid installations. Moreover, they will help reduce CO_2 emissions by an estimated 29,300 tons over the course of the project's lifetime. Solar Mini Grid Project at IDCOL is being funded by the following organizations: DFID, USAID, KfW, GPOBA, JICA, and the World Bank.

4.3 Rooftop Solar

Bangladesh plans to accomplish this goal by relying heavily on solar energy because the country is a good absorber of solar radiation. On the other hand, about 3.5 to 4 acres of land is needed to establish a solar power plant with a capacity of one megawatt. Consequently, it appears that land scarcity is a problem for a highly populated nation like Bangladesh. One possible solution to the problem of limited space for solar panel installation is the availability of many open rooftops. In August 2018, the government of Bangladesh passed the Net Metering Guideline, which aims to promote the utilization of unoccupied areas and rooftops for the production of solar power. Four of the eleven Rooftop Solar Projects authorized by IDCOL have commenced operations, bringing the total installed capacity to around 3.07 MW as of July 2019. It will not be long until the remaining projects are operational. A 3.1 MW system in the Narayanganj area, close to the capital will be installed by Joules Power Limited, a renewable energy producer located in Dhaka. This will be the largest industrial solar rooftop in Bangladesh. Robintex Group, a textile manufacturer owns a number of buildings that will be covered by the 33,000m2 array. Here is the funding arrangement that IDCOL offered for rooftop solar systems:

Table 7 Financial scheme for rooftop solar system in Bangladesh(IDCOL)

Facility	Term Loan
Loan amount	80% of the project cost
Tenor	10 years
Grace period	1 year (principal only)
Repayment	Quarterly
Interest rate	6% p.a. (Fixed for Loan Tenor)

4.4 Solar Irrigation system

An innovative and eco-friendly solution for Bangladesh's agro-based economy is solar-based irrigation systems. In rural areas that do not have access to the grid, the program aims to offer irrigation facilities. During the irrigation season, solar irrigation systems decrease the demand for electricity from the national grid and reliance on fossil fuels. In addition to saving millions of dollars in foreign money, the initiative also cuts carbon emissions. The program's goal is to set up solar PV-based irrigation systems in places that can grow three different kinds of crops all year round without being affected by flooding, arsenic pollution or salt water because of how promising these areas are. For this reason, IDCOL has recently committed to deploying 50,000 solar irrigation pumps by the year 2025. As of this past October 2019, 1,630 solar irrigation pumps with a combined capacity of approximately 32 MWp had been licensed by IDCOL. Among these, 1,323 were already operational. We anticipate that the remaining pumps will be operational soon. Project backers include the World Bank, ADB, GPOBA, JICA, USAID and BCCRF.(www.idcol.org)

4.5 Government Policies and Incentives

Various incentives are offered to attract investment and targets for solar energy capacity are outlined in the National Solar Energy Policy. It also provides standards for project development. With the implementation of net metering in 2018, homeowners are now able to sell any surplus electricity from their solar panels back to the utility company. Subsidies for SHS installations, tax breaks for solar equipment imports and concessional financing are all examples of financial incentives. The World Bank, the Asian Development Bank and a number of bilateral donors have all provided aid to Bangladesh. Rooftop solar systems are being pushed forward by this strategy, which aims to make them more affordable for both residential and business customers. In order to improve the solar infrastructure and capacities of the nation, these organizations offer financial backing, technical help and capacity-building support for solar projects. (ADB, 2023)

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4.6 Case Studies and Projects

In 2023, large-scale PV projects in Bangladesh were approved, totaling 2.19 GW. Tariffs for seven solar power facilities totaling 630 MW were approved in December alone by Bangladesh's Cabinet Committee on Government Purchase (CCGP). During the months of November, October, September and January 2023, approvals were issued for 200 MW, 310 MW, 570 MW, 300 MW, 66 MW and 120 MW, respectively. Around $0.10/kWh in fixed tariffs was achieved by most of these projects. Last year, a 300 MW array was approved as the largest solar project. It was to be built by a consortium that included ACWA Power of Saudi Arabia and locally held companies Comfit Composite Knit, Viyellatex Spinning and Midland East Power. Declined in November was the second-biggest solar power facility. Energon Renewables (BD) and PWR Energy Trading LLC will establish the 240 MW project in Mymensingh, which is in northern Bangladesh. A 200 MW floating and ground-mounted solar power facility was greenlit by the government in September in the Dinajpur district, next to the Barapukuria coal mine. In October, a 180 MW plant was approved to be jointly set up in Jamalpur area by a consortium including Max Infrastructure and Hangzhou Boiler of China.

4.7 Challenges and Opportunities

Because of its high average annual sunshine hours, Bangladesh is a prime location for solar power plants. Funding and technical knowledge can be provided by continuing support from international organizations and partnerships. More efficient and less expensive solar power is possible with new developments in energy storage and related technologies. Greater energy independence, fewer fuel imports and new employment opportunities can all result from a solar industry boom. Water desalination and the cold chain storage of perishable goods (such as agri-food and medicines) could both benefit from the integration of solar energy. Greenhouses equipped with Dutch-developed, high-yielding solar panels can help promote sustainable, sheltered horticulture in Bangladesh. The aquaculture industry can also benefit from solar energy by encouraging the creation of floating solar parks and massive solar-powered fish farms both of which can contribute to the long-term sustainability of aquatic life. Financial institutions can enhance their technical understanding to expand access to financing for more enterprises. Given the dire financial situation faced by many industrial companies, the present refinancing strategy ought to raise the minimum loan amount for a net-metered rooftop system to BDT 100 million. These are a few obstacles the upfront cost of solar power systems is still somewhat high, particularly for large-scale projects. Due to competing land uses and high population density, securing land for major solar installations is no easy feat. Improving the grid's infrastructure and management systems is essential for integrating solar electricity. Delays in project execution may occur due to bureaucratic red tape and conflicting regulations, even when policies are generally helpful.

5 Comparative Analysis with Traditional Energy Sources

Rising urbanization and industrial output have contributed to rising energy demand in Bangladesh. The country's energy comes mostly from three sources: biomass, oil and natural gas. Of these, natural gas is the most used to generate power. About half of all energy consumption comes from natural gas, which is mostly utilized to generate power and has several industrial uses.Imports account for the vast majority of oil, notwithstanding its importance in transportation and manufacturing. The usage of coal to generate electricity is on the rise and there are currently or soon to be a number of large-scale coal-fired power stations. Biomass accounts for a sizable chunk of rural America's energy consumption because to its widespread use in cooking and heating.

While natural gas does not produce as much carbon dioxide as coal or oil, it does add to the problem of greenhouse gas emissions and has environmental consequences due to its extraction methods. Oil a major source of air pollution and the release of greenhouse gases.

The extraction of oil and any subsequent leaks also constitute major threats to the environment. Nearly 0.4173kg of carbon dioxide gas is released for every kilowatt-hour electrical energy of natural gas that is used. A kilowatt-hour of electrical energy of oil combustion releases about 1.1027kg of carbon dioxide gas. Per kilowatt-hour, coal produces about 0.998kg of carbon dioxide. Coal the most polluting fossil fuel in terms of carbon dioxide emissions, it also contaminates water, air and mining-related land. Solar power systems, in stark contrast to more conventional energy sources, do not release any greenhouse gases into the atmosphere when in use. Conversely, after installation, there will be very little emissions of greenhouse gases. Solar panel production and disposal are the primary environmental concerns. Rooftops and the integration of solar panels with agricultural activities (agrivoltaics) can help reduce the need for large-scale projects to require significant land area. Although technological developments are lowering the impacts of the hazardous compounds used to manufacture solar panels, these materials are still used.

Energy from natural gas is transformed into electricity at a rate of 60%. About 30–35% efficiency using oil. Coal roughly 33% to 40% power savings. Energy efficiency of solar photovoltaic systems ranges from fifteen to twenty-two percent. In comparison to more conventional energy sources such as natural gas, which may achieve efficiencies of up to 60%, solar energy systems and photovoltaic (PV) systems have an efficiency range of 15-22%. But solar technology is always evolving to make it more efficient. (International Renewable Energy Agency, 2024)

Sunlight Power while utility-scale solar installations can cost anywhere from $1,000 to $1,500 per kW, the average installation cost for SHS is under $500 per unit. Time-Held Power Costs per kilowatt-hour for natural gas plants are around $1,000 and for coal plants, around $1,500. Operating costs for solar energy are relatively low, at about $20/kW/year. Traditional energy operations at natural gas and coal plants cost between $50 and $100 per kW per year, not including fuel expenses, according to the National Renewable Energy Laboratory (NREL) Traditional Energy. Solar power can reduce gasoline expenses; in fact, a single system can save $5,000 in fuel costs over the course of 20 years. Time-Held Power Fuel price increases cut into long-term savings; the price of oil and natural gas is quite unpredictable.

As a part of government measures to diversify the energy mix and promote energy security, solar energy is gaining traction as a viable alternative, especially for off-grid rural communities. However, a substantial initial expenditure is necessary to establish solar energy installations. But thanks to innovations in technology and economies of scale, prices have been falling. Compared to power plants that rely on fossil fuels, which necessitate constant fuel purchases and more extensive maintenance, solar energy systems have reduced operational and maintenance expenses. Reducing reliance on imported fuels is one way solar energy can improve energy security and save foreign exchange. Local installation and maintenance jobs are also created by it. Solar power helps slow global warming and cleans the air by generating electricity without releasing harmful gases. Rural communities can benefit economically, educationally and in terms of quality of life from increased access to electricity.

The Powering of rural areas with the installation of over 4 million Solar Home Systems (SHS), over 18 million individuals have benefited. Efficient and dependable power for home appliances, schools and businesses is essential to a high quality of life. Positive Effects on Health Using solar power for cooking and lighting instead of biomass reduces indoor air pollution, which is good for people's respiratory health. Solar power has greatly enhanced rural residents' standard of living. Because less dependence on biomass, a source of indoor air pollution, has been made possible by dependable power availability, there have been improvements in health, economic activity and educational achievement.
The socio-economic implications of solar energy plants are substantial. They help underprivileged areas get affordable and reliable power, create jobs and lessen the financial impact of fuel imports. In the long run, this helps the economy grow and promotes social justice.

Renewable energy that is both abundant and sustainable. Operating expenses are low and the impact on the environment is minor. Improved efficiency and decreased costs brought upon by technological developments. High starting capital expenditures. Subject to change and influenced by external factors. Deploying on a wide scale requires land and resources. Government subsidies and assistance from foreign donors. New developments in energy storage and grid integration technologies. Possibility of functioning independently in remote regions. Potential dangers rivalry from both conventional and alternative energy sources.

Uncertainties in economics and policy. Problems with infrastructure and technology that arise with grid integration.

6 Discussion and findings

6.1Key findings

Solar mini-grids, utility-scale solar projects and the Solar Home Systems (SHS) program have all contributed to a meteoric rise in solar energy adoption in Bangladesh. More than 18 million people have benefited from the installation of over 4 million SHS. Mini-grids and utility-scale projects are bringing consistent power to places that aren't connected to the grid. Solar power generates renewable energy, which in turn decreases pollution and boosts the economy by generating local employment opportunities.

Solar power has lower operating expenses in the long run than fossil fuels, despite the expensive initial investment. Since solar energy systems don't need fuel, they're more cost-effective and require less maintenance. Solar power, in contrast to more conventional energy sources has almost little effect on the environment. It greatly lessens the release of pollutants into the air and greenhouse gases. Renewable and plentiful, solar power is the way to go. The effectiveness of solar panels is always being enhanced by technological advancements. Ongoing progress in solar technology and energy storage systems will enhance the efficiency and affordability of solar energy. Agrivoltaics and floating solar farms are technological advancements that can maximize land utilization and broaden the scope of solar energy utilization.

Long-term policy backing and global collaborations will be essential in expanding the scop of solar energy initiatives. Financial and technical support from international organizations will aid in overcoming existing obstacles.

6.2 Discussion

Robust government regulations and unwavering international backing are necessary for the sustained expansion of solar energy in Bangladesh. Measures such as tax exemptions, subsidies and net metering are successful in encouraging the adoption of solar energy. The utilization of solar energy can result in substantial economic advantages such as the generation of employment opportunities, reduction in expenditures on imported fuel and enhancement of energy stability. The availability of solar energy in rural areas improves the standard of living by offering dependable electricity for illumination, education and economic endeavors. Decreasing reliance on fossil fuels leads to a decrease in air pollution and greenhouse gas emissions, which in turn improves public health and promotes environmental sustainability. Energy consumption in Bangladesh is primarily driven by natural gas, oil and biomass. The environmental and economic costs of these sources are substantial. Solar power provides an eco-friendly and long-term solution. A more diverse energy mix and greater energy security can be achieved through the integration of solar energy into the national grid. High recurring expenses from fuel imports and upkeep characterize traditional energy expenditures. Solar energy has a high upfront cost but low ongoing operating expenses, therefore it's a good long-term investment.Conventional Means: Majorly detrimental effects on the environment such as the release of greenhouse gases and air pollution.Solar Power: Once built, solar panels have little effect on the environment but they significantly cut down on pollutants and carbon emissions.

7 Recomendation and conclusion

7.1 Recomendation

Raising Financial Incentives: Subsidies and tax breaks are two ways to boost financial incentives for solar energy adoption.Reduce bureaucratic barriers to project implementation and increase the use of renewable energy sources by establishing and enforcing appropriate rules. Make necessary improvements to the grid infrastructure in order to integrate solar energy more extensively. The use of public-private partnerships can entice private investors to put money into solar energy projects.Encourage the installation and upkeep of solar energy systems by providing local communities and companies with training and resources.

7.2 Conclusion

Solar energy has great promise as a long-term replacement for conventional power in Bangladesh. Although solar energy systems have a high sticker price, they save money and help the environment in the long run. Solar energy outshines conventional fossil fuels in terms of sustainability, environmental friendliness and cost-effectiveness. In the long run, solar power can save money by cutting down on operational expenses and reliance on foreign fuels. Using solar power instead of fossil fuels drastically cuts down on pollution and greenhouse gas emissions. Enhancing energy security and reducing vulnerability to global energy market swings can be achieved by increasing the percentage of solar energy in the energy mix.

7.3 Further Reasearch

Conduct research on emerging solar technology and energy storage systems with the aim of enhancing efficiency and decreasing expenses. Undertake extensive research on the long-term societal, economic and ecological effects of solar energy initiatives in different areas of Bangladesh. Assess the efficacy of existing policies and pinpoint opportunities for enhancement to facilitate the expansion of solar energy.

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