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Renewable Energy: Prospects and Challenges in Bangladesh

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Abstract

Among expert scientists and politicians, there is increasing agreement that it is absolutely necessary to reduce the emission of greenhouse gas (GHG) to lessen the severity of climate change. Although little, renewable energy sources currently reduce GHG that are being emitted from the energy industries. According to the majority of long-term energy estimates, renewable energy will be a substantial addition to the supply of energy worldwide by the end of this century, as capacity of renewable energy is gradually increasing in the early decades. However, developing nations like Bangladesh are largely reliant on pricey imported energy supplies (coal, gas, and oil) that lay a heavy weight on the country's economy. Also, air pollution growing in importance as a national and international environmental issue. Regarding the development of clean and sustainable energy, renewable energy sources seem to be among the most practical and efficient alternatives, in both Bangladesh and globally. The geographic advantages of Bangladesh allow for widespread usage of the majority of such renewable energy sources. The comparative potential and use of fossil fuels against renewable energy sources globally and in Bangladesh is explored in this review.

Keywords

Renewable Energy, Solar and Photovoltaics, Hydropower, Wind Energy, Geothermal

1. Introduction

Energy is the crucial factor for achieving social and economic development and a good quality of life. However, the current energy sources, in particular thermal power plants, might not be viable for long run. Combustion of fossil fuels release

heat-trapping chemicals called greenhouse gases (GHGs) into the atmosphere. Other exhaust gases from thermal plants, such as oxides nitrogen and sulfur, carbon monoxide, and ozone, are extremely hazardous to human health. Fossil fuels are constrained by the earth's finite supply and expected to be depleted by the end of this century. Oil, for example, will be depleted in about 50 years, coal in about 114 years, and natural gas in about 53 years [1]. Since renewable energy is still not widely used, depleting our stocks will hasten its adoption worldwide.

Over the past 50 years, energy consumption across the globe has increased steadily (**Figure 1**), and in 2021 it was about 25,300 TWh. 61% of this electricity was generated using fossil fuels, including coal, natural gas, petroleum, and other gases. In 2019, there was a total consumption of 23,921 TWh [2].

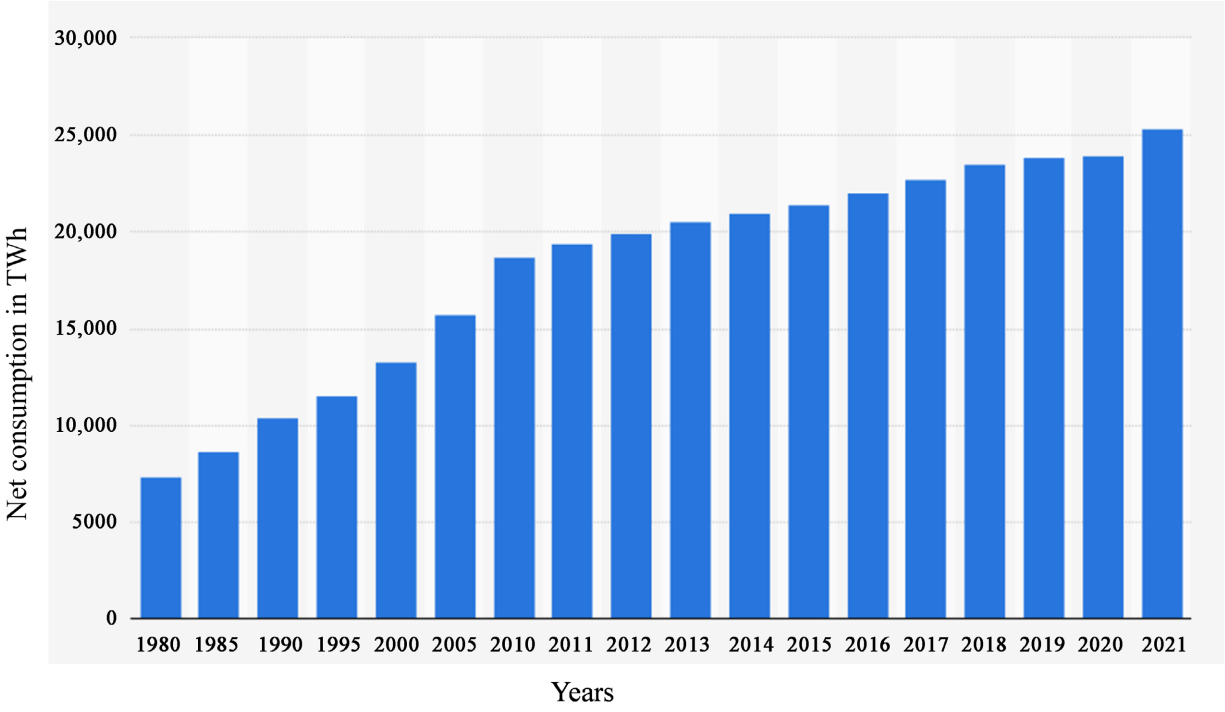


Figure 1. Total electricity consumption worldwide during 1980-2021 [2].

Coal-based thermal power plants generated 60% - 61% of the electricity produced throughout the world, whereas nuclear power plants contributed 10%, and renewable energy sources like solar, wind, hydropower etc. generated about 29% (**Figure 2**).

The world population expanded by nearly 75% between 1980 and 2021, while the use of power more than tripled. Worldwide increases in industrialization have further increased demand for power. It is anticipated that by 2050, the world would produce more than 40,000 TWh of energy, 90% of which will come from renewable sources. Close to 70% will be made up from wind and solar photovoltaics (PV) together. As the International Energy agency (IEA) forecasted in 2014, the sun may serve as the world's main energy source by 2050.

The requirement to control emissions of GHGs and other pollutants into

the atmosphere will increase along with the efficiency of energy production, distribution, transmission and usage. As investors and officials from all over the world increasingly appreciate critical role of electricity in economic development and improving living conditions, infrastructures for power generation and supply are being developed and extended in many developing countries [3] [4] [5]. Additionally, an overabundance of nuclear fuel extraction could result in a nuclear disaster [6]. However, renewable energy sources are so plentiful that they might successfully meet all of the energy demands predicted for the world over the next century [7]-[12].

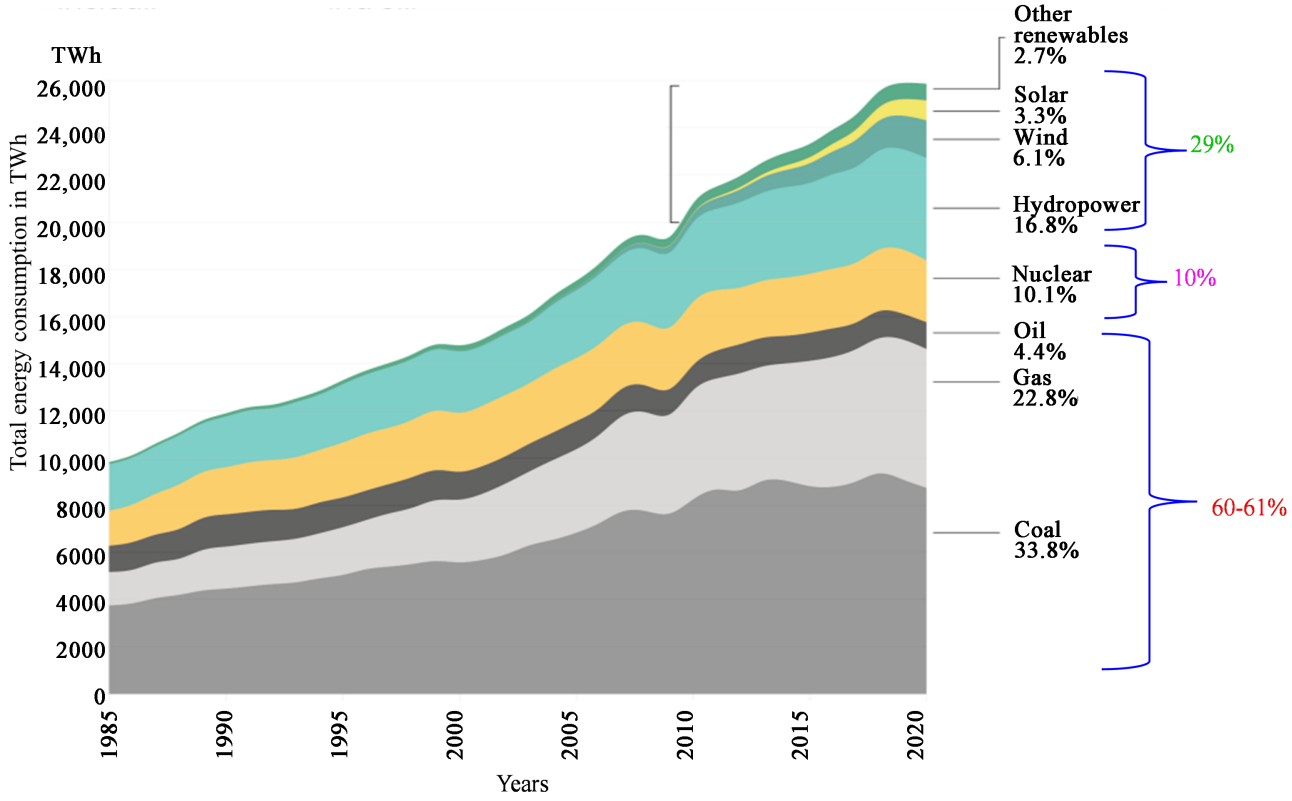


Figure 2. The total amount of energy used globally between 1985 and 2020 based on the sources [2].

Globally, the energy sector is anticipated to develop by about 36% between 2011 and 2030, with 1.6% annual growth on average. The equivalent amount of oil in this will become 16.5 billion tons in 2030 increasing from 10.3 billion tons in 2002. (**Table 1**) [13] [14]. In the past, the yearly growth rate was 2%. It was predicted that the energy usage across the world would rise by almost 78% between 2013 and 2030 [15] [16] [17]. Between 2020 and 2021, percentage of renewable energy in total power generated in the world stayed constant at 28.1%, down from 26.3% in 2019. Globally, the generation of renewable energy increased dramatically (+1.75 points) between 2019 and 2020 but remained constant in 2022.

Oil is the single largest fuel used to meet the world's energy demands. About 78,470 barrels were consumed in 2002, 87,105 in 2007, and then consumption fell in 2009 (84,083 barrels). In 2019, oil consumption peaked once more (97,747 barrels)

Table 1. Total energy (M_{toe}) consumption globally [13] [14].

	1971	2002	2010	2030	2010-2030 (%)[a]
Coal	617	502	516	526	0.2
Oil	1893	3041	3610	5005	1.8
Gas	604	1150	1336	1758	1.5
Electricity	377	1139	1436	2263	2.5
Heat	68	237	254	294	0.8
Biomass and waste	641	999	1101	1290	0.9
Other Renewables	0	8	13	41	6.2
Total	4200	7075	8267	11.176	1.6

[a]Average annual growth rate; M_{toe} equivalent to 11.6279 TWh.

[16]. The percentage of oil used worldwide for transportation increased from 33% in 1971 to 47% in 2002 and is anticipated to reach 54% in 2030. The Organization for Economic Co-operation and Development (OECD) member countries have committed to drastically reduce their usage of oil in the residential and service sectors. In many developing countries, particularly in rural regions, products based on oil will be the main source of contemporary commercial energy for cooking and heating [13].

During the predicted period, 1998-2021, the worldwide natural gas consumption rate was at a steady state of 2.3% annually [17]. It was projected that the household, commercial, and industrial sectors would utilize more natural gas. 60% of the increase in gas consumption would be attributed to the power sector, whose market share will expand from 36% in 2002 to 47% in 2030. In all regions, the demand will be primarily driven by the power sector. Since the need for power is anticipated to increase most quickly in developing countries, this tendency will be particularly noticeable there. Since high-efficiency combined-cycle gas turbines (CCGTs) use natural gas as the preferred fuel, it will continue to be the most affordable fuel for new power plants in the majority of the world. A small but rising fraction of the global demand for natural gas will be met by gas-to-liquid facilities and synthesis of hydrogen as fuel for hydrogen fuel cells [15].

The expected growth in coal combustion from 2002 to 2030 was 1.5% per year. Due to strong efforts made by the OECD and other countries to minimize the use of coal due to carbon emissions, the rate of coal consumption was practically unchanged from 2008 to 2010.But in 2021, when it increased by 6.3%, coal consumption experienced a similar significant rebound as that of oil and natural gas. Non-OECD countries are the consumers of about 81.5% of the coal usage across the world. However, the consumption of coal across the world is expected to rise by a small margin in 2022, bringing it back to the highest point it attained about ten years ago [18].

The peaceful application of nuclear fission for electricity generation came into

focus in the 1950s. Approximately 440 nuclear reactors generate about 10% of the total electricity generated in the world today. Nuclear technology is the second-biggest producer of low-carbon energy globally, accounting for 28% of the worldwide supply in 2019. A few nuclear power plants were constructed and first emerged in 1970, after that, the rate of nuclear energy production significantly rose until 2006. After the accident occurred at the Fukushima nuclear power plant, the rate of nuclear energy output started to drop and eventually reached a minimum [19], but once again been boosted and maintained constant throughout 2019-2021 due to the fuel problem and global warming (Figure 3).

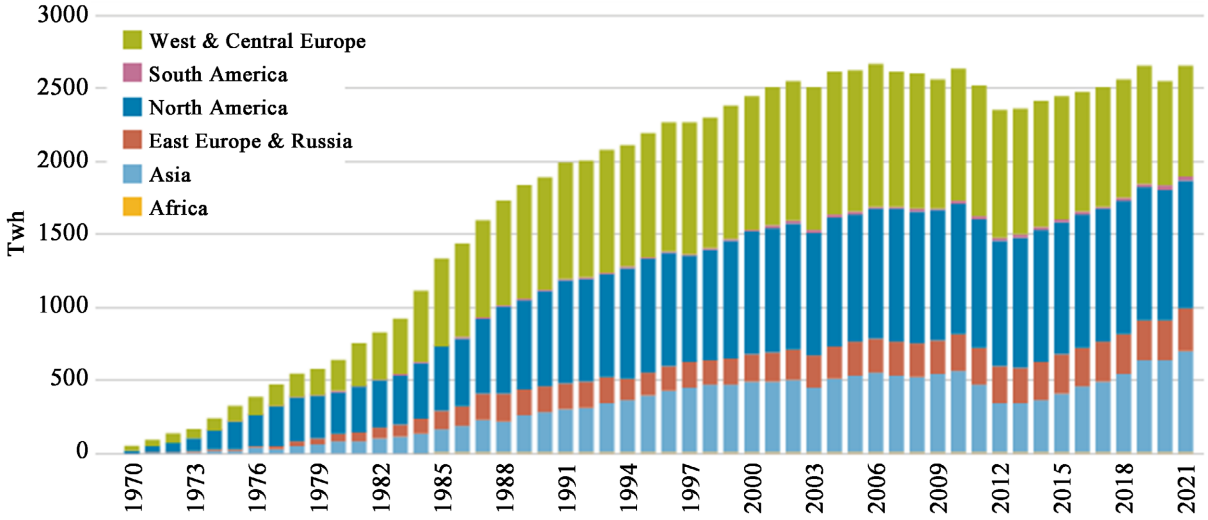


Figure 3. Production of nuclear electricity (IAEA PRIS) [20].

It is anticipated that renewable energy use will increase and reach 247 exajoules (~68,666 TWh) by 2050 (Figure 4). In contrast, the entire consumption of renewable energy was 42 exajoules in 2000 (or approximately 11,676 TWh).

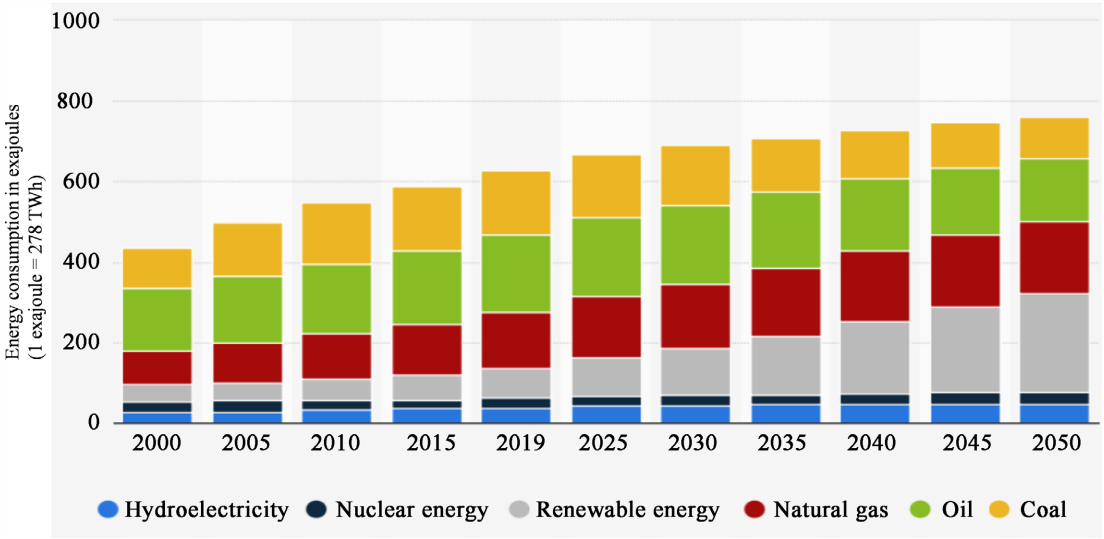


Figure 4. A projection of consumption of energy globally compared to energy source within the period of 2000 to 2019 along with a prediction until 2050 [21].

The rate of consumption of coal and oil will decline over the forecast period (**Figure 4**), whereas the rate of consumption of renewable energy will dramatically rise [21].

2. Sustainable Energy for Development

A crucial prerequisite for development and the eradication of poverty is access to modern energy facilities. The European countries have heavily depended on fossil fuels for their development from the dawn of the industrial period. The environmental costs that ensue, as well as the threats to the global climate, are widely understood. The situation is getting worse as developing countries strive to catch up economically by depending on traditional energy technologies. Therefore, it is becoming more vital than ever to promote renewable energy sources and investigate ways to save energy globally [13]. The industrialized countries bear the primary duty for creating technology for a sustainable global energy system. It is advisable to encourage emerging countries to take part in this international endeavor. In this regard, one only needs to think back to the countries' advantageous natural environments, which would make it easier to use renewable resources like solar panels, wind energy from the Bay of Bengal, and hillside trails, notably in Bangladesh.

Decentralized use of electricity generated from renewable energy offers the greatest benefits. It can open new opportunities for underdeveloped rural areas where it would be economically unviable to build an electricity network. This can help fight poverty. Many developing countries may cut back on their reliance on imported fossil fuels and the financial strain brought on by market volatility with the aid of renewable energy sources [10] [12].

The World Future Energy Summit, the largest business event for sustainability and future energy, took place in Abu Dhabi in 2021 [22]. It placed an emphasis on cutting-edge technology and ideas in the fields of efficient use of energy, water, solar energy, waste management, urban planning, climate, and the environment. Government and business leaders, 840 skilled exhibitors, and 34,000 tourists from 125 different countries were all there. In 2002, Johannesburg, South Africa, hosted the first Sustainable Development Summit. By dedicating one billion euros up until 2007 for initiatives involving sustainable energy for international development, the German government made a strong statement during the summit. The initiative seeks to assist the partner nations improve their access to environmentally friendly energy, fight poverty, and switch from energy production techniques that hurt our climate and ecosystem to environmentally favorable ones [23].

3. Renewable Energies

Renewable energy is that which is produced from resources that can be replenished naturally throughout time. The term refers to energy sources such as sunlight, wind, river flow, and geothermal heat etc. [24]. Although initiatives in-

volving renewable energy are often large-scale, they can also be applied for rural, remote, and underdeveloped countries [25] [26]. Renewable energy is commonly used with further electrification to optimize the advantages of electricity. Electricity is clean at its point of use [27] [28].

Between 2011 and 2021, renewable energy reached 28% from 20% of the worldwide supply of electricity (**Figure 5**). Nuclear power decreased to 10% from 12%, and fossil fuels reached 62% from 68%. Hydropower's contribution dropped to 15% while solar and wind energy increased to 10% from 2% [29] [30]. The proportion of geothermal energy increased by 1%, as did biomass. There are 3146 gigawatts of capacity currently operational in 135 countries, even though 156 countries have laws overseeing the renewable energy industry. China accounted for about half of the increase in renewable electricity produced globally in 2021 [31].

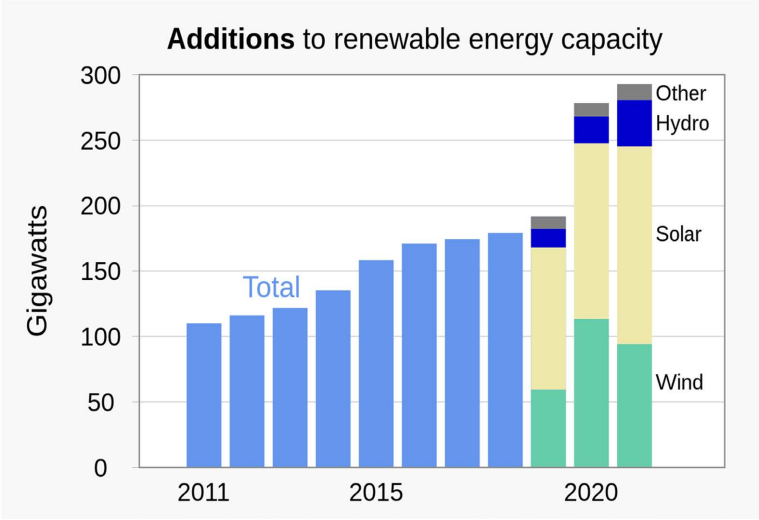


Figure 5. Scenario of renewable energy capacity. About 45% renewable energy was increased in 2020 compared to that in 2019. Among them, 90% wind energy (green) and 23% new solar photovoltaic system (yellow) [31].

Renewable energy systems account for a sizeable fraction of newly established power capacity throughout the world, and they are quickly improving in effectiveness, cost, and share of total energy consumption [32] [33] [34]. In most countries, photovoltaic solar panels or onshore wind power are the least expensive sources of electricity for new construction [35].

Globally, many countries already generate over 20% of the needed energy from renewable sources, and others produce in excess of 50% of required electricity this way [36]. National renewable energy markets are expected to keep growing quickly into the 2020s and beyond [37]. According to studies, it is both technically and economically feasible to transition to 100% renewable energy in all applications, including heating, electricity, transportation, and desalination [38] [39] [40].

The utilization of energy-efficient technologies and renewable energy sources

significantly boosts economic benefits, security of energy, and mitigation of climate change [41]. Renewable energy development is, however, being hampered by subsidies for fossil fuels totaling several hundred billion dollars [42]. In surveys considering international opinion, wind and solar along with other renewable energy sources have received overwhelming public approval [43] [44]. The International Energy Agency indicated in 2021 that greater efforts are needed to promote renewable energy in order to attain net zero carbon emissions, and it urged an increase in generation of about 12% per year until 2030 [45].

3.1. Motives and Advantages

Fossil fuels are being consumed much faster than they are being replaced. The sources of renewable energy are scattered over a large area, in contrast to fossil fuels, which are mainly found in just a handful of countries. The economy and energy security would benefit from rapid adoption of renewable energy sources, improved efficiency, and technically diversified energy sources [40].

Additionally, it would improve public health, decrease early deaths from pollution, and minimize associated expenditures that might save large sum of money annually. Environmental contamination, such as air pollution caused by the combustion of fossil fuels, would also be reduced [46] [47]. The costs of implementing decarbonization measures can be largely compensated by quantitative health gains, according to numerous assessments of these strategies [48] [49].

Concerns regarding climate change, as well as the ongoing reduction in the cost of some technologies that generate electricity from renewable sources like windmills and solar power plants, are driving an upsurge in renewable energy consumption [43]. The sector was able to survive through the global financial crisis better than many other industries thanks to new government expenditures, rules, and policies [50]. The IRENA anticipates that by 2019, renewables' overall share in the energy mix, including energy use, heating, and transportation, must climb six times faster than the present level [51].

3.2. Prospects of Renewable Energy

The growth and development of a system for supplying energy is crucial for any nation to accomplish the objectives of the UN Millennium Declaration. These goals are achieved through using renewable energy resources and energy-efficient technologies in emerging nations. They enable decentralized energy access so that even in rural areas, the problem of energy supply won't be a barrier to development. By substituting them for fossil fuels, they lessen the economic dependence on energy imports that many countries face [52] [53] [54] [55] [56].

The burning of coal, natural gas, and petroleum also endangers the ecosystem and the climate worldwide. The world's energy source must become more sustainable in the future. It must provide for the basic requirements of the world's

impoverished without depleting the planet's finite natural resources and endangering present- and future-generational life. This may be accomplished by utilizing energy more efficiently and relying on sources of clean energy such as wind power, hydroelectric power, solar energy, and geothermal energy. Currently, renewable energy sources provide around 30% of the worldwide overall energy needs. The sun provides the globe with enough energy to theoretically meet all the planet's energy needs 15,000 times over. The goal right now is to exploit some of this potential for the benefit of humanity. By the year 2050, according to experts, renewable energy sources might supply nearly half of the world's energy needs [52] [57]. Many types of renewable energy exist, including massive hydropower dams and windmills, small PV installations that power individual homes or small villages commonly named as solar home systems or drive water pumps off the grid. Geothermal energy provides a cost-effective alternative for heating and electricity generation. It is well recognized that the energy supply has been insufficient in many developing and newly industrial countries up to this point. There is no national electricity network serving vast areas. Large portion of the population's energy needs are traditionally met by natural resources, primarily wood. Because the soil erodes without vegetation cover, this contributes to deforestation, which in many locations causes severe environmental concerns. This is a significant barrier to these countries' economic development [55].

3.3 Renewable Energies to Combat Global Warming

The primary global sources of CO_2, one of the main GHGs, are electricity and heat generation (31%), combustion of fuel for transportation (15%). Agriculture contributes about 11%. About 72% of emissions come from all forms of energy production. By affecting their operations, supply chains, consumers, employees, and other stakeholders, companies in the service sector have a chance to change the behaviors necessary to halt the most devastating effects of climate change [56] [57].

Since the beginning of the industrial period, increasing volumes of gases have been released into the atmosphere. The effects caused by the current energy system on the environment are shown in **Table 2** [58]. **Table 3** illustrates global emission of CO_2 according to region [58].

Combustion of coal, petroleum, and natural gas used in industrialized countries resulted in massive CO_2 emissions into the environment [8] [58]. Globally, temperatures have increased by 0.6˚C on average over the previous century, and severe weather events like droughts, floods and massive storms have been clearly on the rise recently. By the end of 21st century, the CO_2 content might be three times what it was in the pre-industrial era. Intergovernmental Panel on Climate Change (IPCC) predicts that temperature may rise up to 5.8˚C during the next century [6] [7] [8]. The main industry in many developing nations is agriculture. They may suffer significant economic losses due to extreme weather conditions

Table 2. Effects of the current energy system on the environment [53].

Energy source	Inherent		Avoidable	
	Global	Local	Global	Local
Coal	CO_2	Mining	Acid rain	Air pollution
Oil	CO_2		Ocean Pollution	Air pollution, local water resources
Gas	CO_2		Greenhouse gases due to leaking pipelines	
Hydropower		Aquatic ecosystems/ Competition with other water usage		Aquatic ecosystems/ Competition with other water usage
Nuclear	Non-Proliferation			Radioactive waste

Table 3. Global CO_2 emissions (1990-2025) [59].

Mature market economies	10,465	11,877	13,080	13,745	14,392	15,183
North America	5769	6701	7674	8204	8759	9379
Western Europe	3413	3549	3674	3761	3812	3952
Mature market Asia	1284	1627	1731	1780	1822	1852
Transitional Economies	4894	3124	3643	3937	4151	4386
Emerging Economies	6101	9408	13,478	15,602	17,480	19,222
Asia	3890	6205	9306	10,863	12,263	13,540
Middle East	845	1361	1761	1975	2163	2352
Africa	655	854	1122	1283	1415	1524
Central and South America	711	988	1289	1480	1639	1806
Total World	21,460	24,409	30,201	33,284	36,023	38,790

and shifting climatic circumstances. The countries with developing economies under consideration face a serious threat to their existence from climate change, particularly for the less wealthy parts of the population [8]. The industrialized countries bear most of the blame for this. As quickly as feasible, they will need to switch to the production of renewable and CO_2-free energy. Investments in greater energy efficiency are a crucial component of climate change policy.

3.4. Renewable Energy Power Generation

3.4.1. Solar Energy

Sunlight is harnessed utilizing a range of technologies such as photovoltaics, concentrated solar power (CSP), concentrator photovoltaics (CPV) and synthetic photosynthesis [60] [61]. Solar energy now accounts for the majority of new

renewable energy [62]. Together with CSP, solar PV technology has the greatest potential of all the renewable energy sources. It has become a rapidly expanding multi billion-dollar business [63] [64]. CSP devices use mirrors, tracking mechanisms, and lenses to concentrate a broad region of sunlight into a tiny beam. The first commercially viable concentrated solar power facilities were built in the 1980s. The most effective solar energy technology by far is CSP-Stirling. **Figure 6** displays global maps of horizontal sun irradiation.

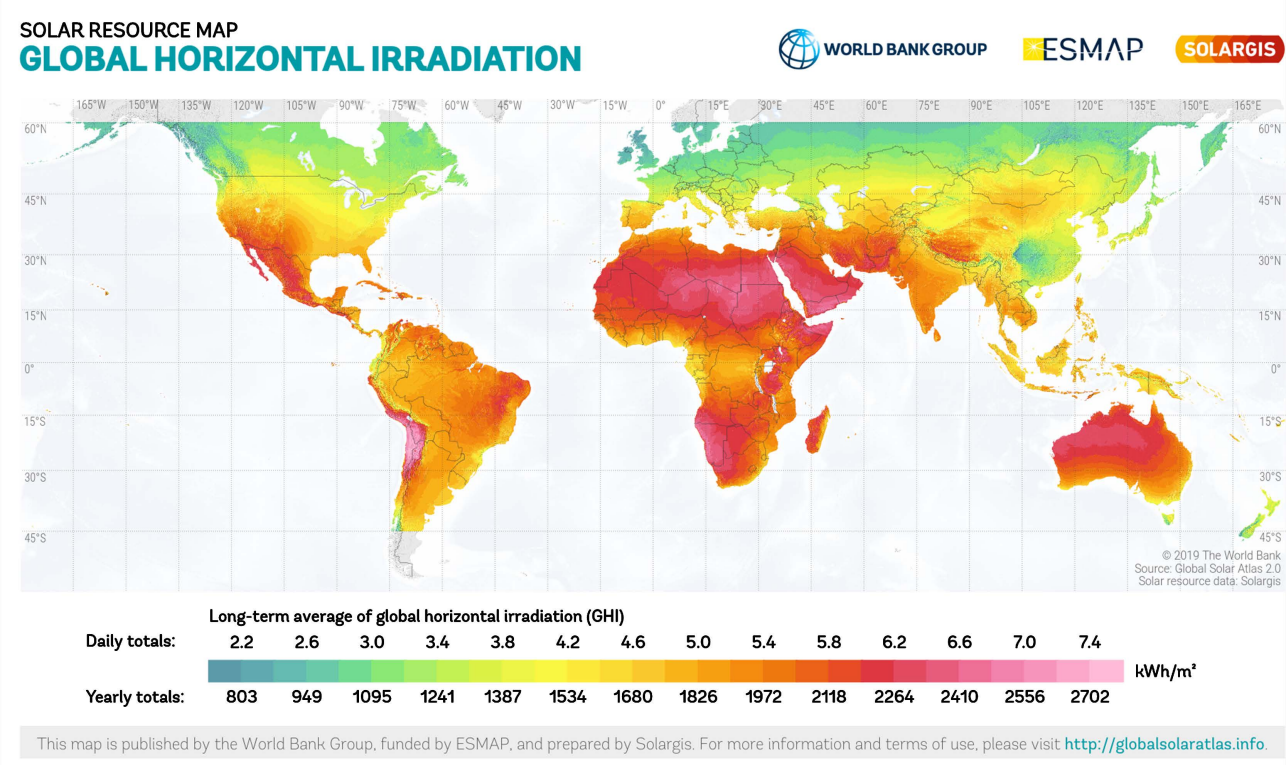


Figure 6. Global map of horizontal irradiation [65].

The IEA stated in 2011 that there will be tremendous long-term benefits from the development of clean, affordable solar energy technology. By relying on a local, limitless, and largely import-independent resource, it will promote sustainability, reduce pollution, lower the cost of tackling climate change, and guarantee lower fossil fuel expenditures. These advantages are universal. As a result, the increased expenses associated with initial deployment should be seen as exploring expenditures; they need to be carefully planned for and budgeted [60]. About 505 GWh per year, or about 2% of global electricity, comes from solar energy. Anywhere that receives sunshine can be used to generate power using solar energy, but the amount that can be used depends on the weather, the location, and the time of day [66]. The IPCC 2022 climate mitigation report states that direct solar energy has a much greater global potential than any other renewable energy source. It goes much above the entire energy required to support mitigation during the 20th century [67]. The world's highest percentage of solar

energy is found in Australia, which will meet 9.9% of the nation's electrical needs in 2020 [68]. Over 30 percent of Australian residences currently have rooftop solar PV systems installed, having an overall power generation capacity of in excess of 11 GWh [69]. **Table 4** displays the global electricity power generation capacity based on solar-based technologies.

Table 4. Global electricity generation using solar-based technologies.

Electricity generation capacity	849.5 GWh (2021) [70]
Annual growth rate of electricity generation capacity	26% (2012-2021) [71]
Percentage of generated electricity	2% (2018) [35]
Leveled price/MWh	USD 38.343 for Utility-scale photovoltaics (2019) [72]
Basic technologies	CPV, PV, solar thermal collector
Additional uses of energy	Heating, ventilation, and air conditioning (HVAC); water treatment; water heating; cooking; water treatment

One of the most promising sources of renewable energy in Bangladesh is solar energy, which experiences more than 300 sunny days annually with an average solar radiation of 5 kWh/m^2. This is because the country lies 2668.68 kilometers north of the equator, placing it in the northern hemisphere. To encourage the use of renewable energy, the government of Bangladesh has already started the "500 MWh Solar Power Mission". Solar energy, wind energy, hydropower etc. can all help to partially meet the country's energy needs. Considering this, efforts are being undertaken to create visible light-sensitive nanomaterials and to mineralize organic contaminants in industrial wastewater while under solar radiation [73] [74] [75] [76] [77].

3.4.2. Wind Energy

One of the promising renewable technologies is wind energy. Wind turbines can be operated by air flow. Modern utility-scale wind turbines have rated powers that range from around 600 kWh to 9 MWh. Since the power produced by the wind is a function of the wind speed, as the wind speed climbs, the turbine's power output reaches its maximum level [78]. Wind farms are typically located in locations with stronger, more consistent winds, like coastal and high-altitude locations. The typical annual full load periods for windmills range from 16% to 57%; however, in particularly advantageous offshore areas, they may be greater [79].

Large-scale wind turbine installation would be necessary for this, especially in locations with abundant wind resources. Offshore wind resources can produce significantly more electricity than turbines that are installed on land since their average wind speeds are about 90% higher than those on land [80]. **Table 5** illustrates the amount of electricity produced worldwide utilizing wind-based tech-

nologies.

Table 5. Global electricity generation using wind-based technologies.

Electricity generation capacity	824.9 GWh (2021) [81]
Annual growth rate of electricity generation capacity	13% (2012-2021) [71]
Percentage of generated electricity	5% (2018) [31]
Leveled price/MWh	USD 30.165 for land-based wind (2019) [82]
Basic technologies	Wind turbine
Additional uses of energy	Windmill, windpump

With 466.5 TWh of wind energy produced in 2021, or more than 29% of the total 1596.4 TWh produced worldwide, the largest producer of wind power worldwide is China. With 139 GWh worldwide, the USA is the second-largest generator of wind energy [83]. On the other hand, at Sonagazi upazila, Feni district, Bangladesh constructed only a 0.9 MWh wind-based power plant in 2005. Three years later, a 1 MWh wind power plant was constructed in Kutubdia, Cox's Bazar.

3.4.3. Hydropower

A current of water flowing slowly or a mild sea wave can produce enormous amounts of energy. Water has the highest conversion efficiency of all renewable energy sources, producing electricity at a rate of nearly 90% [84]. Large structures such as reservoirs and dams provided hydroelectric energy in the past [85]. The largest of them are the Itaipu Dam (1984), constructed by Brazil and Paraguay, and the Three Gorges Dam (2006) on the Yangtze River by China. Hydroelectric power plants are generally capable of producing up to 50 MW of power. The largest generator of hydroelectricity worldwide is China, with more than 45,000 small hydroelectric facilities [86].

Without building a sizable reservoir, run-of-the-river hydroelectricity generators harness the power of rivers. After being moved down the river bank (via pipelines, tunnels, channels etc.) it is lifted above the valley floor in order to drive a turbine. A penstock is typically left open to let the water fall through. A significant amount of energy can be generated by a run-of-river plant which is comparable to the Chief Joseph Dam on the river Columbia in the United States [87]. Even though run-of-the-river hydroelectric power plants are really small or tiny.

In 2010, the Asia-Pacific region produced 32% of the world's hydropower, which is produced by about 150 countries. The majority of the electricity produced by 46 of the top 50 countries in terms of the use of renewable energy sources is hydroelectric [34]. The Itaipu Dam in Brazil, the Guri Dam in the country of Venezuela and the Three Gorges Dam in China are the only hydroelectric power operations that now produce more than 10 GW of electricity [88].

As hydropower is highly adaptable, it complements wind and solar energy [89]. The amount of electricity generated globally using hydro-based technologies is shown in **Table 6**.

Table 6. Global electricity generation using hydro-based technologies.

Electricity generation capacity	1230.0 GWh (2021) [90]
Annual growth rate of electricity generation capacity	2.5% (2012-2021) [71]
Percentage of electricity generated	16% (2018) [31]
Leveled price/MWh	USD 65.581 (2019) [91]
Basic technologies	Dam
Additional uses of energy	Pumped storage, mechanical power

The only hydroelectric power plant in Bangladesh is at Kaptai in the Rangamati district. The facility steadily produced 230 MWh of power between 1962 and 1988 by starting up five units. The installation of two additional hydro-based units at the same location is also being planned [92].

3.4.4. Geothermal Energy

Radioactive disintegration of minerals are the sources of Earth's geothermal energy [93] [94]. Deep under the Earth, up to 6400 kilometers below the surface, heat can be exploited to generate geothermal energy. Over 5000˚C may be reached at the core. The granite surrounding the center radiates heat. Due to its lesser weight than solid rock, magma convects upward. The rock and water in the crust are then heated by this magma to temperatures as high as 371˚C [95].

The Earth's crust is used as a thermal battery to generate renewable thermal energy for the purposes of home and commercial refrigeration, and other things. This is known as low temperature geothermal [96]. This form of geothermal energy transfers heat energy to and from Earth based on a seasonal change for cooling and heating using a geothermal heat pump and ground-coupled heat exchanger. Thus, as part of the continuous transition to net zero energy [97], low temperature geothermal/GHP is gaining national attention and support through a variety of tax credits [98]. **Table 7** displays the total amount of electricity produced worldwide using geothermal-based technologies.

Table 7. Global electricity generation using geothermal-based technologies.

Electricity generation capacity	15.6 GWh (2021) [99]
Annual growth rate of electricity generation capacity	4.5% (2012-2021) [71]
Percentage of generated electricity	<1% (2018) [31]
Leveled price/MWh	USD 58.257 (2019) [100]
Basic technologies	binary cycle power stations, dry steam and flash steam
Additional uses of energy	Heating

Geothermal is the most reasonably priced clean energy. Due to the power crisis and the potential for producing electricity from geothermal energy, there is a big chance to find investment for geothermal energy in Bangladesh's power sector. The first geothermal power station in Bangladesh of 200 MWh capacity will be built by a private enterprise.

4. Connecting Various Sectors and Incorporating into the Energy System

In comparison to fossil fuels and nuclear technology, the production of renewable energy is more erratic and geographically distributed. Technically, it is feasible to include it into the overall energy system, but doing so introduces new problems including lower system inertia and higher production volatility [101]. The risks and expenses associated with the deployment of renewable energy can be decreased by installing energy storage facilities and smart power systems where energy is automatically utilized as it is produced [102].

Flexibility might be improved by combining the power-producing sector with other industries. Using electric vehicle charging stations and power transmission to the grid, for instance, can couple the transportation sector [103]. Similar to how the building sector and the industrial sector can be correlated by thermal energy for heating and cooling [103], the building and industrial sectors can be linked by electrolysis-produced hydrogen [104].

When more energy is produced then needed, extra electricity is stored, particularly for intermittent sources like wind, tidal, and solar power, and released back into the system when use falls. Hydroelectricity provides nearly 85% of all power storage in pumped storage [105]. Batteries are being employed more commonly for grid ancillary services, household storage, and other applications [106] [107].

5. Trends in Markets and Industries

Solar energy is the most common of the new renewables, followed by wind, hydropower, and biofuels [108]. Compared to coal, gas, or oil, investments in renewable energy, particularly solar energy, typically have a higher employment-creating potential [109] [110]. As of 2020, there were 12 million people employed by renewables worldwide, with solar PV accounting for roughly 4 million of those employed [111].

5.1. Growth of Renewable Energy Sources

According to a recent review of the literature, high liability mitigation values will provide potent encouragement for the implementation of renewable energy technologies if emitters start to be held accountable for damages arising from GHG emissions that contribute to changes in the climate [112]. Between 2010 and 2019, the globe invested US$2.7 trillion in renewable energy capacity, with China ($818 billion), Japan ($210.9 billion), the United States ($392.3 billion), Germany ($183.4 billion), and the United Kingdom ($126.5 billion) making up

the top five contributors [113]. This was an increase from the amount invested in the 10 years between 2000 and 2009 by at least three to four times [114].

5.2. Projections of the Future

The IEA forecasted in research published in May 2022 that despite cost increases, renewable energy would still be viable in 2023 despite fossil fuel prices rising more quickly [108]. Solar PV installations would reach approximately 200 GWh by 2023. Both Europe and China are predicted to establish more renewable energy than the United States. India and Indonesia's transport regulations will contribute to a rise in biofuel consumption in both countries in 2023 [108]. Executive director of the IEA stated that countries should increase their investments in renewable energy to "lift the strain on users from high prices of fossil fuel, increase the security of our energy infrastructure and put the world on pace to meet our climate goals" in June 2022 [114]. Increasing direct heating from renewable sources like geothermal and solar thermal is part of China's five-year strategy until 2025 [115]. The EU's Repower EU strategy, which aims to decrease its reliance on Russian fossil gas, is anticipated to ask for significantly cleaner hydrogen [116].

The World Resources Institute and other significant US businesses met in July 2004 and decided to adopt more renewable energy sources. The discussion uncovered a number of guidelines including collaboration, availability of third-party financing options, cost competitiveness, longer-term fixed pricing suppliers, and choice [117]. The proportion of demand satisfied by renewables for "other final users," which are predominantly the service and commercial sectors, which consume relatively substantial amounts of electricity, and industry, varies from a low of 3.4% to highs of over 20%, according to UK statistics (as of September 2020) [118]. By creating infrastructure for renewable energy sources like solar, photovoltaic, wind, and nuclear power, the Bangladeshi government hopes to reduce carbon emissions, which are projected to reach zero by 2050 (**Figure 7**).

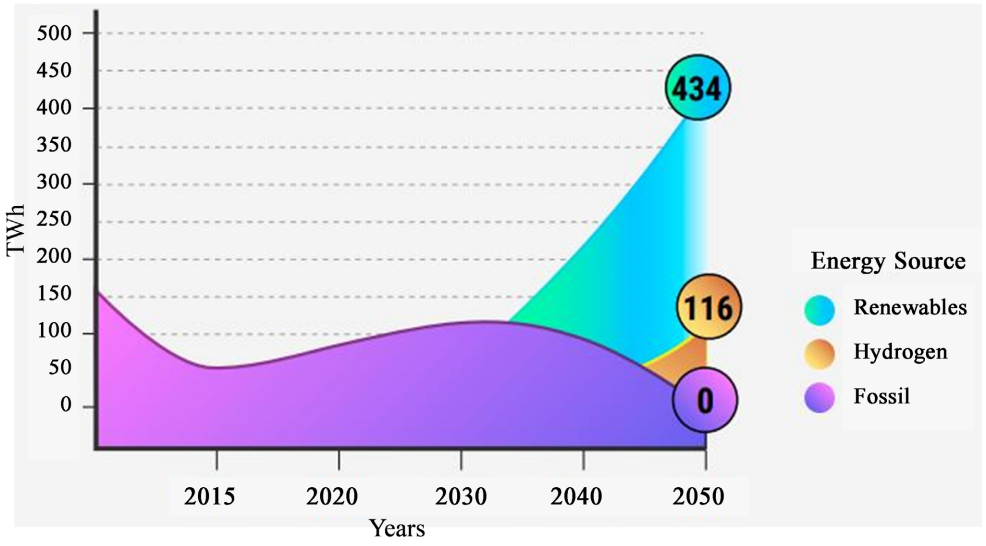


Figure 7. A projection of zero carbon emission in Bangladesh by 2050 [119] [120].

6. Specific Trends in Technologies

6.1. Hydroelectricity

The capacity of renewable hydropower worldwide in 2020 was 1330 GWh [121]. The projected 14,000 TWh/year hydropower potential of the world has only been utilized in a third of its total capacity [89] [121]. Due to their significant effects, such as community relocation, flooding of wildlife habitats, and agricultural land, new hydropower projects are met with criticism from the local community [122]. Therefore, the main obstacles for new developments are high costs and development time from the permission process, risk assessments, as well as a lack of social and environmental acceptance [123]. If the conditions allow, existing dams, like the 1985-built Russell Dam, may be updated with "pump back" capabilities for pumped-storage, which is beneficial for peak demands or to sustain sporadic wind and solar output. VRE is less valuable than dispatched energy [124] [125], thus nations with extensive hydroelectric development, like Canada and Norway, invest billions to modernize their infrastructure and participate in trade with neighbors with little hydro [126].

6.2. Development of Wind Energy

Wind is an eco friendly source of renewable energy. Additionally, once a turbine is built, operating expenses are almost minimal because wind is a free resource. Since 1996, there has been an enormous rise in the usage of wind energy due to mass production, technological advancements, and government tax incentives that make turbines more affordable (**Figure 8**).

6.3. Thermal Solar Energy

From 1.3 GWh in 2012 to 5.0 GWh in 2017 [128], solar thermal energy's capacity has increased. With 2.3 GWh capacity, Spain has the world's largest operational solar thermal power capacity [128]. California accounts for 1.4 GWh of the 1.8 GWh in the United States, which are all from solar thermal power projects [129]. The Mojave Desert in the southwest of the United States has seen the construction of several power facilities. Only four other nations, South Africa (300 MWh), India (229 MWh), Morocco (180 MWh), and the United Arab Emirates (100 MW), had installations exceeding 100 MWh as of 2017 [128]. The US invested a lot in research into concentrated solar electricity and photovoltaics. The Southwest desert is home to some of the largest utility-scale solar arrays in the world. The oldest solar thermal power plant currently in operation is California's 354 MWh SEGS thermal power facility [130]. With a gross capacity of 377 MWh, the Ivanpah Solar Electric Generating System is a solar-powered thermal power plant located 64 km southwest of Las Vegas in the California Mojave Desert [131]. A solar power facility with a capacity of 280 MWh was completed in 2013 close to Gila Bend, Arizona [132]. Three integrated solar thermal/combined-cycle gas-turbine power projects have received the World Bank's approval for poor countries, including Egypt, Mexico, and Morocco [133].

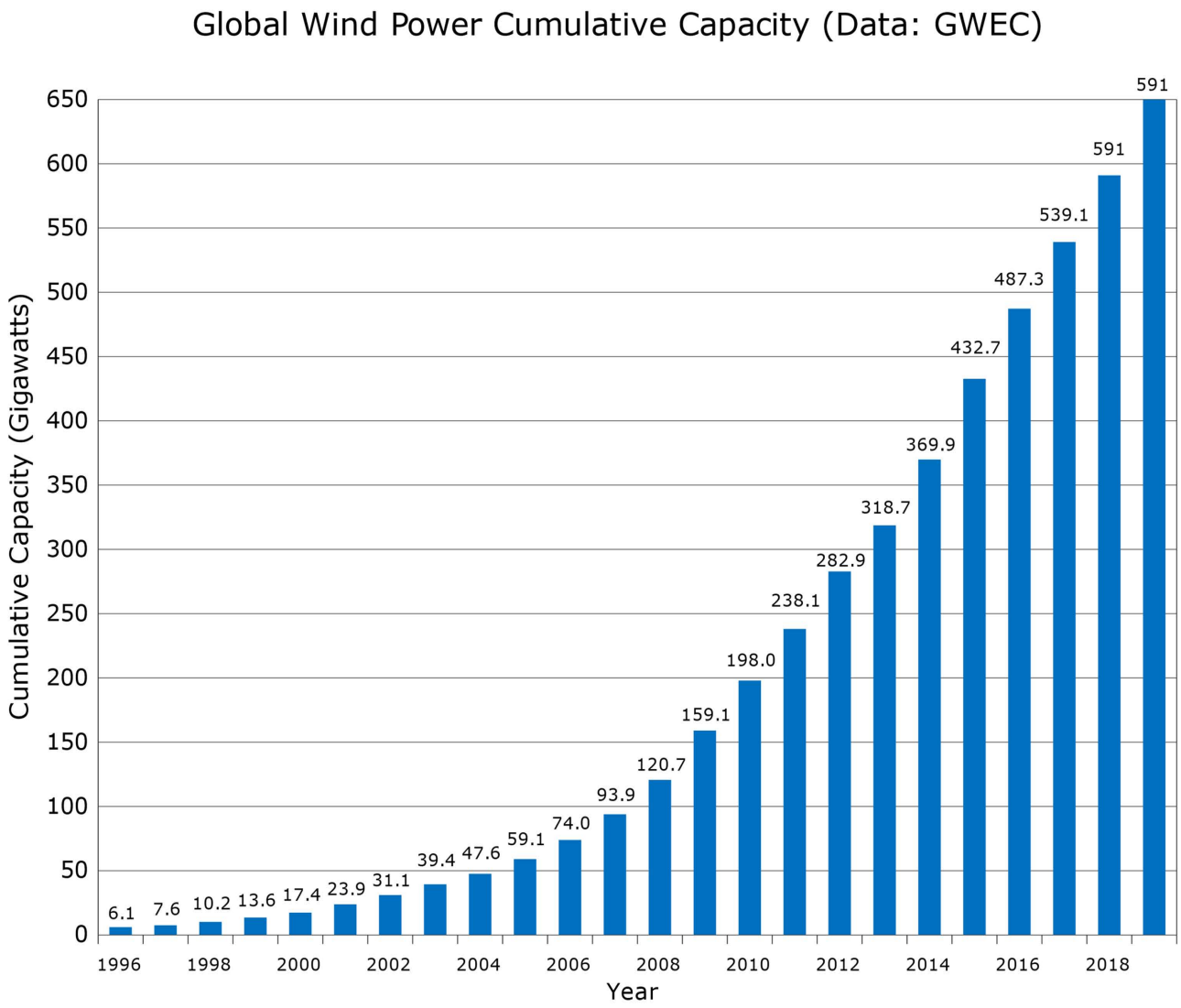


Figure 8. Expansion of wind power capacity globally (1996-2018) [127].

6.4. Photovoltaic Development

The global capacity of PV increased from 177 GWh at the end of 2014 to 385 GWh in 2017 [128]. Thin-film solar cells make up around 10% of photovoltaic installations worldwide, despite crystalline silicon being the most used PV technology. The efficiency of generating electricity from PV technology has increased recently. Its installation cost per watt and energy payback time have decreased, and by 2014, at least 30 distinct markets have reached grid parity [134]. Building-integrated photovoltaics, often known as "onsite" PV systems, make use of existing land and buildings to generate electricity near to where it will be used [135].

Regarding the pace of growth of photovoltaics, Japan and China came in second and third, respectively. Solar photovoltaics and concentrated solar power are expected to contribute 16% and 11%, respectively, to the world's electricity production by 2050. To achieve this, installed PV capacity must expand to 4600 GWh, with more than half of that capacity likely to be installed in China and In-

dia [136]. In the 1980s, the first commercial concentrated solar power facilities were developed. With the cost of solar electricity falling, utility-scale solar power plants with very large capacities are being built, and over one million solar PV units are now linked to the grid. Many solar photovoltaic power plants have been built, mostly in Europe, China, and the US [137]. The largest PV power plant in the world is the 1.5 GWh Tengger Desert Solar Park in China.

6.5. Development of Geothermal Energy

12.9 GWh of geothermal energy was produced worldwide in 2017 [128]. Geothermal energy is inexpensive, reliable, economically viable, and harmless to the environment [138], but has traditionally only been used in regions close to tectonic plate boundaries. Geothermal wells generate GHGs that are deeply buried. However, these emissions typically have a far lower energy density per emission than those from fossil fuels. If geothermal energy is employed extensively in place of fossil fuels, it has the potential to mitigate global warming. With 12.9 GWh of installed capacity in 2017, the United States lead the world in geothermal energy generation [128]. The Geysers, a geothermal area in California, has the world's highest number of geothermal power plants [139]. With 1.9 GWh of capacity online, the Philippines is the second-highest geothermal electricity producer [128].

6.6. Renewable Energy in Developing Countries

As emerging nations expand their energy supply and combat energy deficiency, renewable energy is being employed as a substitute for fossil fuel energy more frequently. Since 2015, non-hydro renewable energy investments in underdeveloped nations have outpaced those in rich nations and made up about 54% of all investments in renewable energy globally in 2019 [114]. According to the IEA, renewable energy will account for 42% of supply growth in China and much of the growth in energy supply in Africa, Central and South America, through 2030 [140]. The majority of developing countries are well endowed with substantial geothermal energy, solar, wind resources for energy production, in addition to the capacity to manufacture the rather labor-intensive equipment required to harness them. Developing nations may be able to reduce their dependency on fossil fuels and create energy inventories that are more resilient to price hikes by encouraging the advancement of such energy sources. These investments may often be cheaper than energy systems that use fossil fuels [141].

6.7. Current Status of Energy in Bangladesh

In the contemporary world, having a supply of electricity is considered a basic human right. The government of Bangladesh has made a number of actions to electrify large populations and regions [142]. Additionally, they support the establishment of industries, factories, and commercial districts in order to boost the Gross Domestic Product (GDP) and get the country closer to the status of

developed nation. The overall usage of energy in 2021-2022 was 85,607 GWh, indicating a notable rise of almost 5184 GWh in comparison to the year before. This increased trend in consumption is anticipated to reach a rate of 7% (**Figure 9**) [143]. Current predictions show that about 5700 MW more electricity generation needs to be ensured by 2040 in order to reach the ever-increasing demand. As of June 2023, Bangladesh has constructed a 26,007 MW plant capacity using a variety of fuels, including natural gas, coal, furnace oil, and diesel [144]. Renewable energy sources, however, are increasingly contributing more and more. The nation's daily total electricity production is about 12,500 MW, with a peak recorded output of 14,800 MW. Because of the harsh weather throughout the summertime, there is a huge increase in power demand. The nation is now producing somewhat more than 50% of its total installed capacity, although having a sizable installed capacity [144]. The main cause of this disparity is the insufficient availability of petroleum and petroleum products, specifically petroleum, gas, and coal. Many plants are thus forced to run in less than their rated capacity.

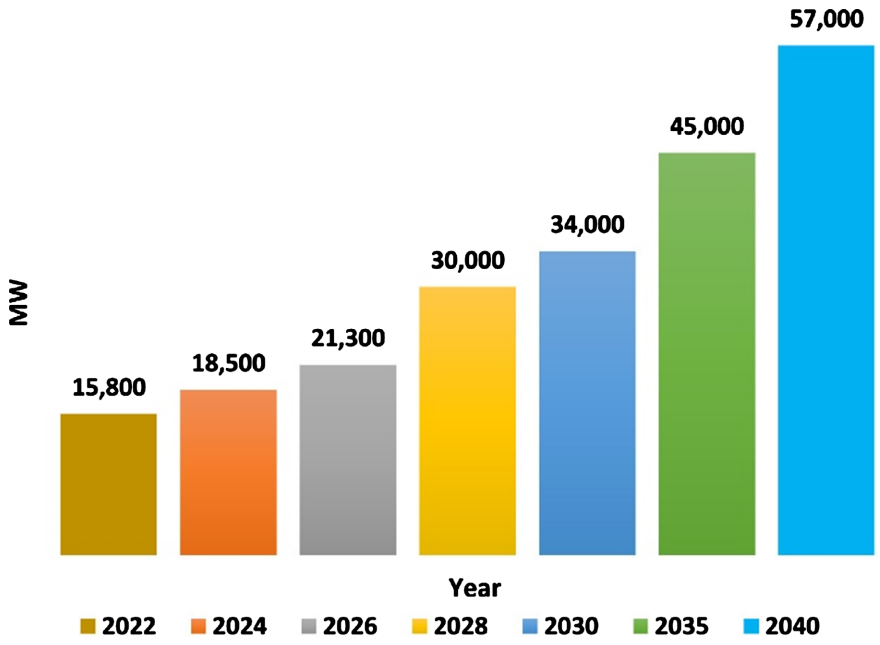


Figure 9. Prediction of electricity demand in Bangladesh up to the year 2040 [143].

It is clear from the facts that natural gas plays a major role in the nation's power production infrastructure, which together generate a significant 44% of the total everyday power generated [144]. There are a number of issues with this over dependency on gas supplies. In particular, according to the yearly inventory, the production of electricity using gas-based methods used around 46% of the entire amount of gas recovered from various gas sources in the year prior. Encouraging the development of hydroelectricity, solar electricity, and wind power installations can reduce the demand on gas supplies and strengthen the power sector's resilience.

6.8. Possibility of Renewable Energy Establishments in Bangladesh

According to Bangladesh's geography, the sun, hydroelectricity, wind, and biofuel are acknowledged as the main sources of renewable energy. With their 1183 MW of installed capacity up to the end of June 2023, these sources of electricity only make up 4.5% of all the total capacity in the nation. When it comes to these resources, solar power leads the pack with an approximately eighty percent contribution, which includes both isolated and on-grid systems [144] [145]. A master plan is currently devised to gradually enhance production from these sources of electricity in the upcoming years. Nonetheless, the projected role of renewable energy is still about 10% by the year 2040 [143] [146].

In 2014 to 2017, government of Bangladesh in collaboration with some private organizations ran an assessment of wind power generation in multiple areas throughout the country, result of which suggested installation of large-scale wind power generation facilities to be futile due to low to moderate wind speed in most areas of the country and a barrage of natural calamities that affect the coastal areas [147].

6.9. Challenges of Renewable Energy in Bangladesh

One of the countries most adversely impacted by climate change is Bangladesh. Various studies highlight the risk that coastal areas and those bordering riverbanks that are constantly eroding and flooding, which also make policy and the development of renewable energy networks more difficult. Bangladesh needs to find solutions to a number of additional problems in order to quickly create a favorable condition in the national power system. A lack of motivation for investors from the private sector also exists as shown by the following: insufficient coordination between ministries; procedural problems; a small budget allotted to RERs-based projects; a slow adoption of new technologies; a lack of knowledge of and compliance to green building regulations; and a lack of electrical infrastructure to cope with increased capacity and demand.

7. Strategy

The strategy aims to improve refugee protection and well-being by increasing the sustainable use of renewable energy sources on a worldwide scale, with the participation of host communities and other stakeholders. Despite the fact that most nations today have some sort of energy policy, Europe took the lead in the development of energy policies in the 2000s [148] [149].

7.1. Strategy Trends

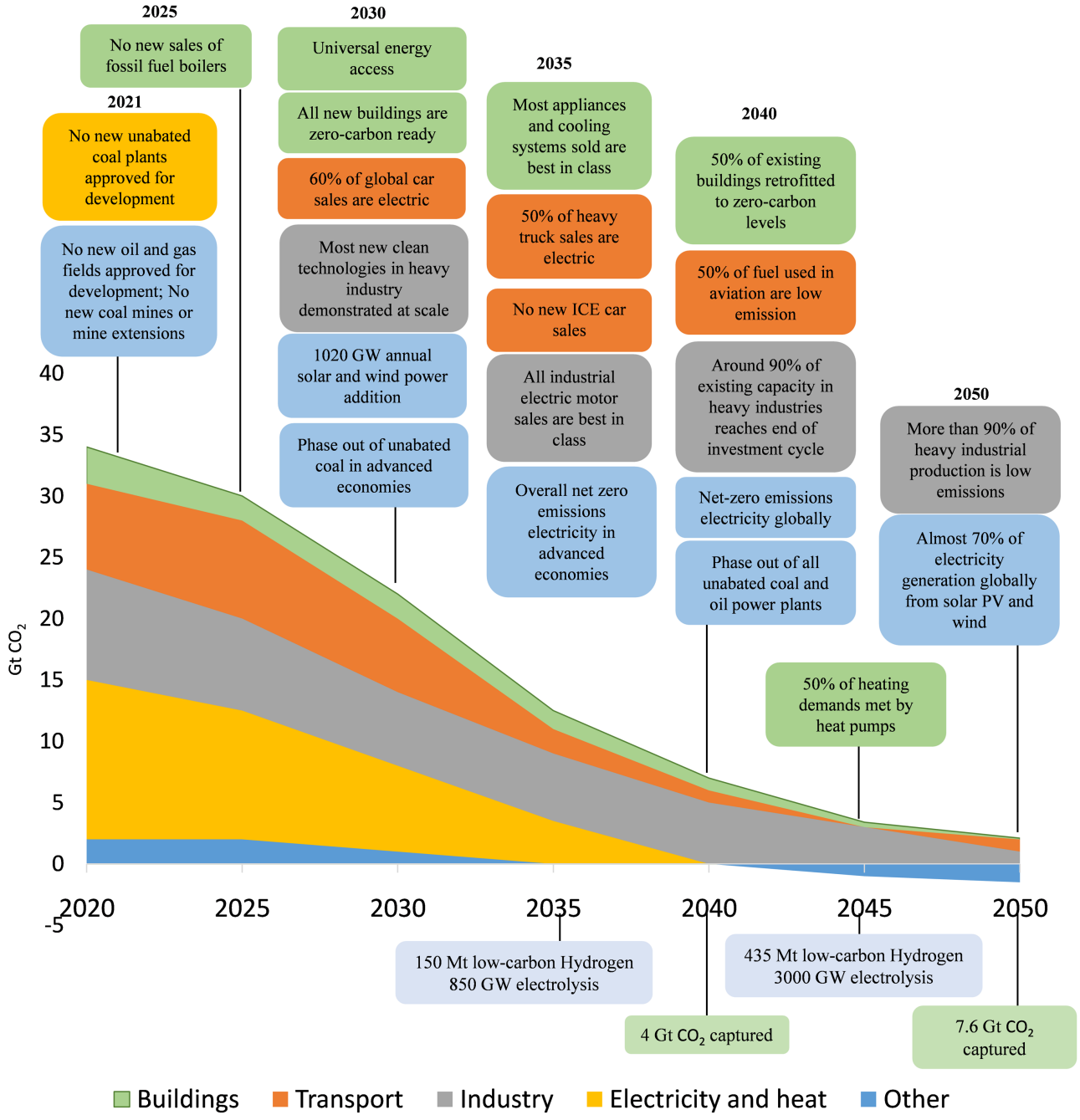
The IRENA works to encourage usage of renewable energy all throughout the world. It attempts to support capacity building and technology transfer while offering specific policy recommendations. As of April 2019, IRENA has 160 members [150]. Former UN Secretary-General Ban Ki-moon asserts that renewable energy can boost wealth in the world's poorest nations [151]. The UN

Sustainable Energy for all program was launched in September 2011, with the goal of increasing access to energy, productivity, and the adoption of renewable energy [152]. Many countries were inspired to create or enhance renewable energy regulations by the 2015 Paris Agreement on climate change [39]. In 2017, 121 countries adopted a renewable energy policy, with Bangladesh being one of the signing countries [153]. In 176 nations, national targets were in place that year. There are also a variety of policies at different administrative levels. Some public utilities provide planning or installation assistance for home energy upgrades. Green banks have been established by numerous local, state, and federal governments. A green bank is a type of financial organization that resembles a quasi-public entity and leverages public funding to encourage private funding for energy-efficient technology [154]. A variety of financial tools are used by green banks to close market gaps that limit the broad use of sustainable energy. Achieving carbon neutrality by 2050 is the main goal of the European Green Deal [155]. The European Union must decarbonize its energy system in order to attain its goal of climate neutrality of "net-zero GHG emissions by 2050". **Scheme 1** shows how energy strategies and policies could gradually reduce GHG emissions; by 2050, it is anticipated that emissions will be net-zero.

7.2. Renewable energy

To be 100% renewable, energy must originate entirely from sustainable sources. Concerns about the effects of climate change, pollution, and numerous other environmental issues, as well as economic prosperity and security of energy, are driving the effort to utilize entirely renewable energy for transportation, heating, cooling, and electricity. Since non-renewable fossil fuels now account for the vast bulk of energy production, a shift in the global energy system is necessary if renewable energy sources are to replace them as the dominant source of energy for the entire planet.

Prior to 2009, there was little study on this subject matter published, but attention has grown in subsequent years. A significant number of studies show that switching to solely renewable sources of energy in all sectors, including electricity, heat, transportation, and desalination, is both technically and fiscally possible [38] [39] [157] [158]. The idea that the most effective answers can only be found if one focuses on creating synergies among all sectors of the energy structure, including electricity, heat, transportation, or industry, is seen as a key component of 100% renewable energy systems [159]. Adoption of large-scale renewable energy and clean energy technologies is expected to encounter more political and social challenges than technological or economical ones [160]. The primary impediments, according to the 2013 Post Carbon Pathways study, which examined many worldwide studies, include climate change denial, the fossil fuels lobby, political rigidity, excessive and inefficient energy consumption, obsolete energy infrastructure, and economic constraints [161].



Scheme 1. Energy strategies and policies to achieve net-zero GHG emissions by 2050 [156].

8. Conclusions

Renewable energy comes from resources of nature that regenerate themselves without depleting the wealth of the planet in a period of time less than a human lifetime. Resources such as wind, tide, biomass, solar energy, thermal energy etc. have the benefit of being accessible practically everywhere in some fashion. They nearly never end. More importantly, they don't significantly damage the ecology or the climate. There are only finite reserves of fossil fuels like petroleum, coal, and natural gas. Eventually they exhaust themselves through constant extraction.

The natural mechanisms that make them do not, however, cause them to replenish as quickly. The usage of fossil fuels is still widespread the present day, and their costs are still heavily subsidized. In the meanwhile, the pollution they cause—which includes dangerous particles and greenhouse gases which damage the environment—has reached record heights. Furthermore, the consequences are catastrophic when something goes wrong, such as when the Deepwater Horizon oil rig blew in 2010. Renewable energy has grown faster than any other form of energy since 2011 overall. A new record was reached in 2021 when the currently operational electrical production from renewable energy expanded by a whopping 314 GWh. At the moment, renewable energy sources contribute approximately 29 percent of our daily energy demands, and that number is continuously increasing.

Key benefits of renewable energy for people and the planet

- *Renewable energy emits no or low greenhouse gases*

The combustion of fossil fuels produces substantial amounts of greenhouse gases. The majority of renewable energy sources are cause of next to no emissions even when the complete life cycle of the technology is taken into account.

- *Renewable energy emits minimal amount of air pollutants*

The growing consumption of petroleum and coal for transportation, industrial activities, and power generation (as well as the continual combustion of trash in many cities) is to blame for rising air pollution levels. Particles as well as other air pollution created by fossil fuels physically choke cities. According to WHO, they cause millions of unnecessary fatalities over metropolitan areas as well as cost large sum of money [162] [163]. Renewable energy serves as a potent driver of social and economic advancement rather than consuming valuable resources and harming the environment.

- *Renewable energy comes with low costs*

Rising energy costs and restricted availability of resources are typically associated with geopolitical upheaval and conflict. Locally generated renewable energy can be less vulnerable to supply chain issues, rising costs, and geopolitical issues. The Bangladeshi government intends to create a new renewable energy policy by 2050, which will further the development of the solar/PV industry. As Bangladesh prepares to switch from fossil fuel to unique fuel sources that are truly clean, renewable, and safe, it is predicted that renewable energies will play a vital role in the upcoming years. It should be noted that the government of Bangladesh has previously decided to build nuclear power plants (2400 MWh), and the plants are now being built. One of the two facilities is anticipated to be operational by the end of 2023, and the other one by the start of 2024. The Bangladeshi government is willing to build two additional nuclear reactors by 2041 in order to completely eliminate carbon emissions by the year 2050.

Data Availability

All the data used to write this article is shown in detail in Tables.

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Conflicts of Interest

The authors declare none of the authors' known monetary conflicts of interest or close personal links have influenced the work described in this study.

References

[1] METgroup (2021) When Will Fossil Fuels Run out? https://group.met.com/en/mind-the-fyouture/mindthefyouture/when-will-fossil-fuels-run-out#:~:text=Oil%20can%20last%20up%20to,coal%20up%20to%20114%20years

[2] IEA (2021) World Energy Outlook 2021. https://www.iea.org/reports/world-energy-outlook-2021

[3] Houghton, J. (1997) Global Warming: The Complete Briefing. 2nd Edition, Cambridge University Press, New York.

[4] Hordeski, M.F. (2002) New Technologies for Energy Efficiency. River Publishers, Denmark.

[5] Williams, L.D. (2005) Environmental Science Demystified. McGraw-Hill, New York.

[6] Hasegawa, A., Ohira, T., Maeda, M., Yasumura, S. and Tanigawa, K. (2016) Emergency Responses and Health Consequences after the Fukushima Accident; Evacuation and Relocation. *Clinical Oncology*, **28**, 237-244. https://doi.org/10.1016/j.clon.2016.01.002

[7] Field, C.B. and Raupach, M.R. (2004) The Global Carbon Cycle: Integrating Humans, Climate, and the Natural World. Vol. 62, Island Press, Washington DC.

[8] IEA (2002) Beyond Kyoto: Energy Dynamics and Climate Stabilization. IEA, Paris.

[9] Wolfson, R. and Schneider, S.H. (2002) Understanding Climate Science. In: *Climate Change Policy*: *A Survey*, Island Press, Washington DC, 3-52.

[10] Berger, J.J. (2002) Renewable Energy Sources as a Response to Global Climate Concerns. Climate Change Policy: A Survey, 411-446.

[11] Boyle, G. (1998) Renewable Energy: Power for a Sustainable Future. Oxford University Press, Oxford, 20-60.

[12] United Nations Development Program (UNDP) (2000) World Energy Assessment.

[13] IEA (2004) World Energy Outlook 2004. IEA, Paris.

[14] Solangi, K.H., Islam, M.R., Saidur, R., Rahim, N.A. and Fayaz, H. (2011) A Review on Global Solar Energy Policy. *Renewable and Sustainable Energy Reviews*, **15**, 2149-2163. https://doi.org/10.1016/j.rser.2011.01.007

[15] British Petroleum (BP) (2004) BP Statistical Review of World Energy 2004. BP,

London.

[16] Chemicals and Resources (2022) Oil Consumption Worldwide from 1998 to 2021. https://www.statista.com/statistics/265239/global-oil-consumption-in-barrels-per-day/#:~:text=Oil%20consumption%20worldwide%20reached%20approximately%2094.1%20million%20barrels%20per%20day%20in%202021

[17] Chemicals and Resources (2022) Global Natural Gas Consumption 1998-2021. https://www.google.com/search?q=annual+consumption+of+natural+gas+in+2021&rlz=1C1MSIM_enBD875BD875&oq=annual+consumption+of+natural+gas+in+2021&aqs=chrome..69i57j33i160j33i22i29i30l2.10746j0j7&sourceid=chrome&ie=UTF-8#imgrc=AT4QFSD4IRcRxM

[18] IEA (2022) Coal Market Update—July 2022. https://www.iea.org/reports/coal-market-update-july-2022

[19] Wikipedia (2022) Fukushima Nuclear Disaster. https://en.wikipedia.org/wiki/Fukushima_nuclear_disaster

[20] Nuclear Power in the World Today (2022). https://world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx

[21] Energy and Environment (2022) Energy Consumption Worldwide from 2000 to 2019, with a Forecast until 2050, by Energy Source. https://www.statista.com/statistics/222066/projected-global-energy-consumption-by-source/

[22] World Future Energy Summit (2021). https://sdgresources.relx.com/events/world-future-energy-summit

[23] World Summit on Sustainable Development, Johannesburg, South Africa (2002). https://www.un.org/en/conferences/environment/johannesburg2002

[24] Omar, E., Haitham, A.R. and Frede, B. (2014) Renewable Energy Resources: Current Status, Future Prospects and Their Enabling Technology. *Renewable and Sustainable Energy Reviews*, **39**, 748-764.

[25] Alazraque-Cherni, J. (2008) Renewable Energy for Rural Sustainability in Developing Countries. *Bulletin of Science, Technology & Society*, **28**, 105-114. https://doi.org/10.1177/0270467607313956

[26] World Energy Assessment (2001) Renewable Energy Technologies. 221.

[27] Armaroli, N. and Balzani, V. (2011) Towards an Electricity-Powered World. *Energy & Environmental Science*, **4**, 3193-3222. https://doi.org/10.1039/C1EE01249E

[28] Armaroli, N. and Balzani, V. (2016) Solar Electricity and Solar Fuels: Status and Perspectives in the Context of the Energy Transition. *Chemistry—A European Journal*, **22**, 32-57. https://doi.org/10.1002/chem.201503580

[29] REN21 (2021) Renewables Global Status Report 2021. https://www.ren21.net/gsr-2021

[30] REN21 (2022) Renewables 2022—Global Status Report (Renewable Energies), 2022. https://www.ren21.net/gsr-2022

[31] IEA (2022b) Renewables—Global Energy Review 2021—Analysis. https://www.iea.org/reports/global-energy-review-2021/renewables

[32] Friedlingstein, P., Jones, M.W., O'sullivan, M., Andrew, R.M., Bakker, D.C., Hauck, J., Zeng, J., *et al.* (2019) Global Carbon Budget 2019. *Earth System Science Data*, **11**, 1783-1838.

[33] Motyka, M., Slaughter, A. and Amon, C. (2019) Global Renewable Energy Trends

2018.
https://www2.deloitte.com/us/en/insights/industry/power-and-utilities/global-renewable-energy-trends.html

[34] IRENA (2018) Renewable Electricity Capacity and Generation Statistics, June 2018. https://irena.org/publications/2018/mar/renewable-capacity-statistics-2018

[35] IEA (2020) Electricity. International Energy Agency, Data Browser Section, Electricity Generation by Source Indicator. https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=WORLD&fuel=Energy%20supply&indicator=TESbySource

[36] Ritchie, H., Roser, M. and Rosado, P. (2020) Energy—Our World in Data. https://ourworldindata.org/energy

[37] REN21 (2017) Renewables Global Futures Report 2017. https://www.ren21.net/2017-renewables-global-futures-report/

[38] Bogdanov, D., Gulagi, A., Fasihi, M. and Breyer, C. (2021) Full Energy Sector Transition towards 100% Renewable Energy Supply: Integrating Power, Heat, Transport and Industry Sectors Including Desalination. *Applied Energy*, **283**, Article ID: 116273. https://doi.org/10.1016/j.apenergy.2020.116273

[39] Teske, S. (2019) Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-Energy GHG Pathways for +1.5 ˚C and +2 ˚C. Springer Nature, Berlin, 491. https://doi.org/10.1007/978-3-030-05843-2

[40] Jacobson, M.Z., von Krauland, A.K., Coughlin, S.J., Dukas, E., Nelson, A.J., Palmer, F.C. and Rasmussen, K.R. (2022) Low-Cost Solutions to Global Warming, Air Pollution, and Energy Insecurity for 145 Countries. *Energy & Environmental Science*, **15**, 3343-3359. https://doi.org/10.1039/D2EE00722C

[41] International Energy Agency (IEA) (2012) Energy Technology Perspectives 2012.

[42] Timperley, J. (2021) Why Fossil Fuel Subsidies Are So Hard to Kill. *Nature*, **598**, 403-405. https://www.nature.com/articles/d41586-021-02847-2

[43] UNEP (2007) Global Trends in Sustainable Energy Investment 2007: Analysis of Trends and Issues in the Financing of Renewable Energy and Energy Efficiency in OECD and Developing Countries. United Nations Environment Program. https://wedocs.unep.org/20.500.11822/7958

[44] Sütterlin, B. and Siegrist, M. (2017) Public Acceptance of Renewable Energy Technologies from an Abstract versus Concrete Perspective and the Positive Imagery of Solar Power. *Energy Policy*, **106**, 356-366. https://doi.org/10.1016/j.enpol.2017.03.061

[45] IEA (2021) IEA Data Tables—Data & Statistics. https://www.iea.org/data-and-statistics/data-tables

[46] Jacobson, M.Z., Delucchi, M.A., Bazouin, G., Bauer, Z.A., Heavey, C.C., Fisher, E., Yeskoo, T.W., *et al.* (2015) 100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for the 50 United States. *Energy & Environmental Science*, **8**, 2093-2117. https://doi.org/10.1039/C5EE01283J

[47] Scovronick, N., Budolfson, M., Dennig, F., Errickson, F., Fleurbaey, M., Peng, W., Wagner, F., *et al.* (2019) The Impact of Human Health Co-Benefits on Evaluations of Global Climate Policy. *Nature Communications*, **10**, Article No. 2095. https://doi.org/10.1038/s41467-019-09499-x

[48] Gallagher, C.L. and Holloway, T. (2020) Integrating Air Quality and Public Health Benefits in US Decarbonization Strategies. *Frontiers in Public Health*, **8**, Article ID: 563358. https://doi.org/10.3389/fpubh.2020.563358

[49] Luderer, G., Pehl, M., Arvesen, A., Gibon, T., Bodirsky, B.L., De Boer, H.S., Hertwich, E.G., *et al.* (2019) Environmental Co-Benefits and Adverse Side-Effects of Alternative Power Sector Decarbonization Strategies. *Nature Communications*, **10**, Article No. 5229. https://doi.org/10.1038/s41467-019-13067-8

[50] Clean Edge (2009) Clean Energy Trends. 1-4.

[51] IRENA Membership (2019). https://www.irena.org/About/Membership

[52] International Energy Agency (IEA) (2003) Renewables for Power Generation: Status & Prospects. IEA, Paris.

[53] International Energy Agency (IEA) (2004) Renewable Energy: Market and Policy Trends in IEA Countries. IEA, Paris.

[54] Beck, F. and Martinot, E. (2004) Renewable Energy Policies and Barriers. In: *Encyclopedia of Energy*, Vol. 5, Academic/Elsevier, New York, 365.

[55] Martinot, E., Chaurey, A., Lew, D., Moreira, J.R. and Wamukonya, N. (2002) Renewable Energy Markets in Developing Countries. *Annual Review of Energy and the Environment*, **27**, 309-348. https://doi.org/10.1146/annurev.energy.27.122001.083444

[56] Martinot, E. (2004) Indicators of Investment and Capacity for Renewable Energy. *Renewable Energy World*, **7**, 35-37.

[57] Martinot, E. (2006) Renewable Energy Gains Momentum: Global Markets and Policies in the Spotlight. *Environment: Science and Policy for Sustainable Development*, **48**, 26-43. https://doi.org/10.3200/ENVT.48.6.26-43

[58] Bilen, K., Ozyurt, O., Bakırcı, K., Karslı, S., Erdogan, S., Yılmaz, M. and Comaklı, O. (2008) Energy Production, Consumption, and Environmental Pollution for Sustainable Development: A Case Study in Turkey. *Renewable and Sustainable Energy Reviews*, **12**, 1529-1561. https://doi.org/10.1016/j.rser.2007.03.003

[59] IEA (2006) World Energy Outlook 2006. IEA, Paris. https://www.iea.org/reports/world-energy-outlook-2006

[60] IEA (2011) Solar Energy Perspectives. IEA, Paris. https://www.iea.org/reports/solar-energy-perspectives

[61] Royal Society of Chemistry (RSC) (2012) Solar Fuels and Artificial Photosynthesis. https://www.rsc.org/globalassets/04-campaigning-outreach/policy/research-policy/global-challenges/solar-fuels-2012.pdf

[62] IEA (2022d) Solar—Fuels & Technologies. IEA, Paris. https://www.iea.org/fuels-and-technologies/solar

[63] National Renewable Energy Laboratory (NREL) (2013) Renewable Energy Technical Potentials: A GIS-Based Analysis. https://www.nrel.gov/docs/fy12osti/51946.pdf

[64] Thinkprogress (2013) National Renewable Energy Laboratory: Solar Has the Most Potential of Any Renewable Energy Source. https://archive.thinkprogress.org/national-renewable-energy-laboratory-solar-has-the-most-potential-of-any-renewable-energy-source-87da2c774fcc/

[65] Global Solar Atlas (2019). https://globalsolaratlas.info/map

[66] Renewable Energy (2021) Center for Climate and Energy Solutions. https://www.c2es.org/

[67] Intergovernmental Panel on Climate Change (IPCC) (2022) Mitigation of Climate Change IPCC. https://www.ipcc.ch/report/ar6/wg3/

[68] Clean Energy Council Australia (2021) Clean Energy Australia Report 2021 (PDF), Clean Energy Australia. https://assets.cleanenergycouncil.org.au/documents/resources/reports/clean-energy-australia/clean-energy-australia-report-2021.pdf

[69] Solar Energy (2022) Australian Renewable Energy Agency. https://arena.gov.au/renewable-energy/solar/

[70] IRENA (2022) Renewable Energy Statistics 2022. 20. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Jul/IRENA_Renewable_energy_statistics_2022.pdf

[71] IRENA (2022) Compound Annual Growth Rate 2012-2021. Renewable Energy Statistics 2022.

[72] Annual Technology Baseline (2021) Utility-Scale PV. https://atb.nrel.gov/electricity/2021/utility-scale_pv#:~:text=Utility%2Dscale%20PV%20systems%20in,et%20al.%2C%202021

[73] Habib, A., Ismail, I.M.I., Mahmood, A.J. and Rafiqueullah, M. (2012) Photocatalytic Decolorization of Brilliant Golden Yellow over TiO_2 and ZnO Suspensions. *Journal of Saudi Chemical Society*, **16**, 423-429. http://dx.doi.org/10.1016/j.jscs.2011.02.013

[74] Habib, A., Muslim, M., Shahadat, T., Islam, N., Ismail, I.M.I., Islam, T.S.A. and Mahmood, A.J. (2013) Photocatalytic Decolorization of Crystal Violet in Aqueous ZnO Suspension under Visible Light Irradiation. *Journal of Nanostructure in Chemistry*, **3**, Article No. 70. https://doi.org/10.1186/2193-8865-3-70

[75] Habib, M.A., Shahadat, M.T., Bahadur, N.M., Ismail, I.M. and Mahmood, A.J. (2013) Synthesis and Characterization of ZnO-TiO_2 Nanocomposites and Their Application as Photocatalysts. *International Nano Letters*, **3**, Article No. 5. https://doi.org/10.1186/2228-5326-3-5

[76] Muslim, M., Habib, M.A., Mahmood, A.J., Islam, T.S.A. and Ismail, I.M.I. (2012) Zinc Oxide-Mediated Photocatalytic Decolorization of Ponceau S in Aqueous Suspension by Visible Light. *International Nano Letters*, **2**, Article No. 30. https://doi.org/10.1186/2228-5326-2-30

[77] Nadarajan, R., Bakar, W.A.W.A., Toemen, S., Habib, M.A. and Eleburuike, N.A. (2018) Structure-Activity Relationship of TiO_2 Based Trimetallic Oxide towards 1,2-Dichlorobenzene Photodegradation: Influence of Preparation Method and Its Mechanism. *Chemical Engineering Journal*, **351**, 708-720. https://doi.org/10.1016/j.cej.2018.06.135

[78] EWEA (2004) Analysis of Wind Energy in the EU-25. European Wind Energy Association.

[79] Kaltschmitt, M., Streicher, W. and Wiese, A. (2003) Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Springer, Berlin. https://doi.org/10.1007/3-540-28205-X_5

[80] The Wayback Machine (2008) Offshore Stations Experience Mean Wind Speeds at 80 m That Are 90% Greater than over Land on Average. Evaluation of Global Wind Power "Overall, the Researchers Calculated Winds at 80 Meters [300 Feet] above Sea Level Traveled over the Ocean at Approximately 8.6 Meters per Second and at Nearly 4.5 Meters per Second over Land [20 and 10 Miles per Hour, Respectively]." Global Wind Map Shows Best Wind Farm Locations.

[81] IRENA (2022) Renewable Energy Statistics. 13. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Jul/IRENA_Renewable_energy_statistics_2022.pdf

[82] Annual Technology Baseline (2021) Land Based Wind.

https://atb.nrel.gov/electricity/2021/land-based_wind#:~:text=The%20representative%20technology%20for%20land,et%20al.%2C%202020)

[83] The World Factbook (2021) Electricity—From Other Renewable Sources—The World Factbook. https://www.cia.gov/the-world-factbook/about/archives/2021/field/electricity-from-other-renewable-sources/country-comparison/

[84] Ang, T.Z., Salem, M., Kamarol, M., Das, H.S., Nazari, M.A. and Prabaharan, N. (2022) A Comprehensive Study of Renewable Energy Sources: Classifications, Challenges and Suggestions. *Energy Strategy Reviews*, **43**, Article ID: 100939. https://doi.org/10.1016/j.esr.2022.100939

[85] Moran, E.F., Lopez, M.C., Moore, N., Müller, N. and Hyndman, D.W. (2018) Sustainable Hydropower in the 21st Century. *Proceedings of the National Academy of Sciences*, **115**, 11891-11898. https://doi.org/10.1073/pnas.1809426115

[86] IRENA (2012) Renewable Energy Cost Analysis: Hydropower. https://www.irena.org/documentdownloads/publications/re_technologies_cost_analysis-hydropower.pdf

[87] Energy Education. Run-of-the-River Hydroelectricity (2018). https://energyeducation.ca/encyclopedia/Run-of-the-river_hydroelectricity

[88] World Watch Institute (2014) Use and Capacity of Global Hydropower Increases. Eco-Business. https://www.eco-business.com/research/use-and-capacity-of-global-hydropower-increases/

[89] International Hydropower Association (IHA) (2022) Hydropower Status Report. https://www.hydropower.org/publications/2022-hydropower-status-report#:~:text=%E2%80%8DNow%20in%20its%20ninth%20edition,in%20the%20clean%20energy%20transition.&text=The%202022%20Hydropower%20Status%20Report%20finds%20that%3A,to%201360%20GW%20in%202021

[90] IRENA (2022) Excludes Pure Pumped Storage. Renewable Energy Statistics 2022. 8. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Jul/IRENA_Renewable_energy_statistics_2022.pdf

[91] Annual Technology Baseline (2021) Hydropower. https://atb.nrel.gov/electricity/2021/hydropower

[92] Chowdhury, S.Q. (2021) Karnafuli Hydropower Station, Banglapedia, National Encyclopedia of Bangladesh. https://en.banglapedia.org/index.php/Karnafuli_Hydropower_Station#:~:text=Karnafuli%20Hydropower%20Station%20the%20only,the%20port%20city%20of%20chittagong

[93] Dye, S.T. (2012) Geoneutrinos and the Radioactive Power of the Earth. *Reviews of Geophysics*, **50**, RG3007. https://doi.org/10.1029/2012RG000400

[94] Gando, A., Dwyer, D.A., McKeown, R.D. and Zhang, C. (2011) Partial Radiogenic Heat Model for Earth Revealed by Geoneutrino Measurements. *Nature Geoscience*, **4**, 647-651. https://doi.org/10.1038/ngeo1205

[95] Nemzer, J. (1998) Geothermal Heating and Cooling. https://geothermal.marine.org

[96] Department of Energy (DoE) (2016) Geothermal Heat Pumps—Department of Energy, US. https://www.energy.gov/energysaver/geothermal-heat-pumps

[97] Net Zero Foundation (2021). https://www.netzerofoundation.bg/en

[98] Database of State Incentives for Renewables & Efficiency (DSIRE) (2017). https://solsmart.org/resource/database-of-state-incentives-for-renewables-and-efficiency-dsire#:~:text=DSIRE%20is%20the%20most%20comprehensive,the%20U.S.%20Department%20of%20Energy

[99] Renewable Capacity Statistics (2022). https://www.google.com.hk/search?q=RENEWABLE+CAPACITY%0D%0ASTATISTICS+2022&sca_esv=297f8d6bee6ef7a9&hl=zh-CN&source=hp&ei=F4zUZdi8NqPWseMP0qWF4AE&iflsig=ANes7DEAAAAAZdSaJ_rQqXLHlNAI2clMkjFMUBqF3LJT&ved=0ahUKEwiYpJ6157mEAxUja2wGHdJSARwQ4dUDCA0&uact=5&oq=RENEWABLE+CAPACITY%0D%0ASTATISTICS+2022&gs_lp=Egdnd3Mtd2l6IiJSRU5FV0FCTEUgQ0FQQUNJVFkKU1RBVElTVElDUyAyMDIySABQAFgAcAB4AJABAJgBAKABAKoBALgBA8gBAPgBAvgBAQ&sclient=gws-wiz

[100] Annual Technology Baseline (2021) Geothermal. https://atb.nrel.gov/electricity/2021/geothermal

[101] CNN (2020) Mapua Student Wins International Design Award for Invention Made from Crop Waste. https://www.reddit.com/r/Philippines/comments/jxqi8n/mapua_student_wins_international_design_award_for/

[102] Olauson, J., Ayob, M.N., Bergkvist, M., Carpman, N., Castellucci, V. and Goude, A. (2016) Net Load Variability in Nordic Countries with a Highly or Fully Renewable Power System. *Nature Energy*, **1**, Article No. 16175. https://doi.org/10.1038/NENERGY.2016.175

[103] Edenhofer, O., Pichs-Madruga, P., Sokona, Y., Seyboth, K., Matschoss, P. and Kadner, S. (2019) Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge University Press, Cambridge.

[104] Ramsebner, J., Haas, R., Ajanovic, A. and Wietschel, M. (2021) The Sector Coupling Concept: A Critical Review. *WIREs Energy and Environment*, **10**, e396. https://doi.org/10.1002/wene.396

[105] Chen, Y. and Gielen, D. (2021) Intelligent, Flexible Sector Coupling in Cities Can Double the Potential for Wind and Solar. Energy Post. https://energypost.eu/intelligent-flexible-sector-coupling-in-cities-can-double-the-potential-for-wind-and-solar/

[106] IEA (2021) Hydropower Special Market Report. IEA, Paris. https://www.iea.org/reports/hydropower-special-market-report

[107] Murray, C. (2022) What Role Is Large-Scale Battery Storage Playing on the Grid Today? Energy Storage News. https://www.energy-storage.news/what-role-is-large-scale-battery-storage-playing-on-the-grid-today/

[108] Heilweil, R. (2022) These Batteries Work from Home. Vox. https://www.vox.com/recode/23057167/home-battery-tesla-powerwall-biden

[109] Gunter, L.P. (2017) Trump Is Foolish to Ignore the Flourishing Renewable Energy Sector. Truthout. https://truthout.org/articles/trump-is-foolish-to-ignore-the-flourishing-renewable-energy-sector/

[110] IEA (2022) Renewable Energy Market Update—May 2022, IEA, Paris. https://www.iea.org/reports/renewable-energy-market-update-may-2022

[111] Jaeger, J., Walls, G., Clarke, E., Altamirano, J.-C., Harsono, A. and Mountford, H. (2021) The Green Jobs Advantage: How Climate-Friendly Investments Are Better

Job Creators. World Resource Institute, Washington DC. https://doi.org/10.46830/wriwp.20.00142.

[112] IRENA (2021) Majority of New Renewables Undercut Cheapest Fossil Fuel on Cost. https://www.irena.org/news/pressreleases/2021/Jun/Majority-of-New-Renewables-Undercut-Cheapest-Fossil-Fuel-on-Cost

[113] Heidari, N. and Pearce, J.M. (2016) A Review of Greenhouse Gas Emission Liabilities as the Value of Renewable Energy for Mitigating Lawsuits for Climate Change Related Damages. *Renewable and Sustainable Energy Reviews*, **55**, 899-908. https://doi.org/10.1016/j.rser.2015.11.025

[114] McCrone, A., Moslener, U., d'Estais, F., Grüning, C. and Emmerich, M. (2020) Global Trends in Renewable Energy Investment 2020. Frankfurt School-UNEP Collaborating Centre for Climate & Sustainable Energy Finance, Bloomberg. https://www.fs-unep-centre.org/global-trends-in-renewable-energy-investment-2020/

[115] IEA (2022) Record Clean Energy Spending Is Set to Help Global Energy Investment Grow by 8% in 2022—News. IEA, Paris. https://www.iea.org/news/record-clean-energy-spending-is-set-to-help-global-energy-investment-grow-by-8-in-2022

[116] Fitchratings (2022) China's New Plan for Renewable Energy Development Focuses on Consumption. https://www.fitchratings.com/research/corporate-finance/chinas-new-plan-for-renewable-energy-development-focuses-on-consumption-19-06-2022#:~:text=Fitch%20Ratings%2DBeijing%2D19%20June,curtailment%20risk%2C%20says%20Fitch%20Ratings

[117] Claeys, B., Rosenow, J. and Anderson, M. (2022) Is REPowerEU the Right Energy Policy Recipe to Move Away from Russian Gas? https://www.euractiv.com

[118] World Resources Institute (2017) Corporate Renewable Energy Buyers Principles. https://www.wri.org/publications/corporate-renewable-energy-buyers-principles

[119] Wazed, A. (2010) Prospect and Future of Biomass Fuel: A Review in Bangladesh Perspective. *Engineering e-Transaction*, **5**, 61-66. https://www.academia.edu/45461908/Prospect_and_Future_of_Biomass_Fuel_A_Review_in_Bangladesh_Perspective

[120] Nature Conservation Management (NACOM) (2020) A Comprehensive Assessment of the Availability and Use of Biomass Fuels for Various End-Uses with Special Attention to Power Generation. National Project Director, SREPGen Project. Project Manager, SREPGen Project. UNDP, Bangladesh. https://sreda.portal.gov.bd/sites/default/files/files/sreda.portal.gov.bd/page/049ce602_4203_49ac_8237_59e6776e255f/2021-06-22-04-52-31df1f5baf3ce33a4d5737629a391869.pdf

[121] Department for Business, Energy and Industrial Strategy (DBEIS) (2020) Aggregated Energy Balances Showing Proportion of Renewables in Supply and Demand. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/920564/Aggregated_Energy_Balances__of_which_renewables_.pdf

[122] Ramsey, W.C. (2006) Energy Technology Perspectives: Scenarios and Strategies to 2050. IEA, Paris, 124. http://www.unece.lsu.edu/biofuels/documents/2007July/SRN_020.pdf

[123] UC USA (2013) Environmental Impacts of Hydroelectric Power|Union of Concerned Scientists. https://www.ucsusa.org/resources/environmental-impacts-hydroelectric-power

[124] Lia, L., Jensen, T., Stensbyand, K.E., Holm, G. and Ruud, A.M. (2015) The Current Status of Hydropower Development and Dam Construction in Norway. https://www.ntnu.no/documents/381182060/641036380/Leif+Lia_FINAL.PDF/32bac8f3-b443-493b-a1eb-e22ce572acd9

[125] Farmer, M. (2021) How Norway Became Europe's Biggest Power Exporter. Power Technology. https://www.power-technology.com/features/how-norway-became-europes-biggest-power-exporter/

[126] Burgland, N. (2022) Trade Surplus Soars on Energy Exports|Norway's News in English. https://www.newsinenglish.no/2022/01/17/trade-surplus-soars-on-energy-exports/

[127] Mckinsey and Company (2022) Succeeding in the Global Offshore Wind Market|McKinsey. https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/how-to-succeed-in-the-expanding-global-offshore-wind-market

[128] Renewable Electricity Capacity and Generation (RECG) (2018). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1126178/ET_6.1_DEC_22.xlsx

[129] Solar Energy Projects in California (2022). https://www.energy.ca.gov/programs-and-topics/topics/renewable-energy/solar-energy

[130] NextEra Energy (2014) Segs Iii, Iv, V, Vi, Vii, Viii & Ix. https://www.nrc.gov/docs/ML0932/ML093280629.pdf

[131] Ivanpah Solar Power Facility (ISPF) (2013) Wikipedia. https://en.wikipedia.org/wiki/Ivanpah_Solar_Power_Facility

[132] Mearian, L. (2013) US Flips Switch on Massive Solar Power Array That Also Stores Electricity: The Array Is First Large U.S. Solar Plant with a Thermal Energy Storage System. https://www.computerworld.com/article/2830218/u-s--flips-switch-on-massive-solar-power-array-that-also-stores-electricity.html

[133] REN21 (2021) Renewables Global Status Report. https://www.ren21.net/wp-content/uploads/2019/05/GSR2021_Full_Report.pdf

[134] Deutsche Bank Markets Research (2015) Crossing the Chasm. https://mdvseia.org/wp-content/uploads/2017/07/solar_report_full_length.pdf

[135] Solar in New Jersey (2022). https://www.nj.gov/dep/aqes/opea-solar.html

[136] IEA (2014) Technology Roadmap—Solar Photovoltaic Energy 2014. IEA, Paris. https://www.iea.org/reports/technology-roadmap-solar-photovoltaic-energy-2014

[137] Denis, L. (2010) Large-Scale Photovoltaic Power Plants Ranking 1-50. https://www.pvresources.com/en/top50pv

[138] Glassley, W.E. (2010) Geothermal Energy: Renewable Energy and the Environment, CRC Press, Boca Raton. https://doi.org/10.1201/EBK1420075700

[139] Khan, M.A. (2007) The Geysers Geothermal Field, an Injection Success Story. Annual Forum of the Groundwater Protection Council. https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2010/0620.pdf

[140] IEA (2020) Changes in Primary Energy Demand by Fuel and Region in the Stated Policies Scenario 2019-2030. IEA, Paris. https://www.iea.org/data-and-statistics/charts/changes-in-primary-energy-demand-by-fuel-and-region-in-the-stated-policies-scenario-2019-2030

[141] Flavin, C. and Aeck, M.H. (2005) Energy for Development: The Potential Role of Renewable Energy in Meeting the Millennium Development Goals. Ren21, 7-9. https://search.issuelab.org/resource/energy-for-development-the-potential-role-of-renewable-energy-in-meeting-the-millennium-development-goals.html

[142] The Daily Star (2023) 100pc Population Now under Electricity Coverage. https://www.thedailystar.net/business/economy/news/100pc-population-comes-under-electricity-coverage-2983111

[143] BPDB (2022) Annual Energy Report (2021-22). http://bd.bpdb.gov.bd/bpdb/new_annual_reports

[144] SREDA (2022) National Database of Renewable Energy. Sustainable and Renewable Energy Development Authority, Bangladesh.

[145] Hossain, S.M., Biswas, S. and Uddin, M.R. (2023) Sustainable Energy Transition in Bangladesh: Challenges and Pathways for the Future. *Engineering Reports*, **6**, e12752. https://doi.org/10.1002/eng2.12752

[146] BPDB (2021) Annual Energy Report (2020-21). https://bpdb.portal.gov.bd/sites/default/files/files/bpdb.portal.gov.bd/annual_reports/7b792f67_bf50_4b3d_9bef_8f9b568005c9/2022-10-18-05-55-f1971a327c2aebfd37f6f9a8e723d1fb.pdf

[147] Jacobson, M., Draxl, C., Jimenez, T., O'Neill, B., Capozzola, T., Lee, J.A., Haupt, S.E., *et al.* (2018) Assessing the Wind Energy Potential in Bangladesh: Enabling Wind Energy Development with Data Products (No. NREL/TP-5000-71077). National Renewable Energy Lab. (NREL), Golden.

[148] IEA (2020) Policies Database. https://www.iea.org/policies

[149] IEA (2020) Signatory States of IEA. https://energy.ec.europa.eu/topics/international-cooperation/international-organisations-and-initiatives/international-energy-agency_en#:~:text=and%20clean%20energy.-,IEA%20members,Kingdom%2C%20and%20the%20United%20States

[150] International Renewable Energy Agency (IRENA) (2019) Renewable Energy Now Accounts for a Third of Global Power Capacity. https://www.irena.org/news/pressreleases/2019/Apr/Renewable-Energy-Now-Accounts-for-a-Third-of-Global-Power-Capacity

[151] Makieła, K., Mazur, B. and Głowacki, J. (2022) The Impact of Renewable Energy Supply on Economic Growth and Productivity. *Energies*, **15**, Article No. 4808. https://doi.org/10.3390/en15134808

[152] Tran, M. (2011) UN Calls for Universal Access to Renewable Energy. *The Guardian*. https://www.theguardian.com/global-development/2011/nov/02/human-development-report-renewable-energy

[153] Berlin, K., Hundt, R., Muro, M. and Saha, D. (2012) State Clean Energy Banks: New Investment Facilities for Clean Energy Deployment. Brookings. https://www.brookings.edu/research/state-clean-energy-finance-banks-new-investment-facilities-for-clean-energy-deployment/

[154] Cienski, J. (2021) Putin Promises Gas to a Europe Struggling with Soaring Prices. Politico. https://www.politico.eu/article/russia-president-vladimir-putin-gas-price-europe/

[155] Simon, F. (2021) The EU Releases Its Green Deal. Here Are the Key Points. Climate Home News. https://www.climatechangenews.com/2019/12/12/eu-releases-green-deal-key-points/

[156] IEA (2020f) Net Zero by 2050. A Roadmap for the Global Energy Sector.

https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf

[157] Ylenews (2019) Cheap, Safe 100% Renewable Energy Possible before 2050, Says Finnish Uni Study. YleUutiset. https://yle.fi/a/3-10736252

[158] Gulagi, A., Alcanzare, M., Bogdanov, D., Esparcia, E., Ocon, J. and Breyer, C. (2021) Transition Pathway towards 100% Renewable Energy across the Sectors of Power, Heat, Transport, and Desalination for the Philippines. *Renewable and Sustainable Energy Reviews*, **144**, Article ID: 110934. https://doi.org/10.1016/j.rser.2021.110934

[159] Hansen, K., Breyer, C. and Lund, H. (2019) Status and Perspectives on 100% Renewable Energy Systems. *Energy*, **175**, 471-480. https://doi.org/10.1016/j.energy.2019.03.092

[160] Koumoundouros, T. (2019) Stanford Researchers Have an Exciting Plan to Tackle the Climate Emergency Worldwide. ScienceAlert. https://www.sciencealert.com/stanford-researchers-have-a-plan-to-tackle-the-climate-emergency

[161] Wiseman, J., Edwards, T. and Luckins, K. (2013) Post Carbon Pathways: Towards a Just and Resilient Post Carbon Future. Melbourne Sustainable Society Institute, University of Melbourne, Melbourne. https://cpd.org.au/wp-content/uploads/2013/04/Post-Carbon-Pathways-Report-2013_Revised.pdf

[162] WHO (2022) Ambient (Outdoor) Air Quality and Health. https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

[163] WHO (2022) Household Air Pollution and Health. https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

Abbreviations

CCGTs	Combined-cycle gas turbines
CPV	Concentrator photovoltaics
CSP	Concentrated solar power
DC	Direct current
GHG	Greenhouse gas
GHP	Geothermal heat pump/Low temperature geothermal
HVAC	Heating, ventilation and air conditioning
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
ISES	International Sustainable Energy Summit
IPCC	Intergovernmental Panel on Climate Change
NO_x	Oxides of nitrogen
NREPAP	National Renewable Energy Policy and Action Plan
OECD	The Organization for Economic Co-operation and Development
PM	Particulate matter
PV	Photovoltaics
SEGS	Solar energy generating systems
SO_x	Oxides sulfur