PhD. DISSERTATION

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The Potentiality and Feasibility of Auction Design in the Renewable Energy Market of a Developing Country —the Case of Bangladesh

PhD. Dissertation

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DECLARATION

Declaration of the author

I hereby declare that the result of this dissertation is my own novel work commenced under the direction of my PhD. supervisors and with the exception of references to the works of other people which have been duly cited. Additionally, I hereby declare that the dissertation has neither in part nor in whole been submitted for any another degree in this university or elsewhere.

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Declaration of the supervisors

We hereby confirm that the research presented in this dissertation was conducted by the candidate under our supervision. Any information or materials sourced from external references have been appropriately credited and cited within the dissertation.

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DEDICATION

Giving all glories to almighty God, I am dedicating this dissertation to my family members who have considered my absence in their lives when it was required. Without their great sacrifice, it would not be possible for me to complete this journey.

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LIST OF PUBLICATIONS

Before submitting this dissertation, sections of this research and associated studies have been published in peer-reviewed journals and presented at various academic conferences, with ongoing evaluations for others. This section provides an overview of these scholarly contributions:

Publications in the peer-reviewed (Scimago Q1, Q2, Q3 ranked) journals

I. Somosi, S., Gábor, D. K., and Tanvir Alam, S. M. (2024). Examination of Carbon Dioxide Emission and Renewables in Southeast Asian Countries based on a Panel Vector Autoregressive Model. *Journal of Cleaner Production*, 436(1), 1-12. https://doi.org/10.1016/j.jclepro.2023.140174

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III. Tanvir Alam, S. M. (2022). Renewable Energy (solar & wind) Generation and its Effects on Some Variables for Selected EU Countries with Panel VAR Model. *International Journal of Energy Economics and Policy*, 12(5), 303-310. DOI: http://doi.org/10.32479/ijeep.13292

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Publications in the Scopus indexed peer-reviewed book chapter

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Conference Presentations

I. Tanvir Alam, S. M. (2022). Clean Energy Policy, Clean Energy Expansion and Political Debate-A recent outlook. In: *II. International Istanbul Economic Research Conference (IIERC) on Green Economy and Sustainable Development.* Istanbul University Faculty of Economics, Istanbul, 87-103.

II. Tanvir Alam, S. M. (2023). Practicing of Renewable Energy Auction Scheme—Expected Societal and Economic Gains for the Developing Countries. In: *19th International Conference on European Integration – New Challenges –EINCO 2023.* Faculty of Economic Sciences, University of Oradea, 14-32.

III. Tanvir Alam, S. M., & Dora, S. (2023). Examination of Economic Growth Trend of Some Resource Rich Countries Using Panel VAR Model. In: *RSEP International Conference on Emerging Issues in Economics & Social Sciences.* BC GRUP INC, Ankara, 16-25.

IV. Tanvir Alam, S. M. (2021). The Potentiality and Feasibility of Auction Design in Renewable Energy Market of a Developing Country — the case of Bangladesh. In: *ENTRENOVA- Enterprise Research Innovation Conference (online).* Udruga za promicanje inovacija istrazivnaja u ekonomiji “IRENET”, Zagreb,79.https://drive.google.com/file/d/1GGw7fvASG_Z6xestGdOW9nHcCDMkppwd/view

V. Tanvir Alam, S. M. (2021). Auctions as a Measure in Meeting Renewable Energy Targets: Selected Cases from Developing Countries. In: *The European Union’s Contention in the Reshaping Global Economy (online).* Doctoral School of Economics, University of Szeged, Szeged, 85-104.

ABSTRACT

Witnessing the harmful consequences of climate change, quite many polls will reflect the transformation of power generation towards renewable energy from using fossil fuels. Prioritizing this dynamism, adaptability of the support mechanisms is required to maintain a steady and lucrative congenial atmosphere for investments in the renewable energy (RE) sector while confirming the durable trustworthiness in the energy system in an economical manner. In this point of view, auctions are gaining remarkable momentum even being the dominant strategy solely or in collaboration with supplementary trials to offer inducements for the positioning of RE.

The wide expansion of the auction is striking; merely six states accepted Renewable Energy Sources (RES) auction in 2005 and at least 84 states had adapted this tool by 2017. The present study aims to reveal the potentiality of the auction mechanism in an RES-promised developing country like Bangladesh, as the country is lagging behind to add required RE capacity in its energy mix due to the gap of suitable support scheme to align with carbon neutrality goals. The research outlines the feasibility of a suggested auctioning scheme, together with potential benefits of the country, highlighting some country-specific empirical evidence. For this, both qualitative and quantitative research has been conducted to develop an auctioning model for the country. The results indicate that for an emergent state gifted with RES, systematic auctioning scheme with socio-economic development instruments under qualification requirement ensures diverse paybacks.

Keywords: Renewable Energy, Auction, CO2 emission, Socio-Economic Development, Qualification Requirement, Paybacks

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LIST OF ABBREVIATIONS

ADP	Annual Development Program
APSCL	Ashugonj Power Station Company Limited (power generation company)
BAPEX	Bangladesh Petroleum Exploration and Production Company
BAU	Business as Usual
BDT	Bangladeshi Taka
BBBEE	Broad Based Black Economic Empowerment
BERC	Bangladesh Energy Regulatory Commission
BGFCL	Bangladesh Gas Fields Company Limited
BPDB	Bangladesh Power Development Board
CfD	Contract for Differences
CNG	Compressed Natural Gas
CO2/CO_2	Carbon Dioxide
CoC	Cost of Capital
CPGCL	Coal Power Generation Company Limited (power generation company)
DESCO	Dhaka Electric Supply Company Limited
DPDC	Dhaka Power Distribution Company Limited
FF	Fossil Fuel
FiP	Feed-in-Premium
FiT	Feed-in-Tariff
FPSB	First Price Sealed Bid
GDP	Gross Domestic Product
GHG	Green House Gases
GO	Guarantees Origin
GIS	Gas-insulated Switch gear
GOB	Government of Bangladesh
Gt	Giga tones
GTCL	Gas Transmission Company Limited
HFO	Heavy Fuel Oil/Furnished Oil
HELE	High Efficiency Low Emission
HSD	High Speed Diesel

IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions
IPP	Independent Power Producer
IOC	International Oil Company
JICA	Japan International Cooperative Agency
kW	Kilowatt
kWh	Kilowatt hour
kWp	Kilowatt peak
LCRs	Local Content Requirements
LCOE	Levelized Cost of Energy
LDC	Least Developed Countries
LNG	Liquedified Natural Gas
mmcfd	million cubic feet of gas per day
MoU	Memorandum of Understanding
Mt	Million tones
MW	Megawatt
MWh	Megawatt hour
NAP	National Action Plan
NDC	Nationally Determined Contributions
NESCO	Northern Electricity Supply Company Limited
NFFO	Non-fossil Fuel Obligation
NWPGCL	North West Power Generation Company (power generation company)
OECD	Organization for Economic Co-operation and Development
PAB	Pay-as-Bid
PGCB	Power Grid Company of Bangladesh Limited (power transmission company)
PV	Photovoltic
PPA	Power Purchase Agreement
RE	Renewable Energy
REB	Rural Electrification Board
RES	Renewable Energy Sources
RES—E	Renewable Energy Sources—Electricity
REIPPPP	Renewable Energy Independent Power Producer Procurement

	Program
RFQ	Request for Quotations
RNPP	Rooppur Nuclear Power Plant
RPCL	Rural Power Company Limited
RPO	Renewable Purchase Obligation
RPS	Renewable Portfolio Standard
SAARC	South Asian Association for Regional Cooperation
SDG	Sustainable Development Goal
SEZ	Special Economic Zone
SGFL	Sylhet Gas Field Limited
SWOT Analysis	Strength Weakness Opportunity Threat Analysis
Tcf	Trillion cubic feet
Twh	Terawatt hour
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USD	United State Dollar
VAR Model	Vector Auto Regression Model
VRE	Variable Renewable Energy
WACC	Weighted Average Cost of Capital
WZPDC	West Zone Power Distribution Company Limited

1 INTRODUCTION AND JUSTIFICATION OF THE TOPIC

Fossil fuels − coal, gas, and fuel oils − have long been burnt during the past decades to generate electricity. Those are the main sources for the rich and developed nations of the world to build a developed economy by meeting their electricity demand. For strengthening the socio-economic progress of a country, energy played an important role in the industrial revolution as well. The 1st revolution brought the steam engine, the 2nd one brought the electricity, the 3rd revolution in the energy field brought the nuclear power and over the phase of 4th/5th we are about to turn to use the renewables.[1] Therefore, the development through industrialization required the widespread use of the latest most efficient energy. Of course, here those countries were the beneficiaries that used to have the original resources. Almost every economic activity involves energy as an input and fortifying sustainable sources of energy is an imperative strategic precedence for most countries.

Depending more on fossil fuel-based power plants, the developed countries have released thousands of tons of carbon dioxide (CO2) and other Green House Gases (GHG) in the troposphere and the energy sector emits two-third of the global GHG (Matthaus 2020). According to our present knowledge, the excessive amount of CO2 in the air is the root cause of global warming and climate change.[2] Observing the detrimental significances of climate modification, a strong opinion is growing in the countries against using fossil fuels in power generation and paying attention to energy transition, i.e., increased usage of renewable energy sources (RES). They are investing in research and development of related technologies. International organizations and development agencies of the world also prefer and encourage investments in the renewable energy (RE) field. Accordingly, the universal policymakers are focusing on 100% zero carbon free energy generation by 2050. Finding out the potentiality of solar and wind energy technologies, those are included in the energy system beset by the energy democracy as a prime site of political-economic challenges and the mentioned technologies are picked up for deploying high volumes of clean energy (Burke and Stephens 2018, Angel 2016).

[1] https://sciencing.com/elements-european-industrial-revolution-8601.html

[2] https://www.carbonbrief.org/solar-wind-nuclear-amazingly-low-carbon-footprints
4−6 grams CO2 emits for generating one kilowatt-hour (kWh) electricity from solar/wind. The emission range is 109 grams for coal, 78 grams for gas, 700 grams for high-speed furnish oil (HFO) and 350 grams for liquified natural gas (LNG).

According to the report of International Energy Agency (IEA 2021_b), almost 90% of electricity should come from RES, with wind and solar Photovoltaic (PV) together accounting for nearly 70% by 2050. A special analysis has also been carried out with the participation of International Monetary Fund (IMF) and International Institute of Applied System Analysis. It shows that the enormous challenges of transforming our energy system are also a huge opportunity for our economics, with the potential to create millions of new jobs and boost economic growth. The report also states that the transition to net zero is for and about people to provide around 4% of cumulative emissions reductions. Zhang et al. (2021) used the provincial data of China for the period 2000-2017 to investigate the aggregate effects of low-emission electricity. The investigation showed that if the ratio of low-emission electricity to total electricity is increased by 1%, then the GDP will be up by 0.16%, and CO2 will decrease by 0.848%. Literally, it has been said that low-emission can chase the target of low-carbon economic development. Aligning with the statement, Rennkamp et al. (2017) states that RE policy lessens the CO2 emission and create socio-economic upliftment for the society.

In the meantime, renewable energy sources (RES) have started their remarkable role in sustaining the current economic growth and in recent years, they have been instrumental in pushing the energy access frontier all over the world. Simelyli & Dudzeviciute (2017) say considering the competitiveness of a specific country in the international arena, energy consumption and its efficiency are interrelated, especially in the case of consumption in the industrial sector. Furthermore, high implications are found for using extended amount of renewable energy in changing the competitiveness of nations and having an accumulated beneficial return in global stage. RE can be utilized at outmost level at any scale and it is possible to lend them better to decentralized forms of energy production and consumption which improves to the democratizing upshot of RE. *"The energy transformation will be the one of the major elements that reshape geopolitics in the 21st century alongside trends in demography, inequality, urbanization, technology, environmental sustainability, military capability, and domestic politics in major states"* (IRENA—GCGET 2019, p. 24).

The global scenario is rapidly changing and the share of RES in the energy-mix across the globe is increasing due to the drastic fall in RES price, technological progress, and growing environmental concerns. As a feasible substitute font of energy globally, RE is getting priority due to climate change, fossil-fuel (FF) exhaustion, subjects of energy security, technology modernization and high and unpredictable prices of petroleum-based fuels (Do Xuan et al. 2020, Ferrer et al. 2018). By stimulating the call for local fitting, locally manufactured machineries and local planning, solar PV is found as a scope to support local employment and engagement of labor (Sweeney 2015).

According to IEA monthly electricity statistics report (December 2020), RE production was 3,269.1 terawatt-hour (TWh) globally in 2020, which was 7.5% higher than in 2019. The share of renewable electricity in the mix was 31.6% in the same year, up from 28.6% in 2019. Wind and solar production were mainly responsible for this increase in renewables, up respectively by 95.8 TWh or 11.6% and 73.0 TWh or 20.2% in 2020 compared to 2019. Since 2018, wind production has increased by 20.1% and solar production by 28.4% highlighting the dynamic growth of the wind and solar power sector. As per the report of IEA (2021_a), global CO_2 emission declined by 5.8% in 2020, or almost 2 Gigatons (Gt) CO_2, which is the largest ever decline and almost 5 times greater than the decline of 2009 that followed the global financial crisis; CO_2 emissions fell further than energy demand in 2020 owing to the pandemic hitting demand for oil and coal harder than other energy sources while renewables increased. Furthermore, the report of IEA (2021_b) says that an unparalleled clean energy investment boom lifts global economic growth. Total annual energy investment surges to US$ 5 trillion by 2030, adding an extra 0.4 percentage point a year to annual global gross domestic product (GDP) growth. In addition, environmental protection activities ensure economic merit by creating the net employment in the whole economy, in that the related reallocation of resources is typically channeled to labor-intensive renewable sector (Frondel et al. 2010, BMU 2009).

Apprehension of the world community of the spectator, the detrimental belongings of climate change, i.e., global warming due to carbon emission has led to invest in/support research in RE with affordable, economical, and technologically developed ways. The 7th sustainable development goal (SDG), “clean energy for everyone” aims to secure access to affordable, reliable, sustainable, and modern energy for everyone.[3] RE technologies, in many parts, have verified themselves to be awfully treasured and vital from time to time. Making RE affordable and economical, the cost must be competitive and should not put further burdens on the country’s economy. If RE prices become competitive, they will become affordable to the wider society. RE

[3] https://unstats.un.org/sdgs/report/2016/goal-07/

sources have about zero marginal cost and especially solar and wind sources relish cost discount about 20% for every doubling of capacity (IRENA-GCGET 2019). Through an affordable price and without additional financial support from the part of the governments and international institutions, RE sources may play a remarkable role in sustaining the current and contributing to future economic growth. The global scenario is rapidly changing, and the share of renewables in the energy-mix across the globe is expanding. It also applies to Bangladesh, as one of the fastest growing economies of the world.

According to the World Bank data,[4] average annual GDP growth rate was 6.60% in Bangladesh for the 2009 to 2019 period which is the second highest among the SAARC[5] countries. In spite of the Covid-19 pandemic in 2020, Bangladesh ensured 2.38% growth, which is the highest positive growth among the SAARC countries, while other countries, except Pakistan, were in the negative growth. As per the projection of Japan International Cooperative Agency (JICA), the GDP per capita (nominal) for Bangladesh is expected to reach 10,993 US$ in 2041 (PSMP 2016).[6] World Bank's analysis says that Bangladesh has an impressive track record of economic growth and poverty reduction. It has been among the fastest growing economy in the world over the past decades. PricewaterhouseCoopers (PwC) predicts that Bangladesh would be the 28th largest economy by 2030 up from 31st in 2016 and has the potential to become the world's 23rd largest economy by 2050. The UK's Center for Economies and Business Research (CEBR) says that Bangladesh will be the 25th largest economy, which is now being ranked by Thailand, one of the Asian giant economies by 2035, and then its economy will cross $1.0 trillion mark at current price. The present government's vision is to advance Bangladesh as a developing country by 2021 and a developed country by 2041. Recently (27 February 2021), Bangladesh got the second recommendation from United Nation Committee for Development Policy to come out from the list of least developed countries (LDC) step up onto the list of developing countries.[7] In addition, the period 2021-2026 is very crucial for Bangladesh because the achievements in this period will bear fruit of the declaration of the stand as a developing country. Within and beyond the time period, a massive development plan is highly recommended and one of

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4 www.dataworldbank.org

5 South Asian Association for Regional Cooperation (SAARC) consists of eight South Asian countries namely Afghanistan, Bangladesh, Bhutan, India, Sri Lanka, Maldives, Nepal, and Pakistan for regional cooperation.

6 Power & Energy Sector Master Plan (PSMP) 2016

7 https://www.un.org/development/desa/dpad/least-developed-country-category-bangladesh.html

the prime recommendations for Bangladesh is industrial development. However, industrial development and especially certain sectors can be highly energy intensive. Only a secured, reliable, and sustainable energy supply plays a pervasive role in keeping industrial growth and industrial production steady (Simelyli & Dudzeviciute 2017). Focusing this development target PSMP (2016) says by 2041 the power generation target is 60,000 megawatts (MW) while 10%, i.e., 6,000 MW will be from RES in Bangladesh.

As a developing country, Bangladesh is thinking in diversified dimensions, but ultimate goals are not being achieved. For example, it is talking about SDG Goal 7: affordable, reliable, sustainable, and modern energy for everyone. The low-cost energy is not being ensured yet, and moving towards that direction is not remarkable. Furthermore, the country cannot perceive the reality that energy security depends on using indigenous energy sources and reducing import dependence to meet future energy demands. The country cannot realize that the import-based energy cannot ensure affordable and secured energy to everyone. When the energy prices are fairly stable, the economic growth might improve and if they are unstable, the price could rise, which would have a negative impact on economic growth (Frimpong et al. 2018, Takentsi et al. 2022). The decision makers of the country are talking about CO2 emission reduction target, chasing energy generation from clean sources, i.e., RE sources, and low-cost energy for all by ensuring steady economic growth. However, the current procurement plans provide little detail on how much RE capacity will be procured and by when; the gap is identified here.

The policymakers of this country are not quite serious to implement RES as a mode of electricity generation like captive power plant or quick rental power plant. Rennkamp et al. (2017) argues that solar PV and wind energy are able to generate electricity in much shorter construction load time compared to a big coal or nuclear power plant. The more the RE will be available, the less the needs will be for base load power that can further emerge from renewable base load power such as biogas. In 2011, 10% electricity of total generation was planned to come from RES in Bangladesh. However, up to 2021, the electricity production from RE is 3%, i.e., 650 MW (Power Cell, Bangladesh), which is far beyond the expected level. For this, CO2 emissions trend from fuel combustion in Bangladesh is upward moving—in 2014 it was 63.10 million tones (Mt) CO2, 82 in 2018 and 89.30 MtCO2 in 2019 (IEA 2019_a).

It is true that there is no scope to overlook the success history of the energy and environmental sector in Bangladesh. Bangladesh's pledge to bring the entire population under power supply coverage is almost achieved. Currently, 99.75%[8] of the population is able to enjoy the benefits of electrification. The positive impact of electrification, especially in the rural areas, can be observed already, but it has also increased the average consumption. Per head electricity consumption was 512 kilowatt-hours (kWh) in 2019-2020 which was 220 kWh in 2008-2009 (Bangladesh Power Development Board (BPDB)) and it has become possible only due to the continuous growth in electricity generation. Recently, Bangladesh has drafted 'National Solar Energy Roadmap 2021-2041' for achieving RE target by 2041 considering 03 scenarios − Business as Usual (BAU), medium case & high case − and based on these potentials of greenhouse gas (GHG) emission reduction has been calculated as well. On the other hand, in alignment with the world's carbon reduction target, Bangladesh has ratified the Paris Agreement[9] on 21 September 2016. On 25 September 2015, it submitted Intended Nationally Determined Contributions (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC) with an ambitious GHG reduction target 15%, i.e., 36 MtCO2 conditional and 5%, i.e., 12 MtCO2 unconditional from BAU by 2030 (INDC 2020). Along with that, Bangladesh has enhanced its contributions amounting to 89.47 MtCO2 equivalent, which is 21.85% emission reductions from BAU by 2030 in its updated Nationally Determined Contributions (NDCs) submitted in August 2021. The country is in the process of finalizing its National Action Plans (NAPs), while it supports to set up a formal process by COP26[10] in order to come up with concrete recommendations on global adaption goal for consideration by COP27.

[8] http://www.powercell.gov.bd/site/view/powerdiv_achievement_at_glance/-

[9] The Paris Agreement is an international treaty signed by almost all countries in the world at COP21 in Paris in 2015. Its aims are to keep the rise in the global average temperature to 'well below' 2 degrees above pre-industrial levels, ideally 1.5 degrees; strengthen the ability to adapt to climate change and build resilience; and align all finance flows with 'a pathway towards low greenhouse gas emissions and climate-resilient development'. The Paris Agreement has a 'bottom-up' approach where countries themselves decide by how much they will reduce their emissions by a certain year. They communicate these targets to the UNFCCC in the form of 'nationally determined contributions', or 'NDCs'.

[10] The word 'COP' stands for 'Conference of the Parties'. In the climate change sphere, 'the Parties' are the governments which have signed the UN Framework Convention of Climate Change (UNFCCC). The COP brings these signatory governments together once a year to discuss how to jointly address climate change. COP26 is the 26th climate change COP and is hosted by the UK in partnership with Italy. COP26 was originally scheduled to take place in November 2020 in Glasgow in the UK but was postponed by one year due to the COVID-19 pandemic. It is now due to take place 31 October-12 November 2021. It is a critical summit for global climate action. To have a chance of limiting warming to 1.5 degrees, global emissions must halve by 2030 and reach 'net-zero' by 2050.

However, Bangladesh is also associated with a complex dimension, such as climate change and securing reliable energy with affordable cost and ensuring economic and industrial growth should move to a comforting track where all can be realized. In connection with this, we can focus on a statement of the United Nations, which mentions that around 17% of Bangladesh will be submerged by rising sea levels, rendering 20 million people homeless by 2050.[11] It is a fact that Bangladesh, for its negligible carbon footprint, may not worry too much now. Nevertheless, considering the grey future, aligned with the decision of the world community, and becoming green in the energy sector, "High Efficiency Low Emissions (HELE)" power generation technologies with affordable cost must be used. Other than promoting safe and secured energy, the dependence on fossil fuels and the tendency of energy import will not be reduced or abolished (Frondel et al. 2010).

The public awareness and robust support are increasing due to the growing emphasis on environmental issues. The industrial sector is being pressured for meeting the needs. Fossil fuel (FF) based power generation could also lose its prior role in the energy-mix for price reduction in the constantly increasing power generation from RE. This can be partially explained by the theory of learning curves[12]. The business case of RE and cost declining of RE technologies; pollution and climate change; accelerating RE deployment target; RE technology innovation; corporate and investors' action for lessening carbon footprint; and public opinion towards RE — these six enabling trends are forcing to drive the deployment of RE (IRENA—GCGET 2019). Power generation from the FF-based sources may gain price benefits from higher efficiency on smart technologies; but the RE market is moving faster than that market. Cost reduction of clean energy arises from fundamental physics and material cost from scale as well as lower labor costs through manufacturing automation and lower waste driven by higher efficiency. Due to manufacturing scale and vertical integration rather than from performance improvement, all these cost reductions appear. Along with the learning curve, indicated technological progress has played a significant role in the drastic fall in RE prices, expanding the accessibility of energy to wider energy consumers. As per IRENA (2019), from 2010 to 2018/2019, the global average contracted price of solar energy dropped by 78% and wind energy also fell by 33%.

[11] https://www.thedailystar.net/environment/climate-crisis/climate-loss/news/rising-sea-levels-can-render-20-million-bangladeshis-homeless-2050-2175646

[12] The learning curve theory proposes that a learner's efficiency in a task improves over time the more the learner performs the task.

National trends, such as Scandinavian countries or Germany, are shifting FF subsidies to RE investments while creating new decent and healthy jobs and ensuring a just and inclusive transition. Abolhosseini & Heshmati (2014) state that the three support mechanisms used to finance RE development programs are: auction, tax incentives, and tradeable green certificates. Some countries are familiarized cash incentives in the private sector for utility-scale RE generation. Some have initiated interest free/negligible level of interest-based credit scheme to the expansion of RE. There are best practices eligible to follow; however, we must admit that. Bangladesh is still far from starting the mentioned practices for the extension of RE. Among the reasons we can see that the level of economic development and the RE share in the overall energy-mix as well.

Cost savings via energy efficiency and implementing competitive renewable energy programs have been pointed out as potential fields to create a win-win situation where emission reduction and economic development go hand in hand (Rennkamp et al. 2017, Beg et al. 2002). Along with the technological cost reduction (IRENA 2020_a), the suitable and tailored RE support system affects the ultimate set of average prices. There is evidence for the impact of fiscal incentives for RE investments on the 16-33% reduction of Levelized Cost of Energy (LCOE) even in a developing country like Colombia (Castillo-Ramirez et al. 2017). Investments in particular technologies should be made within dedicated support frameworks to ensure that the assistance offered is adequate, without exceeding the actual expenses. Presently, onshore wind power costs are already lower than the projections for fossil fuel and nuclear power facilities, and even sizable solar power installations can prove more economical than newly constructed traditional power plants (Nestle & Brugger 2014). Hochberg & Poudineh (2018) state that auction is an operative distribution means for the government and a market-based context as well, which supports encountering different purposes such as positioning of renewable energy, lessening of tariff, augmented overseas investment, upgrading of reliability, regulation of CO2 emissions, and finally, economic development. These are desirable in Bangladesh.

Technological cost reduction has influenced the global RE experts and decision makers decisively to agree to take auction scheme as a medium to shape-up the renewable energy market in their precise framework and skirt investors' windfall turnover. The IEA (2019_b) also states that practicing the competitive auctions hastens the decline of cost for some renewable technologies, mentionable solar PV, and onshore and offshore wind. Furthermore, IEA (2021_b) stated that targets and competitive auctions can enable wind and solar technologies to accelerate the electricity sector transition.

In contrary to the global best practices, power projects of Bangladesh (both conventional & RE) are still awarded on an unsolicited basis like Power Purchase Agreement (PPA) or Request for Quotation (RFQ) and tariffs are determined through direct negotiation (between BPDB & Independent Power Producer-IPP); and for this RE price is higher compared to global trends. As per the calculation of Bangladesh Energy Regulatory Commission (BERC), an independent and statutory energy regulatory body, the weighted average per kilowatt-hour (kWh) electricity generation cost from RE is 0.15 US$ (BDT. 12.85/kWh) at utility scale. The IRENA (2019) says in India per kWh RE generation cost from solar PV was 0.04 US$ in 2018 and 0.16 US$ in 2010 and in Brazil per kWh RE generation cost from onshore wind was 0.02 US$ in 2018 and 0.03 US$ in 2017. Cost declination by following a modern hands-on auction scheme is carrying a good sign for the global energy generation from RES. Kitzing et al. (2019) favors RES auctions, focusing on two arguments: primarily, auctions ensure a perfect support allocation that is fixed with competitive ways, which tends to realize the project cost when it has been completed; and secondly, it controls the support budget avoiding first-come-first-serve strategy.

Due to the climate change and energy security issue, the world is running to hunt RE for producing green energy by following the competitive auctioning scheme. Undermining traditional monopolistic and oligopolistic regimes, the green energy expands competitiveness in the electricity market and creates space for new constituencies and alliances (Mori 2018).

Considering the different aspects, there are already developing countries applying and exploiting the advantages of the auctions on a daily basis. In 2005, more or less 6 countries followed an auction system for RE capacity procurement. Later on, in 2017, at least 29 states used a RE auction scheme and their number increased to 41 in 2019 (USAID 2019). ‘Best’ bid is typically the lowest required support level capacity. Under constrained budget and volume limitations, RES auction can be an appropriate instrument for distributing sustenance and remarkable short-term efficacy gains can be achieved from here. This is the momentum where auction schemes should be investigated, since a suitable and tailored auction scheme can be a solution to achieve the previously mentioned scenarios. Therefore, the research will be a roadmap for achieving the carbon free green energy generation target within the stipulated period for meeting up the future safe and secured energy through a cost-effective auctioning scheme with diverse paybacks.

1.1 Statement of the problem

Enhancing the electricity generation from RE can help Bangladesh to complete the planned addition in power demand, mitigate the reduction in non-replenished local gas resources, and improve energy security by reducing dependence on imported coal and LNG (USAID 2020_b). Along with that, the RE sector can help to create RE technology-based jobs and facilitate the growth of RE industries which can boost local/regional development. Bangladesh has fixed its target at 2,470 MW from RE by 2021 and 3,864 MW by 2041 in its Power System Master Plan 2016, where the key focus has been pointed to the solar PV and wind power. Moreover, its vision is to trade hydro power with Nepal and Bhutan using the Indian transmission grid.[13]

A report of USAID (2021) says that in Bangladesh the electricity generation cost from fossil fuel (especially liquid fuel) are very high to date. Average unit generation cost varies between 0.15 ~ 0.18 $/kWh for heavy fuel oil (HFO) and between 0.26 ~ 0.50 $/kWh for high-speed diesel (HSD). RE's competitiveness can be assessed for Bangladesh by the mentioned unit cost data. Tariffs for new renewable capacity have not been reached some of the low values observed on the global market and in Bangladesh there are some risks and difficulties for developing RE capacity along with an immature market. Nascent market, land acquisition difficulties, and the risks and costs of transmission systems for RE projects have required tariffs for such projects higher than that of international weighted average tariffs.

In December 2020, the Government of Bangladesh approved a 55 MW wind project (IPP model)[14] and before that there was no utility scale wind project. For implementing an IPP model-based RE project, generally the projects incur higher costs for land acquisition and constructing long transmission line for the case of utility-scale solar PV projects. USAID (2020_b) also says that the global average installation cost of utility-scale solar PV declined sharply from 4,621 $/kW in 2010 to 995 $/kW in 2019 by a staggering 78% fall. In 2019, Bangladesh obtained a 7.4 MW utility-scale solar PV

[13] https://kathmandupost.com/money/2019/10/16/nepal-likely-to-export-power-to-bangladesh-using-indian-grid

[14] Cabinet approved Independent Power Producer (IPP) model based 55 MW wind project.

project at a cost of $8.5 million where there was an investment cost about 1,150 $/kW. For keeping the total cost low by removing the land acquisition cost, BPDB[15] sanctioned its own land for the project. The highlighting point is that after giving land freely per kW investment cost is higher than that of the global average whereas India has the lower installed cost of solar PV at 618 $/kW and this has only been possible by following feasible auction scheme in an extreme level (USAID 2020_b).

An auction scheme was initiated for a 50 MW wind project in 2019 in Bangladesh. BPDB received only one bid and the reasons found likely were the lack of project information (e.g., site-specific resource data), lack of sizeable parcels of the land, weak land acquisition regulations, tough terrain for siting and transportation, the responsibilities of developer, and one-month lead time for submitting the bid.[16]

It is well-known that starting anything new is difficult. Nevertheless, measuring the feasibility and potentiality via research and analysis help to reach the desired zenith. India is the neighbor country of Bangladesh (Bangladesh is covered by Indian Territory from three sides) and Bangladesh has imported electricity from India since September 2013 (1000 MW)[17]. Since 2012, India has entered into the journey of RE auction scheme keeping aside the 25-year Feed-in-Tariff (FiT) for increasing the grid connected to solar power generation capacity. For testing the market response of the RE tender, the Indian government started with a small-scale solar project and invited proposals from the bidders at which tariff rates they were willing to invest and from those the government selected the lowest bid proposals. Later, the government called bidding for large projects and asked bidders to place bid price below the first tender and so on. Furthermore, the government ran in-depth studies to learn from the European failed auctions where there was a low bid price, but the contracts were failed to come in effect (Altenburg and Engelmeier 2013). As far as it is known, this research is the first one where the potentiality and feasibility of auction mechanism for the RE sector has been scrutinized for Bangladesh. Being a novice on the mentioned research topic, there is no way to analyze the previous ones and advance further by mentioning the corrective actions/features based on the previous research, which is another gap. Still, the country does not bother about the scheme, either.

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[15] Bangladesh Power Development Board (BPDB)- a public power generation and distribution entity in Bangladesh.

[16] Personal communication with Mr. Bellal Hossain, January 05, 2021.

[17] https://thefinancialexpress.com.bd/public/national/bangladesh-to-extend-power-import-deal-with-india-1634476156

Lack of coherence among different policies is another strong problem for Bangladesh. For example, revisiting PSMP 2016 has fixed up RE target at 5,307 MW by 2030; Renewable Energy Policy 2008 fixed it at 14,660 MW; Bangladesh NDC (considering 5% GHG reduction target) fixed it at 7,330 MW; National Solar Energy Action Plan (utility scale solar-medium case) fixed it at 3,625 MW (USAID 2021, p. XII). Therefore, focusing on the year 2030, the different policies have mentioned different RE targets. Consequently, the appropriate target and their achieving paths become volatile. Ultimately, all efforts go in vain.

In practicing the auction process, the RE prices, i.e., utility scale power generation cost has declined a lot, which is currently competitive to other FF-based energy generation sources, according to the information available. However, Bangladesh is still in lag due to the nonexistence of realistic decision making, the absence of previous research related to this issue, and deficiency of consistency in different policies.

1.2 Purpose of the study

The main purpose of the study is to build up a feasible auction scheme for the developing countries, such as Bangladesh, mingled with socio-economic development instruments under qualification requirement that ensures diverse paybacks. Existing literatures are added to the study and for doing so, some methodological issues inherent in the literature were addressed. Addressing the literatures, **the main research question** is: **What will be the final renewable energy auction model for Bangladesh that will ensure diverse paybacks?**

To answer the main research question, obtain more accurate findings, and conduct proper research from the study, the following hypotheses construct the basis of the train of thought:

- *H1*: Last few years, the emerging and open economies are getting some benefits for adding electricity into their energy mix from RE sources.
- *H2*: There are auction features by which a potentially beneficial auction can be established for a developing country like Bangladesh due its persistent contribution.
- *H3*: Implementation of the auction technique has led to a global decrease in the Levelized Cost of Energy (LCOE), indicative of the affordability of energy derived from renewable sources. However, in Bangladesh, where this technique

is not consistently employed, the LCOE appears comparatively higher than in other nations in Asia.

- *H4*: The qualification requirements needed in the auction model already exist in Bangladesh and thus the instruction of RE auctions can bring gains for Bangladesh.

Focusing on the broad objective and research questions, it was aimed to conduct both qualitative and quantitative research and, in connection with that, a systematic literature review and Panel VAR econometric analysis and levelized cost of energy (LCOE) model were followed. The research was conducted by aiming at the below-mentioned narrow objectives:

(1) Evaluate the role of energy in the development of Bangladesh;
(2) Recommend strategies to implement robust RE development path with affordable cost that will lessen the dependency on fossil fuels & energy import and increase the sustainability in the energy sector;
(3) Clarify the country-specific benefits for accelerating the uptake of utility-scale RE by tailoring feasible auction features for getting potential returns;
(4) Fix the RE generation target and GHG reduction commitment merging with all existing policies; and
(5) Calculate the 'Levelized Cost of Energy (LCOE)[18]' for the case of Bangladesh and compare with the global status.

The mentioned broad objective and research question have led the author to receive the ultimate result of the study with some policy recommendations for the decision makers.

1.3 Conceptual Framework and Outcomes

To address the research objectives and identified research issues, a conceptual framework were followed which served as a guide for developing a suitable auction outcome for developing countries like Bangladesh with various gains. Haelg (2020) classified various auction design features under four wide-ranging categories along with the auxiliary policies for getting the ultimate auction outcomes. He indicated the

[18] The LCOE represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle and is calculated as the ratio between all the discounted costs over the lifetime of an electricity generating plant divided by a discounted sum of the actual energy amounts delivered.

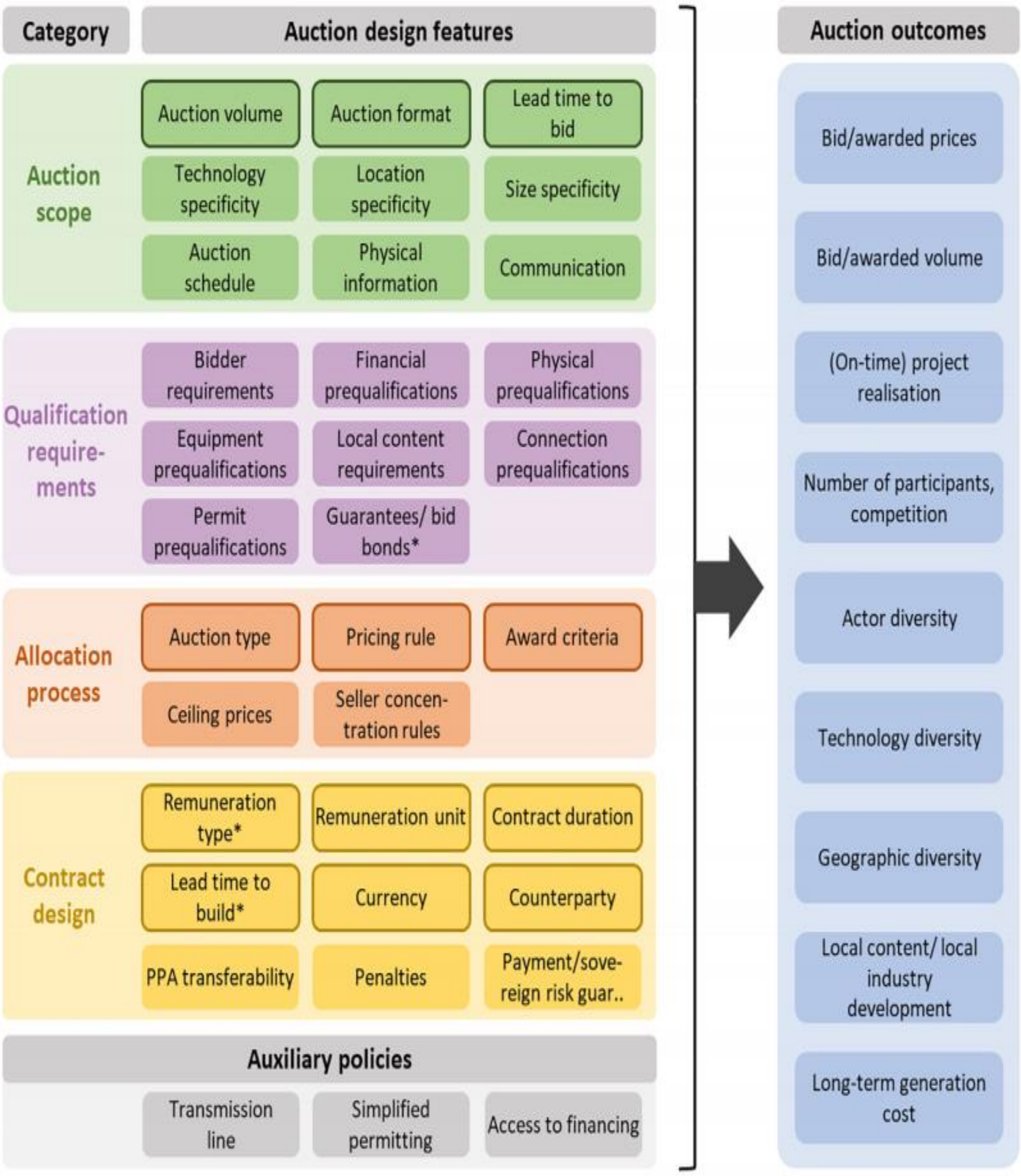
obligatory design features in an auction design along with some optional design features (*Figure 1*).

First, what is being tendered is defined in the auction scope. Haelg (2020) states that if the auctions scopes are defined or clarified, then most auction design structures in the auction scope have optimistic outcomes. For example, the application and vibrant construction of the design features typically lead to lower tender prices, more viable and more assorted pool of contributing actors. Cautiousness is required here as sometimes the policymakers demand elaborate and classified additional design features under an action scope that leads to higher policy cost. He defines *auction volume* as the auctioned quantity, which can be delimited in terms of capacity, energy, or budget; the auction volume is awarded to one project or to multiple projects and it is specified in the *auction format*; how much time is granted for bid preparation and when the bid needs to be submitted are explained in the *lead time*. Other than above-mentioned auction features, i.e., *technology specificity*; *location/site specificity*; *auction schedule*, i.e., how frequently and how regularly the auction schedule will take place, *physical information* and *communication* are the optional design features.

Second, the qualification requirements, i.e., the requirements for the participants in the auction process, which their projects have to fulfill to be able to end in the auction. Under this category, the auction features like *bidder requirements* (i.e., justifying the technical soundness of the project developers); *financial pre-qualifications* (i.e., measuring the bidders' financial support level); *physical pre-qualifications* (i.e., resources and feasibility studies); *equipment pre-qualifications* (i.e., the usage of definite equipment); *local content requirements* (i.e., whether to share a specific equipment/service from locally); *connection pre-qualifications* (i.e., grid access agreement or studies); *permit pre-qualifications* (i.e., taking advance permission from the concerned end by the bidders) and *bid bonds* (i.e., providing a specific sum of money as guarantee as for not complying the responsibilities by the winning bidders) are totally optional for the policymakers (Haelg 2020). Haelg remarks that these design features under the qualification requirement category enhance the projects' realization rates in most of the cases.

Third, besides the auction scope, Haelg (2020) includes *auction type* (i.e., whether the auction process is static/sealed-bid, which means the winners receive awards based on submitting one bid or dynamic/descending clock auction, which means that after a specific period the winners are awarded based on the bids at hand); *pricing* *rule* (i.e., how the bids are accounted for); *award criteria* (i.e., clarify the award allocation criteria) and *ceiling price* (i.e., upper boundary of the potential bids) as the essential auction design features under allocation process category. Along with that *seller concentration rule* (i.e., the restrictions on the number of projects that one bidder may submit or awarded) are optional auction features of the category.

Figure 1 Classification of Auction Design Features & Auction Outcomes



Source: Haelg (2020, p. 14)

Note: *These auction designs are used in the Levelized Cost of Energy (LCOE) analysis

Fourth, the contract design category defines the characteristics of the contract awarded to the bid winners. The auction design features include *remuneration type* (i.e., whether the remuneration is disbursed in the form of fixed or sliding premium); *remuneration unit* (i.e., whether the remuneration is offered based on electricity or capacity or time of delivery or any other form); *contract duration/support period* (i.e., the year counting for the remuneration); *lead time/realization time limit to build*, clarifying the operation date of the projects and the construction period; *currency*, specifying the form of currency (i.e., local or hand currency, with or without indexation) of the disbursement of the remuneration, and *counterparty*, stating the type of counterparty like national government, utility, etc. of disbursement of the remuneration as the mandatory part of the contract design category. Furthermore, *PPA transferability* (i.e., granting permission for bid winners to hand over contract to other party with/without charges); *penalties* (i.e., imposing fines for any non-compliance issue or making delay for project completion); and *sovereign risk guarantee* (i.e., assets insurance of the project developers) are the optional design features. Finally, Haelg (2020) mentions some auxiliary policies like transmission line, simplified permitting, and access to financing, which are not strongly linked with the auction process; but those have remarkable positive consequences on auction outcomes.

In the various country-specific auction implementation reports of AURES II, del Rio & Menzies (2021), Bartek-Lesi et al. (2020), del Rio et al. (2019) mention that the main characteristics of auction are counterparty, technology specificity, lead time to build, auction schedule/frequency of auction. They focus some general design features of auctions like auction format, auction procedure (i.e., auction type, auction criterion), financial prequalification requirements (bid & performance bond), materialistic prequalification requirements, auction volume, price limit, penalty, remuneration type/form of support auction, support level adjustment. Further, the author reviewed different auction design features categorized by AURES (2015) and Fleck & Anatolitis (2023).

By assessing the mentioned literatures under sub-section 1.3 in connection with the auction features, the author’s motivational toolkit for the dissertation is to get the final outcome, i.e., an auction model for the developing countries like Bangladesh with diversified gains for sustaining the research issues.

1.4 Structure of the Dissertation

The dissertation consists of nine chapters, which are interconnected and built up on each other. The introduction chapter has pointed out the research issues, rationality for the study, objectives, research questions, research gap, and theoretical model. Chapter two highlights the overall energy scenario (past and present) of Bangladesh, such as the power and gas sector, the power generation capacity growth, actors and industrial basis of power and energy market, etc. The third chapter discusses the theoretical background, i.e., history of the auction concept, its continuous development trend, applying the auction concept into the electricity sector and RE sector and the auction theory and its match-up with the electricity field, the economic prospects of auction. The fourth chapter focuses on the relevant literatures, sorting out the advantages and disadvantages of other RE support schemes and SWOT analysis of the auction scheme. Methodology, models, pattern, and the analysis of the dissertation are presented in the fifth chapter. The sixth chapter contains the results and analysis of the results. Chapter seven highlights the discussion and decision part where the proposed renewable energy generation goal for Bangladesh, the logic for setting that goal and the final auction model have been described. In the eighth chapter, some policy recommendations along with conclusions will be found. After that, limitations and suggestions for future research are offered. The dissertation finishes with the list of references and appendix.

2 OVERVIEW OF THE ENERGY SCENARIO IN BANGLADESH

2021 is the year of golden jubilee of glorious liberation of Bangladesh. It has earned its liberation through supreme sacrifices of millions of martyrdoms and has made giant strides in many different areas including energy and power over the last 50 years. Many consider Bangladesh as the emerging tiger of the East. Every New Year brings many challenges that require Bangladesh to better coordinate endeavors for consolidating the achievements. Bangladesh has ensured its steady economic growth in the last decade.

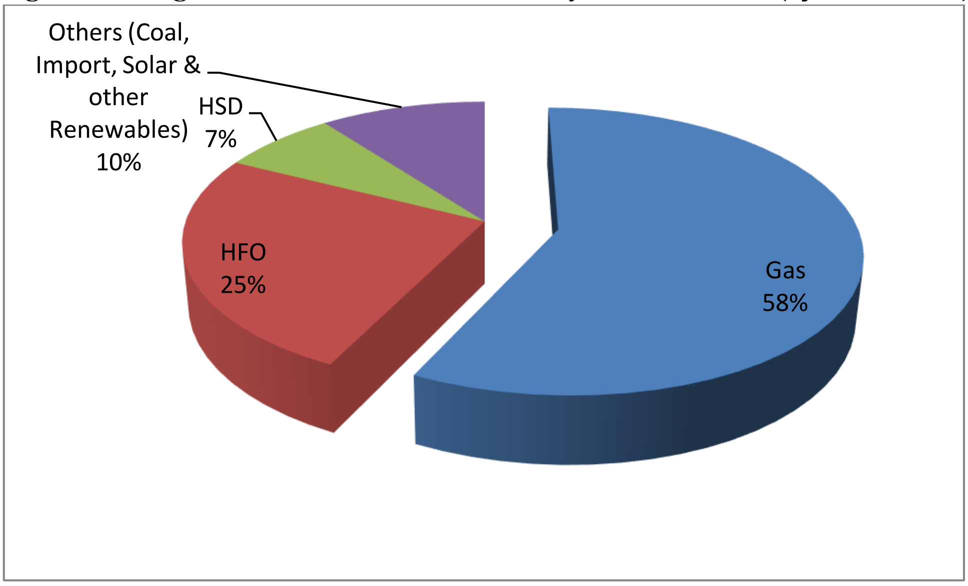
Sustaining a reliable energy supply is crucial for Bangladesh's growth in the future. The absence of a steady energy supply can hinder both economic and social progress. The Bangladesh government (GOB) is making efforts to enhance its domestic energy production. Currently, Bangladesh relies on a mix of natural gas, oil, and coal to fulfill its energy needs, but still remains dependent on energy imports, making it susceptible to global market fluctuations. In addition, due to the diminishing indigenous gas reserve, the country is importing high-priced and high volatile LNG from the international market.

2.1 Power Sector in Bangladesh

The objective of the country's power sector is to deliver uninterrupted and affordable quality electricity to all by 2021. Once Bangladesh was in the trap of huge power crisis. In the period 2001-2006, power demand rose to 6,000 MW; but generation capacity was only about 4,000 MW. Consequently, 8-10 hours chronic load shedding brought economic activity to stand still. For mitigating the power crisis instantly and accelerating the country’s economy, Bangladesh initiated captive and quick rental power plant concept.[19] In the period 2009-2021, the power producing capacity has raised from 4,000 MW to around 25,000 MW and this availability of power led to achieving impressive economic growth (5.05% to 8.15% GDP growth consistent in last 10 years). A major part of the electricity in Bangladesh is produced by gas (57.36%), followed by 25.16% by heavy fuel oil (HFO), and 7.23% by high-speed diesel (HSD) (*figure 2*) (Power Cell, Bangladesh in June 2020).

[19] https://www.youtube.com/watch?v=2SPjrmzqoRY

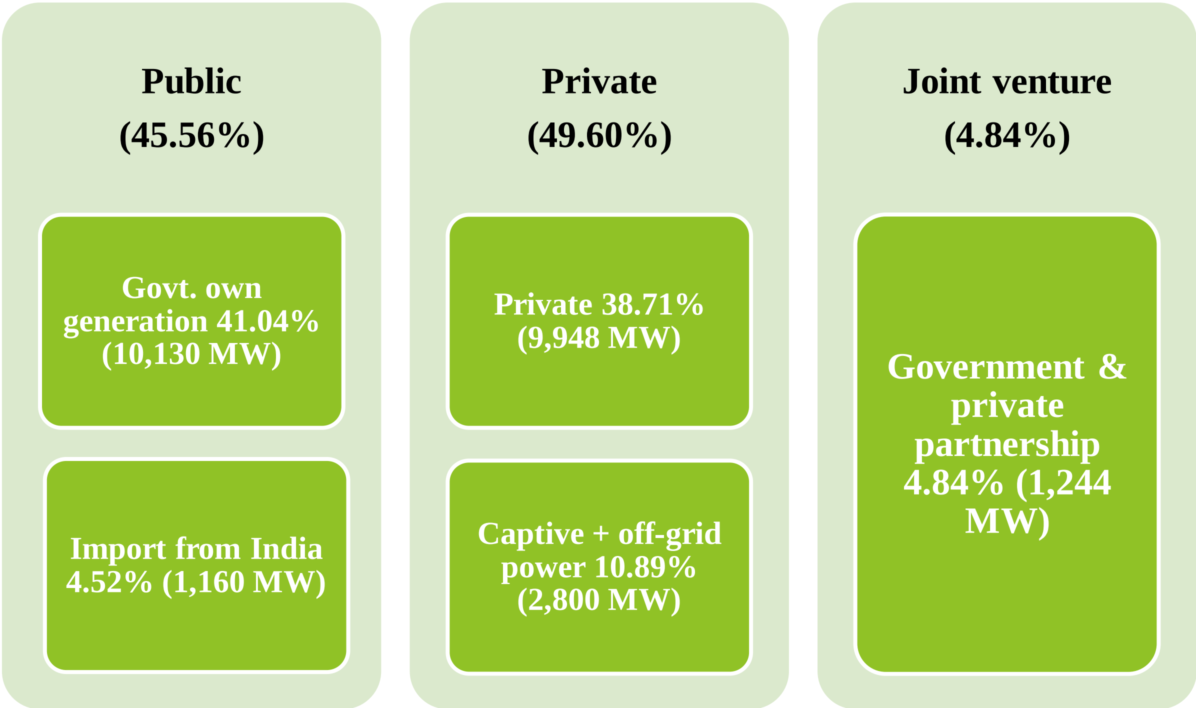
Figure 2 Bangladesh's Power Generation by Fuel Sources (by June 2020)



Source: Author's own creation by the collected data of Power Cell, Bangladesh

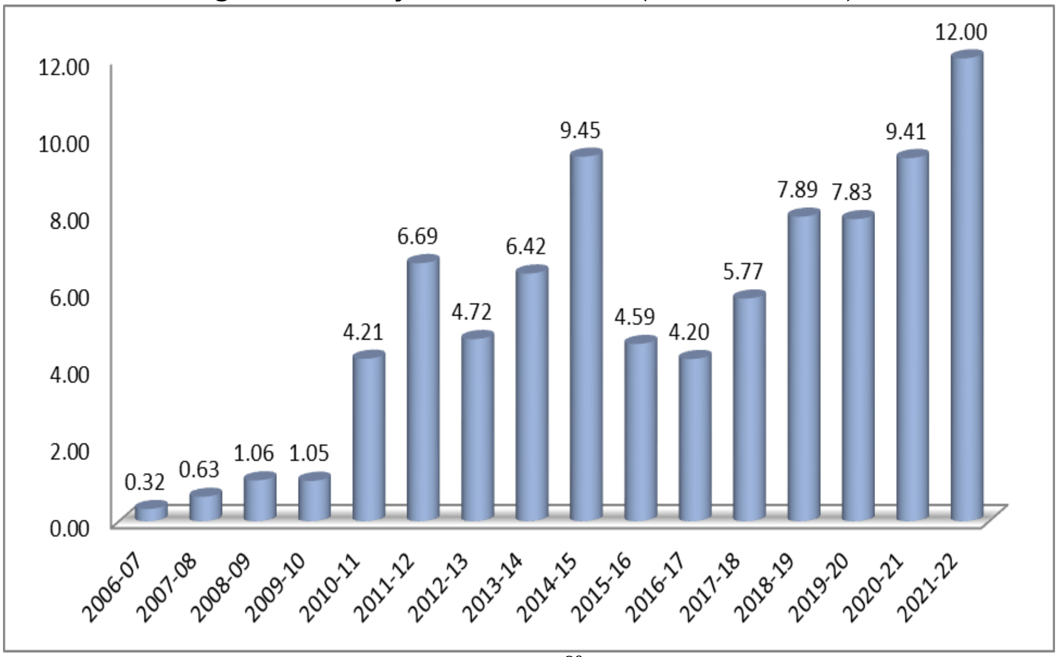
According to the GOB's Power Division report (2022), as of December 2021, 87.48% (i.e., 22,482 megawatts) is grid power and 12.52% (3,218 megawatts) is non-grid connected power. 45.56% of the total power generation was by the public sector, while the private sector accounted for 49.60% (25,700 MW) and 4.84% was from joint venture. There were 43.1 million electricity consumers, with a per-capita energy generation of 608.76 kWh (0.61 MWh) and 100% access to electricity for the entire population (*Table 1*). *Figure 3* provides an overview of Bangladesh's power generation at a glance. Data from the Power Division shows that natural gas generated the highest amount of power, while renewable energy sources generated the least. 4.52% of power (around 1,160 MW) is imported from India.

Figure 3 Bangladesh's Power Generation Statistics (considering 25,700 MW to Dec 2021)



Source: Author's own creation by the collected data

Figure 4 Subsidy in Power Sector (in million USD)*



Source: Collected by author's own communication[20]

*conversion rate: 1 USD = 95 *Bangladeshi Taka* (BDT)

Domestic users consume the most electricity according to the Power Division's 2022 statistics. The Bangladesh Energy Regulatory Commission (BERC), the country's independent energy sector regulator, reports that per-capita energy generation was 350 kilowatt-hours (kWh) as of May 2018.[21] The World Bank's (2014) report shows that per-capita energy consumption in Bangladesh was 227 kilograms of oil equivalent, which increased to 452.22 kilograms of oil equivalent in 2018, due to increased energy imports and generation.[22] This resulted in an increase in the nation's per-capita energy usage.

Table 1 Status of Power Sector from Consumers' Point of View

Head	Description
Access to electricity (of total population)	100%
No. of total electricity consumers	43.1 million
Per capita electricity generation	608.76 kWh
Per capita energy consumption	452.22 kg. of oil equivalent

Source: Author's own creation by the collected data

[20] Author's personal communication to Mr. Mizanur Rahman, email to author, 05 February 2023
[21] Author's personal communication to Mr. Raju Ahmed, email to author, 30 December 2022
[22] https://data.worldbank.org/

However, the power sector in Bangladesh is subsidized and the amount of subsidy increases every year. The data of the last 16 years show that from the fiscal year of 2006-07 to 2021-22, the subsidy expanded from 0.32 million USD to 12 million USD (*Figure 4*), which is an extra financial pressure for the government. The power sector suffers from a lack of transparency regarding subsidy allocation, its beneficiaries, and the rationale behind the government's subsidy policies. Specifically, there is ambiguity surrounding the extent of subsidy provided to fuel imports, particularly imported oil, which significantly impacts fuel prices. Identifying the recipients of these subsidies is crucial. To shed light on this issue, let’s examine the period from 2011-12 to 2021-2022. During this 11-year span, private entities operating in the power sector received a total of 8208 million USD (BDT. 90,000 *crore*) in subsidies. Notably, a substantial portion 5472 million USD (BDT. 60,000 *crore*) was distributed among only 12 companies. However, these funds were not allocated for electricity production but rather to ensure non-production through contractual agreements between these companies and the government. This arrangement entails that these power sector entities receive payments, termed ‘capacity charges’, even if the government does not purchase electricity from them.[23]

Pointing to the case of subsidy, it is highlighted an analysis of IISD (2012) which says that the primary focus of the Bangladeshi government is the development of the nation's substantial natural gas reservoirs. However, progress has been severely hindered by a lack of domestic funding and limitations in implementing advanced technologies. Despite the involvement of international oil companies in offshore gas exploration and development, Bangladesh has struggled to attract sufficient investments. This situation is mirrored in the independent power production sector, where sustained expansion remains elusive. The inefficiency in coal resource development persists due to funding constraints. In numerous instances, subsidized prices fail to cover immediate expenses, and the pricing structure does not facilitate the accumulation of funds to support expansion, growth, and the recovery of depreciation costs.

[23] https://www.thedailystar.net/opinion/views/news/where-do-the-subsidies-the-power-sector-really-go-3102086

2.2 Natural Gas Sector in Bangladesh

A key goal in Bangladesh's gas industry is to provide energy for sustained economic development and secure the country's energy supply. Independent experts predict an annual increase of approximately 6% in the demand for natural gas in Bangladesh over the next 20 years. Natural gas can be used for power generation and various other purposes, such as petrochemicals, CNG for vehicles, and fertilizer production.

However, due to the gradually declining indigenous gas reserves and limited exploration of new gas wells, Bangladesh is steadily moving towards energy importing (such as LNG, coal). Nevertheless, there are some challenges, such as (Webinar of EP talks-series 25)[24]:

- Remarkable LNG terminal infrastructure has not been built yet due to the limited scope for land-based terminal. For high cost and volatility of market (considering both infrastructural development & LNG price), LNG based power generation is not sustainable either. It can be a temporary solution for Bangladesh;
- Shallow draft along Bangladesh coastline restricts the creation of enabling import infrastructure to *Matarbari* alone;
- The proposals for supplying LNG through 60 kilometers subsea pipelines and setting up LNG infrastructure in the deep sea off the coast of *Payra* seaport would be exorbitantly expensive and risky for Bangladesh. Such projects would not be bankable in the prevailing LNG market scenario. Low-cost energy production cannot be possible in this way;
- Financing issues and challenges of transportation of coal puts the government of Bangladesh in the dilemma of reviewing imported coal-based power plants in the pipeline.

Despite the country's high use of natural gas, it possesses few proven reserves. According to the WEC (2018), Bangladesh holds approximately 0.10 percent of the world's proven natural gas reserves, which is equivalent to seven times its annual consumption. However, because the power generating sector of Bangladesh largely depends on natural gas and the country's reserves are predicted to be depleted by the year 2028, the nation's energy security is jeopardized (*Table 2*). It shows that compared

[24]https://www.youtube.com/watch?v=2SPjrmzqoRY

to the year 2018 and 2022, gas demand is increasing, supply is declining, and reserve is also falling sharply.

*Table 2 Bangladesh's Natural Gas Sector at a Glance***

Factor	**Quty. in 2018**	**Quty. In 2022**
Number of gas fields in Bangladesh	27	28
Number of gas fields under production	19	19
Number of gas wells under production	110	113
Current gas production capacity	2,750 mmcfd	2,752 mmcfd
Supply of LNG	320 mmcfd	660 mmcfd
Current daily gas demand	4,000 mmcfd (approximately)	4,600 mmcfd (approximately)
Current daily gas supply	3,070 mmcfd	2,968 mmcfd
Number of gas consumers	4.18 million	4.30 million
Estimated gas reserves (proven & probable)	27.77 Tcf	28.30 Tcf
Total gas production since inception	15.22 Tcf	19.54 Tcf
Remaining gas reserves (proven & probable)	12.54 Tcf	8.76 Tcf

Source: PetroBangla, 2018 & 2022

**Tcf = trillion cubic feet, mmcfd = million cubic feet of gas per day; LNG = liquefied natural gas

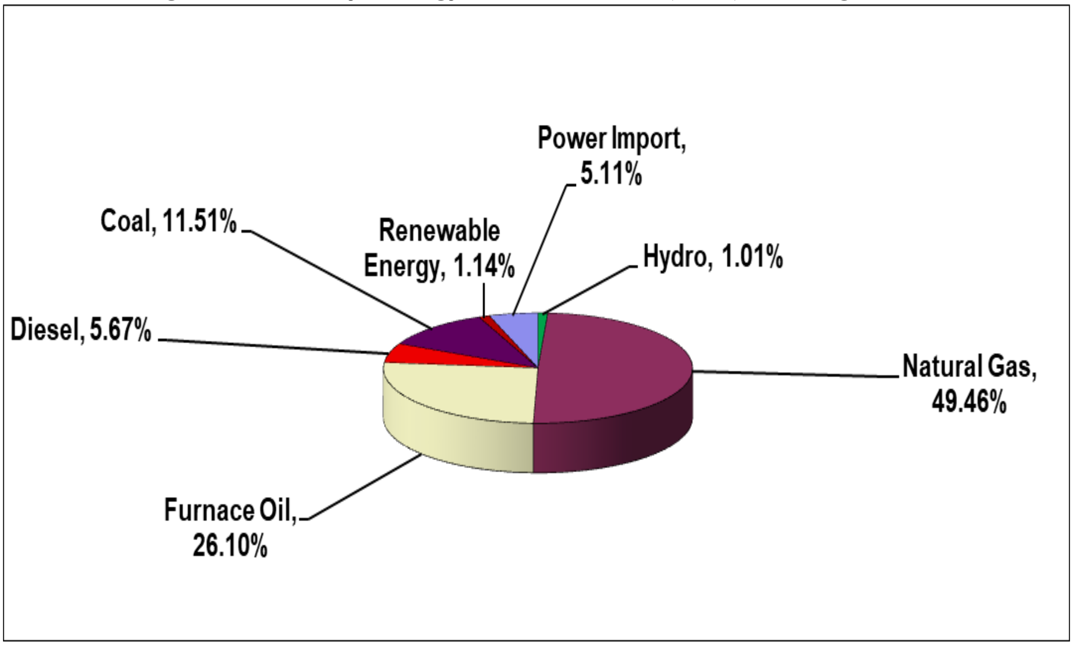
The situation is complicated by declining domestic gas production, leading the Bangladesh government to import gas to meet demand and support economic growth. Ensuring a sufficient gas supply is a pressing concern for the government. To address this, it has signed 15-year LNG import deals with Qatar Gas and Oman Gas. A regasification plant has been set up in *Chottogram*, where LNG is being re-gasified, mixing with domestic natural gas, and transporting via pipeline, primarily for power generation. The captive power, industrial, and domestic sectors consume about 16% of the 2,752 million cubic feet of gas per day (PetroBangla, 2022). The process is not capable to ensure low-cost sustainable energy for all.

Analysis says that if Bangladesh goes for 90% energy import, then per year energy bill will increase to about 20 billion US$ by 2030. As Bangladesh incurs a budget deficit every year (FY 2021-22, the deficit was 6.2% of GDP and FY 2020-21 it was 6.1% of GDP)[25] in the take-off stage unnecessary expenditures should be wisely cut-off. Otherwise, the potential and expected development sectors will be lagging behind. Bhattacharya and Jana (2009) state that import-based energy sources would infer not only more economic burden in upcoming days but also create greater energy insecurity. Further, a lot of evidence shows that the continuation of subsidies has an adverse effect on the countries' social, fiscal, and environmental sectors (Pegels et al. 2018, Beaton et al. 2013).

2.3 Aspects of Primary Energy-mix in Bangladesh

To ensure Bangladesh's energy security, managing its primary energy mix is crucial. Currently, the country heavily relies on hydrocarbons and has limited domestic energy reserves, making renewables an attractive alternative. Analysis by BERC shows that natural gas, condensate, coal, oil, imported power, hydro power, and other renewables are the primary energy sources in Bangladesh. As of the 2016-2017 fiscal-year, the country's total energy was 73,460,967.699 tons of oil equivalent, and the average energy expenditure per person was $226.56[26]. In comparison, the US had energy expenditure per person of $3,211 during the same period (IEA, 2016). *Figure 5* provides an overview of Bangladesh's primary energy mix.

Figure 5 *Primary Energy-mix Scenarios (in %) in Bangladesh*



Source: Author's own creation by data collection from MoP, 2022

[25] An Analysis of National Budget for FY 2021-22 organized by Centre for Policy Dialogue (CPD) on 04 June 2021

[26] Author's own calculation when the author worked in BERC

Bangladesh faces energy security issues due to its heavy reliance on natural gas and oil 49.46% and 31.77% of the total generation respectively. Diversifying its energy mix with more renewables would improve its energy security, promote sustainable economic growth, and have a positive impact on the environment. A lower-carbon energy mix would also help the country mitigate the effects of climate change, as it is highly vulnerable to its consequences. It is highlighted that the diesel (i.e., HSD) and furnace oil (i.e., HFO) are not environment friendly sources at all as they emit huge CO2 in the environment.

In addition, in Bangladesh, power projects (both conventional and renewable) are granted through unsolicited methods such as the Power Purchase Agreement (PPA) or Request for Quotation (RFQ). Tariff rates are determined through direct negotiations between BPDB and Independent Power Producers (IPP). This result in higher power generation costs compared to global trends which follow a competitive auction scheme. *Table 3* mentions the per unit (kWh) utility-scale power generation cost.

Table 3 *Cost of Different Fuel-mixes (considering 22,482 MW as grid connected generation)*

Fuel as generation source	Generation (MW)	Cost/kWh (in USD)***
Gas (blended, i.e., local + LNG)	11,476	0.04
Furnace Oil/Heavy Fuel Oil (HFO)	6,329	0.19
Diesel/High Speed Diesel (HSD)	1,290	0.32
Coal	1,768	0.14
Import	1,160	0.06
Renewables	229	0.14

Source: Collected by author's own communication[27]

***conversion rate: 1 USD = 95 *Bangladeshi Taka* (BDT)

As the indigenous gas reserve is depleting sharply and as the country is enhancing its dependency on LNG for satisfying the gas demand, the utility scale power generation from LNG will be volatile and higher as well. For example, the LNG based power generation is 0.13 USD/kWh[28], which is obviously higher compared to the global RE based utility-scale power generation cost.

It is a good sign that the electricity generation in Bangladesh has significantly improved since its independence in 1971. In 1970-1971, net generation was only 225

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27 Author's personal communication to Mr. Raju Ahmed, email to author, 30 December 2022
28 Author's personal communication to Mr. Raju Ahmed, email to author, 30 December 2022

MW, but by 2009-2010 it had risen to 4606 MW and reached 14,782 MW by 2021-2022 and linking with this increase the per capita electricity consumption has been amplified meticulously (BPDB, 2022), as shown in *Table 4*.

The government has allocated substantial funds in its Annual Development Program (ADP) to improve the power sector through various projects. The ADP allocated 2,276.23 million USD (24,139 crore BDT.) for 34 projects in the 2022-23 fiscal year and 1,529.29 million USD (16,217.83 crore BDT.) (BPDB, 2022), for 88 projects in the 2016-2017 fiscal year (BPDB, 2017), demonstrating a 48.84% growth in funding within 6 years.

Alongside the good signs related to net power generation growth and fund allocation growth for the power sector development, there exists a horrible picture in this sector. In the last 12 years (from 2010 to 2022), the government has paid 8,486.73 million USD (90,000 crore BDT.) as 'capacity charge' unreasonably (i.e., not producing electricity from those) to the rental and quick rental power plants as per the terms and conditions of the contracts. The government passed a special act in 2010 to run rental and quick rental power plants to meet the urgent shortage of power. Although those plants are not required any more for the country's current generation and environmental context, the government is extending its contract unreasoning again and again due to the political viewpoint. Nevertheless, the country could utilize this irrational expenditure amounted 8,486.73 million USD for other permanent and clean energy generation projects, which would be helpful for the country's self-dependency in the power sector.

Table 4 *Historical Electricity Generation Capacity, Net Generation, Per Capita Production and Consumption Scenario in Bangladesh*

Fiscal Year	**Generation Capacity (MW)**	**Net Generation (MW)**	**Per Capita Production (kWh)**	**Per Capita Consumption (kWh)**
2000-2001	3830	3033	125.13	87.83
2001-2002	3883	3218	136.02	94.58
2002-2003	4368	3428	138.36	103.98
2003-2004	4315	3592	150.16	113.41
2004-2005	4365	3721	156.26	119.26
2005-2006	4614	3782	164.36	129.67
2006-2007	4623	3718	164.09	131.85
2007-2008	4776	4130	173.48	141.97
2008-2009	5166	4162	181.98	150.59
2009-2010	5271	4606	197.88	166.42
2010-2011	6639	4890	209.46	177.60
2011-2012	8100	6066	231.65	197.72
2012-2013	8537	6434	248.73	213.01
2013-2014	9821	7356	270.83	232.56
2014-2015	10939	7817	290.28	250.95
2015-2016	11170	9036	326.41	283.30
2016-2017	12771	9479	354.10	310.75
2017-2018	15410	10958	383.00	336.71
2018-2019	18438	12893	426.05	374.73
2019-2020	19892	12738	426.23	378.16
2020-2021	21280	13792	475.00	422.13
2021-2022	21680	14782	518.33	464.20

Source: BPDB annual report 2021-2022

Furthermore, a *Rooppur* nuclear power plant (RNPP) equipped with two Russian generation III+ VVER-1200 reactors of a total 2400 MW capacity is being implemented. The construction of the plant started in 2009 and expected to end in 2025 with an expenditure of 12,650 million USD, where the Russian government is funding 90% (Russian loan will be repayable within 28 years with a 10-year grace period) and

10% funding is coming from the Bangladesh government.[29] Bangladesh received its initial shipment of uranium fuel from Russia for its inaugural nuclear power plant in October 2023. The anticipated commencement of operations for the plant's first unit in July 2024 has been postponed due to various factors. The COVID-19 pandemic hindered the progress of experts, compounded by the absence of essential transmission lines required to distribute power generated by the plant to households and establishments nationwide. Additionally, ensuring frequency stability in the power transmission system from the RNPP poses a significant challenge, as it involves a novel electricity format with consistent demand in transmission and supply networks, as reported anonymously due to the sensitive nature of the issue. The government is contemplating advanced training for personnel involved, further contributing to the delay. Moreover, the RNPP missed the December 2023 production deadline, as German company Siemens AG declined to supply the gas-insulated switchgear (GIS) for the project's substation. Consequently, the government is shifting procurement to China, which will further prolong the overall process.[30] [31]

After Russia's invasion of Ukraine, the US, EU, and UK imposed sanctions on Russian banks and restricted their use of SWIFT, the global payment network. As additional sanctions have been put in place, the situation for Russian companies and their partners has become more challenging. This situation is making the project vulnerable as the equipment and funding are mostly coming from Russia. Bangladesh is a developing country with a land area of 148,460 square kilometers. Therefore, how much and to what extend the NPP is safe is still questionable to the specialists, when the developed countries are shutting down and planning to shut down NPP from their countries due to security concern.

Last but not the least; the country is going to import another 1,600 MW coal-based power from '*Adani Power*' of India from 26 March 2023.[32] The plant will run fully with import-based coal, where cost per kWh will be at least 0.1787 USD (including transmission cost). Here also arises the question about the per unit power generation cost, which is higher compared to global average.

[29] https://www.aljazeera.com/news/2023/10/6/bangladesh-gets-first-uranium-shipment-from-russia-for-nuclear-power-plant

[30] https://www.tbsnews.net/bangladesh/rooppur-nuclear-power-plant-set-face-major-delay-commissioning-officials-695110

[31] https://www.tbsnews.net/bangladesh/energy/rooppur-npp-commissioning-unit-1-get-delayed-least-6-months-559702

[32] https://www.facebook.com/watch/?v=686298786323362&extid=CL-UNK-UNK-UNK-AN_GK0T-GK1C&mibextid=cz6gg9&ref=sharing

While the commencement of electricity supply for commercial purposes from this plant is imminent, concerns over the lack of transparency surrounding the terms of the agreement and the potential financial burden on Bangladesh have heightened discontent within the country. The agreement was made under a contentious Special Act of Bangladesh that permits the government to engage in unsolicited Power Purchase Agreements (PPAs). Bangladesh is slated to pay considerably higher prices for lower-grade coal compared to what it typically pays for coal-based power. This coal will originate from an *Adani*-owned mine in Australia, be transported to an *Adani*-owned port in India, and then shipped to the *Godda* plant, situated in a coal-rich state. Furthermore, Bangladesh is not benefiting from the tax exemption granted to *Adani* Power Ltd. when the *Godda* plant was designated as a Special Economic Zone (SEZ); this exemption should have been extended to Bangladesh. The electricity tariff from the *Godda* plant will be $0.1363 per kWh, inclusive of a fixed capacity charge of $0.0424, and not $0.24 per kWh. The capacity charge represents the fixed sum paid to a power plant regardless of electricity consumption. It is speculated that Bangladesh pursued this electricity deal due to its significant political implications for the ruling *Awami League* (AL) party at the time.[33]

2.4 Potentiality of renewable (solar and wind) energy in Bangladesh

Bangladesh is the largest delta[34] of the world and it has the potential to get electricity from solar (mostly) and wind. According to the National Renewable Energy Laboratory (NREL) 2019, the country gets wind speed 5.75 — 7.75 ms^{-1} and there are more than 20,000 m^2 of land with a gross wind potential of over 30,000 MW. NREL also says that Bangladesh receives moderate level solar radiation on a daily basis (GHI≈ 4.5 kWh/m^2), which can be converted into reasonable sources of energy via either thermal or PV route.

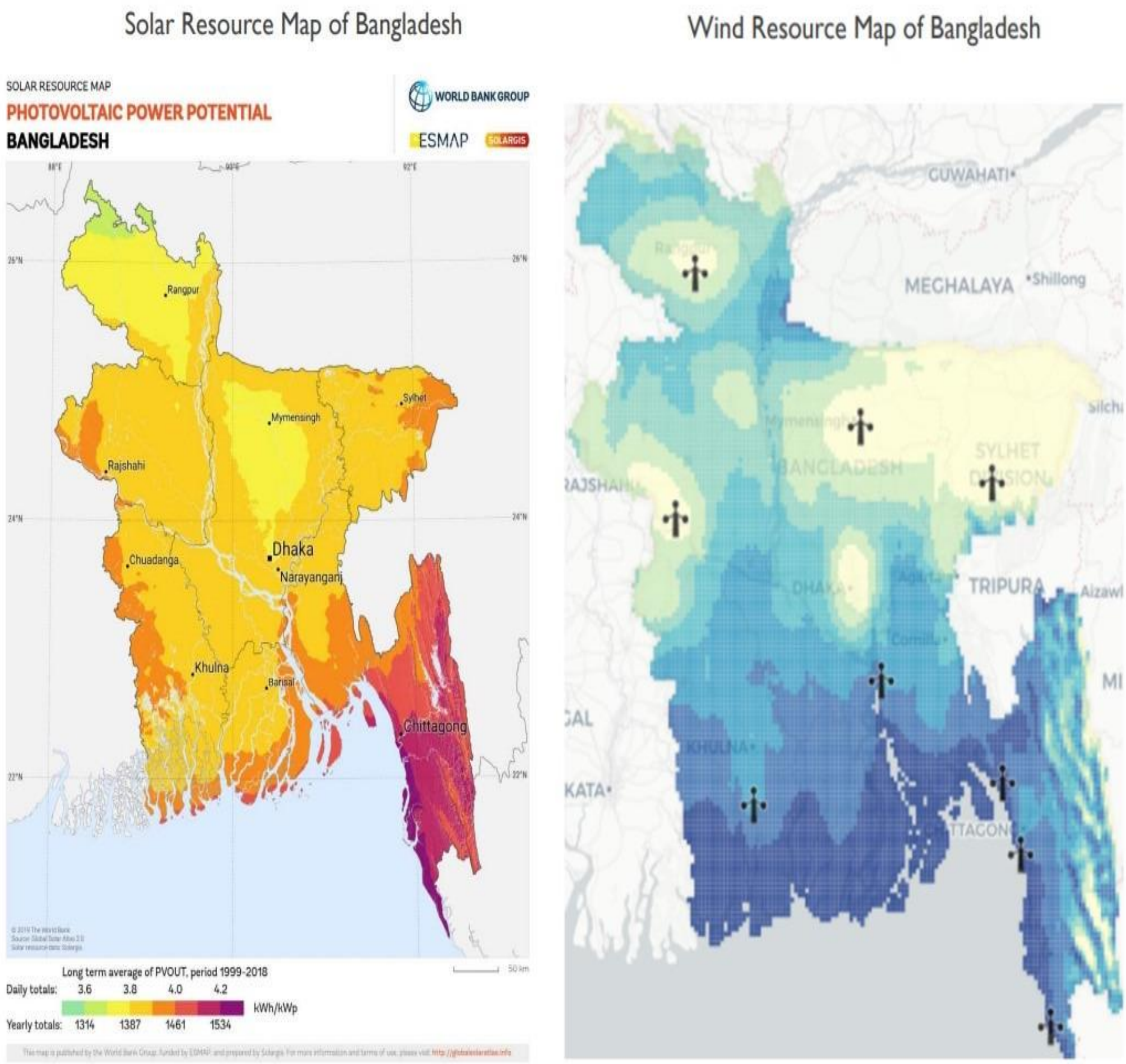
In a 2010 investigation employing a geographic information system (GIS), it was determined that approximately 1.7% of the nation's territory is suitable for grid-connected solar ventures. After evaluating factors such as the annual average solar radiation and solar panel efficiency, the study arrived at a total solar power potential of 50,174 megawatts (MW) for the country. Additionally, leveraging the Hybrid

[33] https://www.aljazeera.com/economy/2023/3/30/bangladesh-in-a-hot-seat-over-adanis-power-deal

[34] Bangladesh is the world's largest river delta, and it empties into the Bay of Bengal with the combined waters of several river systems, mainly those of the *Brahmaputra* River and the *Ganges* River. It is also one of the most fertile regions in the world, thus earning the nickname the Green Delta.

Optimization of Multiple Energy Resources software, the research projected a wind power potential of 4,614 MW, accounting for constraints like limited grid access and wind resource availability.[35]

Figure 6 Solar and Wind Map in Bangladesh



Source: USAID (2020$_c$), p. 9

The availability of solar and wind energy in Bangladesh is not consistent throughout the country. The southern coastal regions, particularly in the Chattogram area, represent the strongest potential for solar PV with an average annual output of around 1,500 kWh per kilo-watt peak (kWp). Conversely, the northern regions of Bangladesh experience a weaker solar PV potential, producing between 1,300 and 1,400 kWh per kWp. As for wind energy, the coastal areas in the south and southeast offer the

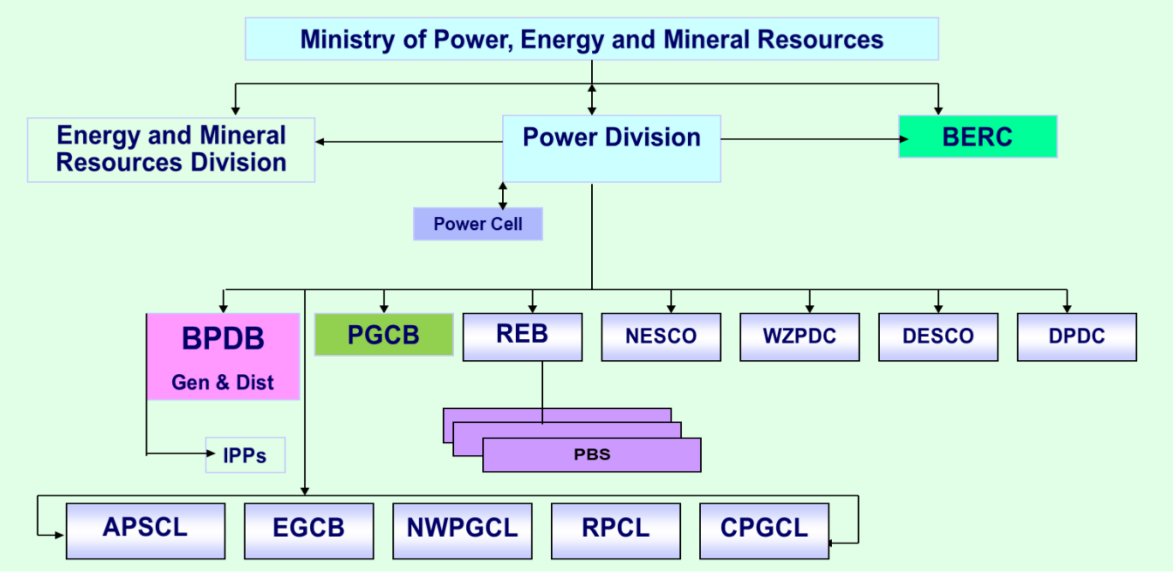
[35] https://www.nbr.org/publication/building-renewable-energy-in-bangladesh/

best conditions with wind speeds reaching up to six meters per second when measured at a height of 100 meters (USAID, 2020c). *Figure 6* depicts the solar and wind map in Bangladesh. The report suggests that as the regions with abundant solar and wind resources are also susceptible to cyclones, to ensure the successful development of these energy sources in these areas, it is necessary to implement mitigation strategies during the site development phase by evaluating the cyclone history and incorporating resilient equipment and plant designs through proper engineering and design assessments.

2.5 Actors and industrial basis for Bangladesh's power and energy market

The power market in Bangladesh is horizontally integrated (*Figure 7)*, with six local distribution companies responsible for electricity distribution, including the Bangladesh Rural Electrification Board (BREB) through its 80 *Palli Biddut Samity* (PBS), the Bangladesh Power Development Board (BPDB), Dhaka Power Distribution Company Limited (DPDC), Dhaka Electric Supply Company Limited (DESCO), Northern Electricity Supply Company Limited (NESCO), and West Zone Power Distribution Company Limited (WZPDC).

Figure 7 Present structure of power market in Bangladesh



Source: Author's own creation

Being a 'single buyer' power market in Bangladesh, BPDB is the only purchaser, i.e. purchase electricity from the electricity generators (both public like APSCL, NWPGCL, CPGCL and private like IPPs) and sell bulk electricity to the distribution entities via the transmission line of PGCB. Distribution companies purchase bulk electricity from the single buyer and sell it to the end customers. It needs to mention that BERC acts as the regulatory body in the energy sector in Bangladesh.

On the other hand, in the gas market, exploration and production initiatives, led by *PetroBangla*, are carried out by organizations such as Bangladesh Petroleum Exploration and Production Company (BAPEX), Bangladesh Gas Fields Company Limited (BGFCL), Sylhet Gas Field Limited (SGFL), and international oil companies (IOCs). The Gas Transmission Company Limited (GTCL) is responsible for transmitting natural gas to the distribution company. The six local distribution companies (*Titas Gas*, *Bakhrabade Gas*, *Jalalabad Gas*, *Karnaphuli Gas*, *Poschimanchol Gas*, and *Sundarban Gas*) distribute gas to end consumers.

Besides India, through bilateral and cooperation, Bangladesh has taken initiative in cross border trade of electricity with Nepal, Bhutan and Myanmar. China is contributing in Bangladesh's power sector in electricity generation, transmission, distribution, efficiency, and renewable energy under a 'Memorandum of Understanding (MoU)' signed on 21 October 2012 (Power Division, 2019). Nevertheless, Bangladesh is contemplating the expansion of its energy partnerships with Russia. Over the years, Moscow has played a crucial role in assisting Bangladesh in gas exploration, drilling operations, and the development of nuclear power plants. Additionally, Bangladesh is also increasing its collaboration with China, which finances a substantial 90% of the country's energy projects currently in the pipeline. Experts caution that an excessive reliance on China could expose Bangladesh to debt burdens and potential liabilities, as recent experiences in other Asian nations have demonstrated.[36]

In May 2023, Bangladesh secured a loan of US$1.4 billion from the International Islamic Trade Finance Corporation to cover fuel import expenses from July 2023 to June 2024, and also sought an additional US$900 million in July 2023. Notably, this loan surpasses the estimated annual investment of US$1.71 billion required for the development of renewable energy-based power plants in Bangladesh.[37] Increasing the dependency on import based energy and unrest in pricing of energy importing are insisting Bangladesh for entering in this debt crisis. However, weak financial institutions, an unfavorable balance of payments, and deteriorated credit ratings resulting from economic mismanagement may pose challenges to Bangladesh's ability to secure the required investments for renewable energy initiatives. Moreover,

[36] https://energytracker.asia/energy-security-in-bangladesh-is-threatened-by-fossil-fuels/
[37] https://www.eastasiaforum.org/2023/08/19/renewing-bangladeshs-energy-transition/

corruption and imperfect competition stemming from collusive contracting could deter foreign investments in the power sector. Given the escalating costs of power generation and potential disruptions arising from global conflicts, experts have recommended policy measures to enhance the proportion of renewable energy within the energy mix. Consequently, it is advisable to consider reallocating the budget to prioritize renewable energy as a potential solution to this issue.

Overlapping the bad news, Bangladesh stands as a robust emerging market in Asia, experiencing a rising demand for raw materials and manufacturing technologies. Presently, Bangladesh has achieved self-sufficiency in terms of production capacity for both finished and semi-finished (billet) steels. Steel serves as the fundamental raw material for infrastructure development and various other applications.[38] For structuring wind turbine, the steel segment plays a vital role. A quarterly report of BBS (2023), the contribution of industry and manufacturing in GDP (at constant price) was 36.92% and 24.29% respectively in 2021-2022 fiscal year that is 4.43% and 3.01% higher compare to fiscal year 2015-2016.

Not only that Bangladesh is moving forward for manufacturing solar panels and batteries. Solar Power & Electric Industries Ltd., a subsidiary of GTS GROUP, stands as a prominent solar panel manufacturer in Bangladesh. It holds the distinction of being the initial and largest solar panel producer in our nation, boasting the capacity to manufacture solar batteries, solar charge controllers, and solar LED bulbs/tubes. *Grameen Shakti*, Rahimafrooz Solar, Greenergy Solutions, XOLAREN Bangladesh, Sharp Solar, Solar Power and Electric Industries Limited, Suntech Solar, Trina Solar, Solarland, Canadian Solar are the top ten solar manufacturer in Bangladesh those are contributing internationally as well. Cases by case, the companies assemble solar panels, monocrystalline & polycrystalline panels, as well as convertors and batteries.[39]

IRENA's (2020_b) calculations suggest that in Bangladesh, approximately 137,400 jobs are associated with the nation's 5.8 million decentralized solar home systems, which constitute roughly 80% of the overall installed solar capacity. While the majority of solar employment opportunities in Bangladesh are found in sales, installation, and maintenance roles, there is also a workforce of approximately 10,000 individuals engaged in module assembly.[40] Bangladesh Power Management Institute

[38] https://adda.royalcapitalbd.com/steel-industry-overview-2020/
[39] https://mybangla24.com/solar-panel-brands-bangladesh
[40] https://www.pv-magazine.com/2020/05/04/bangladeshi-solar-module-companies-seek-covid-19-stimulus-package/

(BPMI) conducted a survey recently to know about the impact of electricity sector on economic growth and job creation in Bangladesh. The result of the survey found a high level of correlation between independent variable energy consumption and dependent variables GDP growth and employment rate.[41] Sustainable and Renewable Energy Authority (SREADA) is actively working to create a conducive environment for renewable energy. The organization conducts workshops and training sessions with various stakeholders to help them grasp the advantages of embracing renewable energy. Bangladesh stands fifth among 161 countries in renewable energy jobs.[42] Some formal educational institutions are introducing RE technological research in their course curriculum. So, industrial development and training & skills enhancement may make more employment and technological self-sufficiency scope for Bangladesh in the upcoming days.

Along with that the government has developed several essential strategic policy documents aimed at fostering greater coherence within the development planning process in Bangladesh. A series of pertinent national plans and policies have been formulated to support endeavors concerning climate change actions. Highlighted below are some of the groundbreaking initiatives outlined in the INDC of MoEFCC (2020):

- ***Mujib* Climate Prosperity Plan up to 2030—**the strategic investment framework aims to mobilize financial resources, particularly through international collaboration, to support the implementation of initiatives focused on renewable energy and climate resilience;
- **National Solar Energy Roadmap 2021-2041—**has been crafted to develop a long-term vision for the nation and establish feasible capacity targets for the country's solar energy initiative;
- **Renewable Energy Initiatives—**one notable effort involves crafting a Renewable Energy Policy, stipulating that a minimum of 10% of the overall power generation must originate from renewable energy sources;
- **Promoting Green Technology—**the central bank initiated a refinance scheme to support environmentally friendly technologies like solar energy, bio-gas plants, and Effluent Treatment Plants (ETP);

41 https://www.bpmi.portal.gov.bd
42 https://www.tbsnews.net/bangladesh/energy/renewable-energy-creates-137-lakh-jobs-bangladesh-139222

- **National Action Plan for Clean Cooking 2020-2030—**Bangladesh's Country Action Plan for Clean Cook Stoves 2013 (CAP 2013) primarily aimed to eliminate financing obstacles by facilitating Small and Medium-sized Enterprises (SMEs) in accessing capital. It also sought to enhance access to climate funds, utilize government funds to support women-led businesses in the sector, and advocate for more financing opportunities from international donors at favorable rates. Building on the achievements of CAP 2013, a new National Action Plan for Clean Cooking in Bangladesh (2020-2030) is presently under development;
- **Forest and Carbon Inventories—**to mitigate carbon emissions from the forestry sector, Bangladesh has developed the Bangladesh National REDD+ Strategy (BNRS) and implemented a National Forest Monitoring System (NFMS) to regularly monitor tree and forest cover;
- **Bangladesh National Action Plan (NAP) for Reducing Short Lived Climate Pollutants (SLCPs)—**the comprehensive execution of the National SLCP Plan is anticipated to decrease black carbon emissions by 40% and methane emissions by 17% in 2030 compared to business-as-usual scenarios;
- **Energy Efficiency and Conservation Master Plan up to 2030—**in this extensive strategy, the government's objective is to decrease energy intensity (the national primary energy consumption per unit of GDP) by 20% in 2030 compared to the 2013 level. This initiative anticipates saving a total of 95 million toe during the specified timeframe;
- **Clean Development Mechanism (CDM)/Carbon Trading—**Bangladesh possesses a modest CDM project portfolio with notable potential for emissions reduction across various registered initiatives. These include addressing natural gas leakage from transmission lines, implementing solar home systems, introducing energy-efficient brick kilns, and promoting improved cook stoves programs;
- **Monitoring and Reducing Air Pollution—**the Bangladesh government has issued extensive guidelines or directives aimed at controlling and mitigating air pollution from various sources such as brick kilns, construction activities, vehicles, open biomass burning, industry, and others, in line with their Nationally Determined Contributions for 2020. To tackle air pollution

comprehensively, they have drafted a 'Clean Air Act, 2020,' which is currently pending approval.

If we analyze the whole energy portfolio of Bangladesh, we can see that there is still a lack of rationality in the energy market. Irrationality is in a sense that there is scope, but it has not been utilized. Rather, high-cost energy is being exploited for nurturing political interests, leading to improper policy making and mismanagement in this sector. Furthermore, a drastically huge amount of money is wasted on the energy sources, while it could be saved with a proper and timely policy decision for setting up stable, safe, secured, and low-cost energy sources. In addition, the country is visualizing a safe, secured, stable, and low-cost energy supply for climate mitigation resilience; yet it is not seen in the practical field.

3 THEORETICAL BACKGROUND

The theoretical background is one of the essential segments of a research work. This is a structure that captures or backs a theory by introducing and describing the rationality of investing the issue. The concept of auction is not new; it has a historic pathway. In this chapter, the historic introduction of the auction process and its gradual advancement will be presented. Along with that, the initiation of auction in the energy sector will be highlighted here.

The English word 'auction' is practically originated from the Latin word '*augerė*' which means 'to increase' or '*augeō*' which means 'I increase'. If it is traced back to the auction history, in the ancient Greece, recorded as early as 500 BC by Herodotus, auctions of women for marriage and slavery were documented. The auction system was adopted by the Romans for 'art' auctioning, where sales were usually held either to resolve cases of insolvency or to dispose of war booty and slaves.[43] According to Britannica, as far back as the Homeric era, the antique Greece had the indication of slave auctions and the practice persevered through the Roman Empire.[44]

For settling property and estate goods, the Roman Empire also used an auction system. The system, which at that time was practiced for this purpose, was called "atrium auctionarium". The "atrium auctionarium" system was used by the soldiers within the Roman Empire for selling goods. In 193 A.D., aside from the Roman Empire, the Buddhist monks in China followed an auction mechanism to fund the creation of temples (Cassidy 1967).

In the American soil, the auction begun with the pilgrims. Crops, livestock, tobacco, and other objects were auctioned by the Americans at the early stage of auctions around 1600s. In the USA, auctions have performed at a high volume for economic activity since 1980. The seal-bid auction is followed every week by the US Treasury for selling out bills and notes worth billions of dollars (Milgrom and Weber 1982).

According to the Oxford English Dictionary, the first mention of auction appeared in 1595. During the 17th and 18th centuries, in some parts of England, for selling out goods and leaseholds, the 'auctions by candle' were initiated and for auctioning the artwork, the system was frequently held by the end of 18th century.[45] The

[43] https://magazine.artland.com/a-short-history-of-art-auctions/
[44] https://www.britannica.com/topic/auction
[45] https://en.wikipedia.org/wiki/Auction

‘Christie’s Auction House’ was founded by James Christie, who was a Scottish-born UK auctioneer in 1766 in London. By selling a renowned artist’s artwork following the auction scheme, it started its journey in the UK.[46] According to Cassidy (1967), basically the 17th and 18th century was said to be the modern evolution stage of auction. Until the early modern stage of the auction mechanism, slave auctioning was held in America. In the last part of the 19th century, the Netherlands and Germany practiced auction, although the Netherlands used auction in 1887 for selling fruits and vegetables. In the same year, the German fishermen started to use auction for selling their fish. This fish auction helped the fishermen liquidate their caught fish quickly and allocated more time for fishing to satisfy the growing customer demand.

It can be mentioned that due to expanding the popularity of selling and buying through an auction system, the first and oldest known auction house was set up in Sweden in 1674 by Baron Claes Ralamb[47] and Sotheby’s auction house is the world’s second largest house established in 1744.[48]

3.1 The Economic Prospects of Auction

In the broad field of economics, Klemperer (1999) mentions that the auction theory is treated as an applied branch of economics. This branch of economics tells us about the role of bidders in the auction market, besides; the branch always seeks to get an optimal output from the forecasted market. According to the auction theory, the sellers want to maximize their revenues whereas the buyers would like to buy the products at a lower cost. The ultimate settlement occurs when the economic equilibrium happens for both buyers and sellers. The auction theory is important for practical and theoretical reasons: firstly, a large number of economic transactions are conducted via auction; secondly, auction offered a marvelous testing-ground for the economic theory due to its well-organized and simple economic environment, and finally, in the process, buyers and sellers perform actively and competitively for setting the price.

The Columbian University’s professor, William Vickrey, was the first to explain ‘auction’ academically in 1961. He pointed out three types of auctions — English ascending-bid auction, the (first-price) sealed-bid auction, and the Dutch declining-price

[46] https://www.artdex.com/history-of-auctions-auction-houses/
[47] https://www.lskauctioncentre.co.uk/news-item/a-brief-history-of-auctions/
[48] https://www.artdex.com/history-of-auctions-auction-houses/

auction and he used game theory[49] (Vickrey 1961). Since 1893, the system has been used by stamp collectors for stamp auction following English ascending-price auction rules (Lucking-Reiley 2000). Earlier in 1797, a sealed-bid, second-price auction was used by Johann Wolfgang von Goethe, a German poet and theatre director for selling his manuscript (Moldovanu and Tietzel 1998).

The first energy-market relevant implication of auctions occurred in the 80's and late 90's. During these decades the enactment of industrial deregulation, the vertical unbundling of the power sector, the succeeding separation of the electricity generation and distribution business, the procurement of electricity initiated by the electric utilities happened in the concerned countries. Fundamentally, the first electric auction was introduced globally on a short-term basis by independent system operators, which were permitted for an efficient and least-cost dispatch process. Offers like the energy consumption at various price levels and in expectancy of demand requirement and bidding process, the subsequent market operators set day-ahead prices at each point of the network and day-ahead plans for generation components and loads. That time, there was no long-term contract system (Maurer and Barroso 2011).

For a long-term electricity contract between state utilities and independent power producers (IPP) and unbundling the power sector, the auction scheme was first adopted in 1990. The bidders who offered the lowest price for electricity were able to sign a Power Purchase Agreement (PPA) with the utilities and that PPA had most of the elements of auction. The countries espoused a 'first-price sealed-bid (FPSB)' category auction when the competition became conceivable and desirable. The FPSB category was an integral part of the IPP-PPP competitive business model for power swapping for the first generation and for making a new generation project bankable, in which PPA was an important portion. Latin America pioneered the usage of auction to trade long-term products via energy acquaintances of reliability (IRENA 2013, Maurer and Barroso 2011).

For expanding renewable energy (RE) generation in an economic-efficient way, the Non-Fossil Fuel Obligation (NFFO) of the United Kingdom initiated an auction scheme as a pioneer in 1989. Due to underbidding capacity and shifting to Feed-in

[49] Game theory is a theoretical framework for conceiving social situations among competing players. In some respects, game theory is the science of strategy, or at least the optimal decision making of independent and competing actors in a strategic setting.

Tariff (FiT) scheme, the current RE auction scheme was not very positive (WBG 2014, Pollitt 2010).

When the second wave of the power sector came into existence in 2004, the auction scheme was highlighted again and for generating and consuming an adequate volume of power at a lower cost fulfilling other objectives, the scheme was further implemented by a number of developing countries. Brazil, Canada, Chile, Ireland, Portugal, and the UK were the pioneer countries who implemented RE auction (IRENA 2013). Realizing the benefits and practicability, the European Commission changed its state aid guidelines to the energy field in 2014 and the new guidelines recognized the competitive bidding (auction) as the main scheme to deliver state aid for renewable energy from 2017 (Botta 2019, Leiren and Reimer 2018). In addition, the economists named Paul R. Milgrom and Robert B. Wilson were the Nobel laureates in Economics in 2020[50] for improving the auction theory and inventing new auction formats. This auction theory visibly brought a revolutionary impact into this field as well.

Linking the auction theory with the competitive renewable energy auction market, the price which mollifies the aggregate demand of winning buyers and covers the aggregate costs of the winning sellers is called the market-clearing price. This clearing-price clears the energy market as the aggregate quantity demanded and aggregate quantity supplied is equal, which the term is denoted in economics as market equilibrium. If any gap exists, i.e., the price is set lower, then there would be more quantity demanded than supplied and vice versa; and there would not be a market equilibrium in the renewable energy market (Morey 2001).

As a summary of the theoretical economic implication, auction has a primitive antiquity that helps the economy to fix an equilibrium price where both buyers and sellers are happy to buy and sell their products by ensuring their profits from their own standing respectively. Auction scheme in the RE market can guarantee a desired quantity of energy with low cost where both the buyers and sellers will be benefited. By this, there is no doubt that the whole economy along with the energy sector will be profitable; it only needs a proper application.

[50] https://indianexpress.com/article/world/nobel-prize-2020-economics-paul-milgrom-robert-wilson-6721939/

4 CURRENT STATE OF ART OF RENEWABLE ENERGY SUPPORT MEASURES

For the analysis of the research topic, the author reviewed a comprehensive summary of previous research based on scholarly articles, books, reports, etc. which are relevant to the research area. The author followed a systematic literature review based on zero emitter low-cost renewable energy by following auction scheme that has diversified gains. Different country-specific cases are emphasized for configuring the auction model for developing countries like Bangladesh. In other words, this chapter is the base for the auction model.

Policies substantially contribute to ensuring future and long-term development in any sectors. The renewable energy sector is not an exception of this eternal truth. The decision makers set country-specific goals based on the energy policies for realizing a country's energy vision, which tends to form market steadiness, enhance the investors' confidence, and thus allow for energy support to be apprehended. Considering the harmful consequences, future energy focus is pointing to the renewable energy sources (RES). Andrews-Speed (2016) states that low carbon energy transition concept has come from the broad concept that energy and energy usage pattern is highly entrenched in societies. The government needs to intervene in the costly energy transition technologies for ensuring long-term public benefit.

For the transition to low-carbon, governments need to balance between inside and outside. The first one comprises more impulsive deeds of the government and the later one infers an executive tactics to navigate the transition (Smith and Stirling 2007). Supporting the early statement, Andrews-Speed and Zhang (2015) state that promoting renewable energy requires setting the limit, massive funding from the state, and robust administrative measures, which will necessitate an operative side-step of the requirement for elusive strategic instrument.

For the expansion of renewable energy, many governments set policy supports and targets which highlight reducing emissions, ensuring energy supply security, and making energy sources available (REN21 2009, REN21 2007). In spite of having different implemented support schemes, governments alter their choices of support schemes time to time due to political environments, tightening of local or global targets, updating of technologies or being unable to provide supports to the schemes under financial crisis (Boomsma et al. 2012). On account of the political and economic necessities of the energy sector, policy paradigms play a particularly strong role in the governance of this sector (Kuzemko 2013, Mitchell 2008, Helm 2007). Along with that, resolving prices and support policy play a perilous role (Butler and Neuhoff 2008).

Germany was the pioneer for initiating renewable energy (RE) policy instruments, i.e., feed-in-law in 1991 in the European Union (EU) in the wind power market. From then, Germany became the global leader for installing wind capacity (Bechberger and Reiche 2004). The timely initiation and perfect implementation made Germany the global leader in RE sector. Wusterhagen and Bilharz (2006) mentions that Germany is the fastest in adding new capacities from RES compared to other countries of the globe due to practicing time bound support schemes.

4.1 The existing and applied renewable energy support measures

Globally, the three major and commonly practiced RE schemes are: Feed-in-tariff (FiT), quota allocation, and, very recently, competition auction/tender technique (Hansen et al. 2020, Yalili et al. 2020, IRENA 2017, Kreiss et al. 2017, Toke 2015). Fostering RE technologies, FiT, Feed-in-Premium (FiP) and tax reductions are the main support schemes followed by different governments of the world (Matthaus 2020). Shrimali et al. (2016) mention auction technique and FiT as the two well-used procurement mechanisms for RE globally.

Reviewing the literatures, we see that the widely practiced RE support schemes/instruments are FiT, FiP, quota, tax reductions/tax credit and auction/tender. Universally, there are some other instruments such as Power Purchase Agreement (PPA), direct negotiated tenders, green certificate, Renewable Energy Certificate Trading, Renewable Purchase Obligation (RPO), and Renewable Portfolio Standard (RPS), whose practice is limited in the number for supporting RE.

Every scheme has some advantages and disadvantages. Focusing on the present research topic, some well-adopted support schemes will be analyzed compared with ‘Auction’ based on some existing literatures to justify our stand in favor of the ‘Auction scheme’ as the best support instrument for the robust expansion of RE in the current scenario.

4.1.1 Feed-in-Tariff (FiT)

FiT is a fixed price set in administrative way for compensating RE fed into grid (IRENA-CEM 2015). "*Under FiTs, a total payment per MWh of RES-E generated, paid in the form of guaranteed and combined with a purchase obligation by the utilities is provided*" (del Rio 2017, p.2). The mechanism follows first-come-first-serve basis. Due to setting a perfect value, FiT is not able to ensure efficiency. Most countries designed FiT as a prime instrument to inspire the advent and positioning of energy from RES. However, FiT generally offers a definite procurement of electricity produced from RES within enduring typically 15-25 years. It mostly relies on the prices set for the energy to be procured under long-term contracts (Mourer and Barroso 2011). FiT scheme ensures prices for the renewable energy sources electricity (RES-E) generators usually without a cap on the total support cost (del Rio 2017). Although FiT guarantees a fixed payment for electricity, the mechanism is not always the best for the governments to set a correct and competitive tariff and not to be able to reduce investment (Shrimali et al. 2016, IRENA 2013, Maurer & Barroso 2011, Kreycik et al. 2011).

FiT is well-accepted in encouraging individuals to use RES (such as wind energy as a primary source). It does not hold sufficient capability to initiate a liberalized and single form of energy market (Abolhosseini & Heshmati 2014). Different FiT designs cannot eliminate price risks; their works perform uncertainty (Devine et al. 2014, Ritzenhofen & Spinler 2014). Aligning with the immediate statement, Fronder et al. (2010) mention FiT as the subsidy-based mechanism and based on FiT, producing electricity from RE technologies incurs high costs and the authors give Germany as an example. Moreover, FiT incentivizes further rent-seeking behavior and the scheme poses increased risks to consumers, who may encounter significant uncertainty regarding future electricity prices, particularly when renewable energy policy instruments are funded through levies on consumer electricity prices (Marschinski & Quirion 2014). Hungary implemented the FiT subsidy system from 2002 to 2017 primarily to encourage the co-firing of coal and biomass in existing power plants. This played a significant role in achieving the established 13% renewable energy (RE) target by 2010. However, policymakers expressed a desire for more cost-effective approaches to achieve larger targets (Bartek-Lesi et al., 2020). Calling FiT as a controlling regulation measure, researchers claim, by following the FiT policy, the government can direct the RE market as per the defined rate of contracts. Under a control budget, FiT scheme is not able to give adequate support (de Vos & Klessmann 2014). According to USAID (2019), FiT is good for less competitive and less mature markets, whereas it is more focused on price rather than quantity and when the RE price changes, the reaction level of the market is low under a FiT scenario.

4.1.2 Feed-in-Premium (FiP)

FiP is a top-up payment of the electricity market price to the RE generator. Here remuneration is more uncertain, and more financing is required as incentive when the power system demands electricity the most (IRENA-CEM 2015). FiP scheme ensures prices for the renewable energy source electricity (RES-E) generators usually without a cap on the total support cost (del Rio 2017). A producer sells electricity at the market price under the fixed FiP, in addition to that the producer gets a fixed premium as a separate, guaranteed revenue stream. In other words, a fixed FiP ensures lowest level of revenues along with lowest debt capacity. With a fixed FIP, premium projects bear the full brunt of market price fluctuations (AURES II 2021_b). In the case of FiP, the responsible regulatory body sets a price and market actors set the quantity of RE electricity generation. According to Xydis and Vlachakis (2019), FiP is a fixed price mechanism for RES support determined by the government and the price is paid to the Independent Power Produce (IPP) owners in addition to their marginal price. The income of RE generators is not fixed like FiT and it depends on the System Marginal Price (SMP). Due to depending on the market dynamics, they indicate FiP as a more market integrated mechanism. Inversely, Xydis and Vlachakis (2019) demonstrate FiP as riskier for investors due to lack of purchase guarantee of their produced electricity and costly policy to implement due to its significantly higher payment levels. The authors suggest FiP as beneficial for less sporadic RES technologies like hydro and biomass in exchange of costly technologies like wind farms or solar PVs. Marschinski and Quirion (2014) mention of their analyses that FiP exhibits diminishing performance as the magnitude of the externality grows. This is attributed to the assumption of a constant positive external effect, which becomes increasingly incompatible with the non-linearly increasing benefits from learning.

4.1.3 Renewable Energy Quota

Under RE quota obligation, governments impose an obligation on consumers, suppliers, or producers to source a certain percentage of their electricity from renewable energy. The system requires grid operation and provincial government to obtain up to certain fraction of their energy from RE sources (Xiong et al. 2014). The main benefit of RES quota is that the RES policy targets can be obtained in a cost-effective way; but the scheme is far from the market reality and the overall cost is always higher compared to other support schemes such as FiT.[51] Therefore, the statement proves that market oriented and low-cost RE cannot be possible to get from the scheme. Marschinski and Quirion (2014) highlight that in the event of a shock; a quota can lead to substantial additional expenses in the production of either fossil fuels or renewable energy.

4.1.4 Renewable Energy Tax Reduction/Tax Credit

RE tax reduction or tax credit is a specific mechanism for the expansion of the rooftop solar industry where a business entity can claim tax credit from government to develop, install, and finance that project.[52] The credit is nonrefundable, so the credit amount a customer receives cannot exceed the amount the customer owes in tax. A customer can carry forward any excess unused credit, though, and apply it to reduce the tax a customer owes in future years. A customer can not include interest paid including loan origination fees. A customer cannot claim the credit if the customer is a landlord or other property owner who does not live in the home.[53] For any small-scale RE production, the scheme works nicely; but it reduces direct tax of a country, in addition, an unfair playing field is created for continuing long time tax credit.[54,55] The sources prove that it is basically helpful for modest production (most of the cases for solar energy production) and it has some limitations.

4.1.5 Power Purchase Agreement (PPA)

A Power Purchase Agreement (PPA) serves as the fundamental contract between public and private sector entities, forming the basis of a power sector’s Public-Private Partnership (PPP). Usually, it involves a public sector purchaser, referred to as the "offtaker" (often a state-owned electricity utility in jurisdictions where the power sector is primarily state-operated), and a privately-owned power producer. The PPA typically functions as the primary revenue source that supports the PPP project. Consequently, the structure and risk allocation system within the PPA play a crucial role in enabling the private sector participant to secure financing for the project, recoup its capital

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51 https://energypedia.info/wiki/Renewable_Energy_Quota_and_Certificate_Schemes
52 https://www.americanprogress.org/article/renewable-energy-tax-credits-case-refundability/
53 https://www.irs.gov/credits-deductions/residential-clean-energy-credit
54 https://www.wri.org/research/bottom-line-renewable-energy-tax-credits
55 https://www.wsj.com/articles/will-solar-energy-plummet-if-the-investment-tax-credit-fades-away-1447643512

expenses, and generate a return on its investment.[56] But according to AURES II (2021_b) corporate PPAs are significantly influenced by the regulations of member states regarding guarantees of origin (GOs). These GOs are essential for corporations to authenticate that their purchased electricity meets green energy standards.

According to AURES II (2021_c) PPA offers potentially more revenues than that of auctions; but the risk is higher than that of auctions. Due to high riskiness, auction mechanism will be the prime driving investment in RES projects. As per the analysis of AURES II (2021_a), the project that secures a long-term PPA gets benefit from a stronger price stability and consequently present a lower weighted average cost (WACC)[57]. However, a large number of PPA signings set the price and level of agreement very low, which situation does not ensure enough incentive to the power producers.

PPAs are intricate agreements and often necessitate extensive time and negotiation before reaching a resolution. The extended-term nature of PPAs can become a drawback if there are adverse price developments affecting either party. Additionally, electricity production, particularly from renewable sources like wind and photovoltaics, can vary. In situations where the predetermined electricity quantities are not accessible during delivery, the plant operator is obligated to offer financial or physical compensation or seek assistance from a third party, such as an electricity trader.[58]

4.1.6 Direct Negotiation Tenders

According to Maurer and Barroso (2011), under the negotiated tenders' mechanism, a buyer freely negotiates the terms and commercial conditions of the electricity produced. Although it is a popular mechanism, the process is not fully transparent, and its efficiency mostly depends on the 'Benchmark'[59] price. Besides this, the negotiation mechanism is more inclined to corruption and nepotism and challenging if the political wind changes in due course of time. USAID (2019) mentions that the advantageous position of negotiated tenders is the volume control and wider flexibility to tailor projects and the process gets some competitive pricing that is not too high compared to an auction. On the contrary, the report highlights a little bit more disadvantageous points of this mechanism, for instance, it is difficult to scale if many bidders are present;

[56] https://ppp.worldbank.org/public-private-partnership/sector/energy/energy-power-agreements/power-purchase-agreements

[57] The weighted average cost of capital (WACC) represents a firm's average cost of capital from all sources, including common stock, preferred stock, bonds, and other forms of debt.

[58] https://www.next-kraftwerke.com/knowledge/ppa-power-purchase-agreement

[59] Benchmark price means comparing one's prices to the prices of competitors in a particular market segment, a valuable tool in determining prices to achieve greater value.

awarding in not possible if the bidders face risk; there might be a risk of delay at the negotiation stage; and finally, the mechanism has a lack of transparency.

4.1.7 Green Certificate

A green certificate is a tradeable asset which proves that the electricity has been produced by a RE foundation. The certificate is delivered and dealt in acquiescence market due to administrative strategies which involve traders to have a fixed portion of RE production in their supply range. The price of green certificate relies on the market scarceness and the price becomes higher when the certificate scheme is obsessed by constricted goal of government policies. Due to this feature, the scheme has mislaid its acceptance.[60] Under green certificate, when power is selling to the market directly, the revenues are not sufficient under green certificate for the power producers to compensate the low market price they receive. The scheme is riskier as well compared to PPA and FiT (AURES II 2021_a). The scheme does not support deploying high level of electricity from RES (Haufe & Ehrhart 2015). According to Dubois et al. (2013), the dominance of major electricity producers might diminish market efficiency within the framework of green certificates. Poland shifted its RES production away from the green certificate scheme with the aim of reducing the required support for the expansion of renewable generation. This move was intended to bolster RES capacities that might struggle to compete with larger wind or PV installations, thereby enhancing market participation and diversifying actors involved (Szabó et al. 2020).

4.1.8 Renewable Energy Certificate Trading

Boomsma et al. (2012) mentions that renewable energy certificate tradings are sanctioned to the producers who produce power from renewable sources in proportion to the generated and traded power when portfolio canons or quotas compel suppliers or consumers to yield or use certain share from RES and reveal amenability with an obligatory numeral of certificates. In comparison, the authors mention FiT and renewable energy certificate trading as the most extensively used support mechanisms, both of which have uncertainty. FiT is more effective in stimulating renewable electricity investments compared to when facing high market risks under certificate trading.

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[60] https://www.kyos.com/faq/green-certificate/

After examining various literature sources in section 4.1, the author aims to consolidate the benefits and drawbacks of different renewable energy (RE) support mechanisms such as FiT, FiP, quota systems, tax incentives, PPA agreements, negotiation tenders, and RE certificate trading. This summarized information, presented in *Table 5*, offers readers a concise overview.

***Table 5** Advantages and Disadvantages of the RE Support Schemes*

Name of Support Scheme	Advantages	Disadvantages
FiT	❖ Administrative & subsidy-based mechanism; ❖ Good for less competitive and less mature market; ❖ Suitable for small scale RE projects and individual RE production; ❖ Ensures payment guarantee for project developers for a fixed period; ❖ Suitable for individual level expansion	❖ Not enough cost-effective for chasing higher RE target; ❖ Does not have sufficient capability to initiate liberalized energy market/power market development; ❖ Cannot create enough competition and seek for higher support cost; ❖ Not fit for setting perfect value & viable RE tariff; ❖ Complex for small & distributed finance; ❖ Lack of efficiency; ❖ Cannot eliminate price risk; ❖ Under control budget, cannot give adequate support; ❖ Reaction level is low when RE price changes; ❖ Mostly suitable for solar PV; ❖ Not suitable for robust RE deployment;

Name of Support Scheme	Advantages	Disadvantages
FiP	❖ Administrative/regulated fixed price mechanism; ❖ Suitable for less sporadic RES like hydro & biomass technology; ❖ Payment guarantees for project developers for a fixed time; ❖ Regulator set price and market actors set quantity	❖ Costly policy for higher payment level; ❖ Not suitable for robust RE deployment and liberalized RE market; ❖ Not too effective for higher sporadic technology like solar or wind; ❖ More financing is required; ❖ Ensure lowest level of revenue; ❖ Income of the investor is not fixed like FiT and depends on System Marginal Price (SMP); ❖ Riskier for the lack of purchase guarantee; ❖ Complex for small & distributed finance
Quota	❖ Good for starting stage of RE production; ❖ RE target can be achieved in a cost-effective way	❖ Far from market reality; ❖ Large scale RE deployment is not possible; ❖ Overall cost is higher than that of FiT; ❖ Market oriented low-cost energy cannot be produced by this scheme; ❖ Complex for small & distributed finance
Tax Reduction/Tax Credit	❖ Suitable for rooftop solar technology	❖ Reduce tax collection of the government; ❖ High/utility-scale RE deployment is not possible; ❖ May create unfair level playing field in RE market for long time tax credit; ❖ Complex for small & distributed finance

Name of Support Scheme	Advantages	Disadvantages
PPA	❖ Offers more revenues than that of auction scheme; ❖ Long-term PPA gets stronger price stability benefit and lower Weighted Average Cost of Capital (WACC)	❖ Risk is higher than that of auction (***for this, policymakers suggest an auction scheme***); ❖ Lack of competition and liberalized RE market may not be established; ❖ High number of PPA signing does not ensure enough incentive; ❖ Lack of transparence ❖ Depends on the regulations of the member states regarding GOs
Negotiation Tender	❖ Possible to negotiate freely the term and commercial conditions; ❖ Get competitive price (***but not as much as an auction scheme***)	❖ Not fully transparent; ❖ Efficiency depends on 'Benchmark' price; ❖ More inclined to corruption & nepotism and challenging; ❖ Depends on the country's political wind; ❖ Awarding is not possible when bidders face risk
Green Certificate	❖ Administrative strategy; ❖ Suitable for producing low portion of electricity from RES	❖ Market efficiency is reduced day by day; ❖ Riskier compared to PPA & FiT; ❖ Selling power in the open market, producers get lower market price; ❖ Relies on market scarcity ❖ Not convenient for high scale RE production
RE Certificate Trading	❖ Administrative mechanism; ❖ Extensive use like FiT	❖ High level of uncertainty; ❖ Less effective compared to FiT under stimulating investment and high market risk scenario

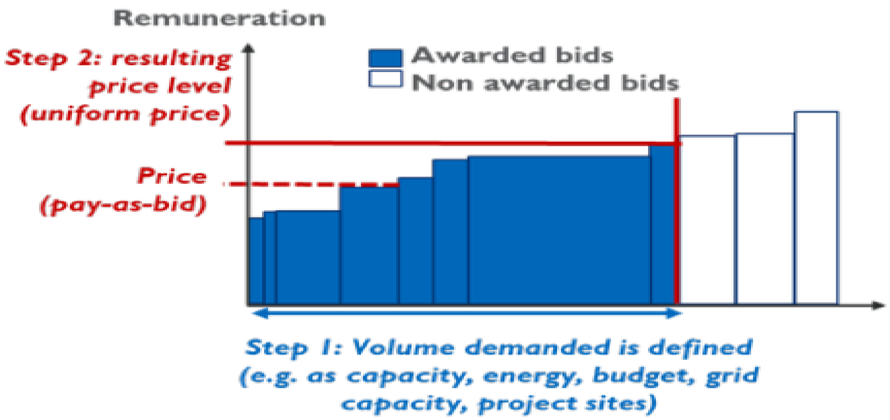
Source: Author's own creation analyzing literature

4.2 Renewable Energy Auction/Tender

RE auction/tender is a process that assists a country to acquire clean/green power at competitive prices. In this process, a government sets the rubrics and route for the purchasers and the suppliers. The sellers/suppliers of RE bid against each other for deals to generate power for the buyers where the buyers select sellers' offering power at the lowest price.[61] In other words, in the auction process, the government sets the auction volume that is demanded (step 1 in *Figure 8*). Bidders then propose prices and auctioneers place exuberant bids. The final price is determined based on either the ranked bids, resulting in a uniform pricing, or by the pay-as-bid (PAB) method, where each individual's bid is taken into account (step 2 in *Figure 8*) (USAID 2019).

The auction system for renewable energy (RE) projects is often considered economically vibrant because the compensation process is competitive, and the cost is usually close to the bidders' actual cost. This system allows for more efficient expansion of capacity. The regulatory body sets the quantity, and the project developers use a bidding system to determine viability (Bichler et al. 2020, Yalili et al. 2020, Kreiss et al. 2017, Mora et al. 2017, Held et al. 2014, del Rio & Linares 2014, IRENA 2013).

Figure 8 Price Formation of Auction



Source: USAID (2019), p. 5

The process is selected as a flexible process that requires policymakers of a country to adopt it considering the specific circumstances of a country, such as driving RE volume target. Policymakers are postponing FiT scheme due to its administrative procedure (AURES II 2020b). The auction scheme has the ability to balance between cost and effectiveness (Shrimali et al. 2016). The auction has demonstrated

[61] https://www.usaid.gov/energy/auctions/auction-explainer-video

effectiveness in achieving the intended auctioned amount and eliciting significant interest among developers. If the auction proves successful in terms of realization, the significant variance in support costs implies that the previously administratively determined FIT may have been inflated relative to the actual levelized cost of projects. The success of the auction in **fostering competition and obtaining more precise information on development costs** is evident (Bartek-Lasi et al., 2020).

Under the umbrella of the auction scheme, an RE project development follows four steps: planning, winner selection, construction, and operation (Botta 2019). According to IRENA (2019), the factors that impact the price resulting from auctions are (i) country specific condition; (ii) investors' confidence and learning curve; (iii) policies supporting renewables; and (iv) auction design. Kitzing et al. (2019) highlight that when there are budget and volume limitations, RES auctions can be a perfect mechanism for allocating support and the mechanism can achieve a remarkable short-run efficiency gain. They refrain from auction when (i) there might not be an expected reasonable competition; (ii) the project costs are predominantly indefinite for external aspects; and (iii) confirming local added value or actor assortment are being trailed.

de Rio et al. (2017) show that as a support scheme, auction **can cut support costs** by 5% compared to harmonization based on FiT and by 23% compared to FiP for EU in 2030. However, these savings are highly dependent on the market scenario of a specific country for specific technologies and the auction design pattern. When any RE project is commissioned timely, the auction is less costly compared to FiT and considering the cost-effectiveness as baseline tariff, the auction mechanism can save up to 58% from the baseline FiT (Shrimali et al. 2016). Supporting the cost saving issues, Botta (2019) mentions that auction design features can lead to judicious upgrading in financing cost by letting down the cost of equity between 0.5% and 1.5%. Therefore, the auction scheme **can persuade reinvestment in RES** without unreasonable extra costs for end users. Compared to fixed FiT and FiP, the auction has potentiality to lessen remuneration which requires to avoid overcompensation; but here the condition is that the auction must be designed and implemented perfectly (Bichler et al. 2020, Mora et al. 2017, del Rio & Linares 2014, de Vos & Klessmann 2014). With its focus on **cost-effectiveness and addressing overcompensation concerns**, **the auction scheme is increasingly gaining traction** as it supplants other support schemes such as FiT/FiP.

Hansen et al. (2020) suggests that to support large scale RE development, auction-based (tender) scheme is well accepted compared to previously used instruments like FiT and quotas because *"it can activate a vicious circle where slower deployment results in slower technology learning that, in turn, would lead speculators to wait longer to install capacity"* (Botta 2019, p. 06). In the case of India, Shrimali et al. (2016) claim FiT has less deployment experience compared to auction. They indicate three main objectives for implementing auction scheme for deploying energy from RES — (1) competitive and policy goals are achieved in a cost-effective way; (2) auction helps to enhance the deployment of RE; and (3) policy goals are achieved in an equitable way. Nevertheless, they identify some auction design risks such as flawed tariff determination method, lack of competition, technology neutral auction, and contact re-negotiation. From their perspective, **auctions are deemed more advantageous compared to FiT and quota** schemes, especially concerning the implementation of large-scale renewable energy projects. However, due to the competitive nature of auction, developing countries are joining the trend of low-price level subsidy free auction scheme (Martin et al. 2020).

IRENA (2013) and IRENA (2017) highlight some advantages and disadvantages of auction mechanism:

Advantages

- Cost efficiency due to price competitiveness
- Useful to establish competitive pricing
- High investor security linked to long-term PPAs
- Useful for volume and budget control
- Increase the predictability of RE-based electricity supply if the auction is well-scheduled
- Helpful to achieve other policy objectives

Disadvantages

- Discontinues market development (stop & go cycles)
- Relatively high risks of not winning a project for high investment cost for bidders
- Underbidding risk

Marinescu (2020) states that in the primary stage, different types of strong policy support including investment subsidies, soft loans, tax incentives gave back up for the expansion of renewable energy overall, and it started from early 2015. A competitive mechanism based on market named 'Auction' replaced FiT for maximum RE installation projects. Only small RE-based power plants are still getting benefits from the FiT scheme. Marinescu argues that due to the side effects of **economic crisis**, the favorable supporting mechanisms were cutbacks consecutively for the robust growth of RE by the policymakers, especially by the EU leaders and attention is thrown to the **more cost-effective auction scheme replacing FiT and green certificate**. AURES II (2020_a) supports the statement of Marinescu (2020). It says that FiT remains in place for giving the support of smaller-scale RES projects but for the robust RES deployment and for meeting the climate target, auction is a best route as support mechanism. In facilitating the establishment of large-scale renewable energy (RE) power plants, **auction techniques prove more advantageous when compared to FiT and green certificates**. Szabó et al. (2020) say auctions serve as efficient mechanisms for tracking the cost reductions of Renewable Energy Sources in Electricity (RES-E) technologies as opposed to administrative procedures such as Feed-in Tariff schemes. Numerous countries, including Denmark, Hungary, and the UK, have demonstrated noteworthy cost reductions upon transitioning from conventional, administratively driven support schemes. Additionally, the adaptable nature of auction design enables policymakers to tailor them to the specific circumstances of their respective countries.

Butler and Neuhoff (2008) made a comparison between FiT with quota and auction scheme as a support mechanism for deploying wind energy in the UK and Germany and they mention that **FiT cannot cultivate enough competition in the RE market**. Couture and Gagnon (2010) focused on the market-independent policies rather than market-dependent policies due to their higher strength, cost-effectiveness, higher investment security, and lower cost of RE deployment. The mentioned features are more associated with auction than FiT.

For setting of the remuneration of RES-E projects, auction scheme is regarded as a useful alternative of other support schemes. The scheme has been implemented or on the way to **be implement for the expansion of RES** either as the main support scheme or for specific technologies by replacing existing support schemes like FiT, FiP, green certificate, PPA, renewable energy certificate trading and negotiation is aimed to lessen cost of support and identify the 'best' suppliers for renewable energy by the EU and non-EU countries (AURES 2015). Supporting this statement, Botta (2019) and IRENA-CEM (2015) state that renewable energy auction scheme is treated as a **hybrid instrument**, i.e., price and quantity both are fixed prior to the initiation of the project via a bidding process. More elaborately, it can be said that the process ensures a 'stable revenue guarantee' for the project inventors, which is analogous to the FiT mechanism, simultaneously it is able to meet the RE generation target precisely similar to a renewable purchase obligation (RPO)[62] and FiP. So, auctions are **positioned more favorably compared to RPO and FiP** in providing revenue assurance to investors.

Analyzing the **effectiveness of auction** and making a comparison between the auction, FiT, and FiP, IRENA (2013) says that after following the competitive auction process, FiT and FiP are found overpaid compared to auction pricing. The report also says that as auction scheme focuses on the deployment of volumes, the lack of budget for capital support does not hamper chasing the target that may occur for FiT and FiP. Policy instruments, namely FiT, quota-based subsidy scheme, tax incentives, or grants are complex for small and distributed finance for the transition to green energy (Polzin & Sanders 2020, Curtin et al. 2017). Polzin and Sanders (2020) claim that wind farms and utility scale solar PV have low operational, market, and regulatory risks, as well as stable cash flow and low risk profile.

Blazquez et al. (2016) claims that successful infiltration of RE could fall victim to its own success in slackened power markets, enhancing the cost of future positioning of renewables and lessening their scalability and the situation is mentioned as the 'renewable energy policy paradox'[63]. The authors criticized that when the generic RE promoting financial instruments like FiT or bilateral PPA, FiP or a production tax credit and direct subsidy for critical investment are instigated in the markets with declining, but more unstable prices; so is the case in the electricity markets with high dispersion of renewable technologies: the outcome will be either less deployment than anticipated at first or more expensive policy support.

While fostering competition and promoting competitive pricing in RE, providing accurate development cost data, establishing RE power markets, ensuring cost-effectiveness, avoiding overcompensation, and supporting robust RE deployment to meet specific targets within set timelines are essential goals. Auctions represent a lucrative market-based mechanism compared to other support schemes and this motivates the author to examine auction techniques and analyze further various auction features sourced from multiple literatures.

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[62] An obligation mandate to purchase minimum level of RE out of the total consumption by the obligated entity.

[63]The renewable energy policy paradox is that the same market design and renewables policies that led to current success become increasingly less successful in the future as the share of renewables in the energy mix grows.

4.3 Auction Design Features

Under the current state of art of renewable auction/tender, this section explains the auction pricing types, technology neutrality, long-term planning for auctions scheme and auction's contribution for the local development.

4.3.1 Types of auction pricing

For overcoming the 'renewable energy policy paradox' situation, the Blazquez et al. (2016) suggest auction (more specifically pay-as-bid auction[64]) for alternative price setting mechanisms as of receiving actual bid for each market generator, again up to the uppermost market clearing bid.

In the arena of RE auction, **pay-as-bid pricing mechanism** is the most common approach. By pay-as-bid (PAB) pricing rule, auction bidders pay their reported demand for each unit they obtain, and winners are awarded the remuneration for which they bid (Haelg 2020). PAB implementations are typically seen as a means to minimize costs, offering bidders no more than their bid, which is supposed to be the minimum required for developing the renewable energy project. These give these schemes a much wider appeal from a social and political standpoint. The **cost-effectiveness** of the auction mechanism tends to be an important driver behind the widespread adoption of PAB pricing (IRENA-CEM 2015). This pricing may favor more financially viable projects with a higher likelihood of on-time implementation (Shrimali et al., 2016). Renewable energy projects implemented by Argentina, Hungary, Mexico, Portugal, and Ukraine have followed pay-as-bid pricing rule in auction features (Anatolitis & Grundlach 2020, Bartek-Lesi et al. 2020, Menzies et al. 2019, del Rio 2019, del Rio et al. 2019). Considerably, **price-only** award criteria lead to lower bid prices than multi-criteria auctions. They may nevertheless **protect underbidding**. On the contrary, additional award criteria do not necessarily favor the lowest bids and may rather lead to higher bid prices (AURES II 2021$_b$, IRENA 2016).

Linking with the PAB pricing rule, the predominant auction approach across the case studies was the **static, sealed bid method**. This involved participants submitting bids for either a single price or volume (capacity or energy) without access to information about other bidders' prices or any interaction between competitors during the bidding process (Szabó et al. 2020). In a **static seal-bid auction**, all bids are

[64]In the pay-as-bid auction bidders pay their reported demand for each unit they obtain, while in the uniform-price auction all bidders pay the market-clearing price for each unit they obtain.

submitted simultaneously, and bidders are unaware of the prices being offered by other participants. This type of auction is often preferred by government agencies due to its simplicity. Additionally, static seal-bid auctions are less prone to collusion, which is the coordination of bids by participants in order to drive prices higher and exclude other bidders. They are also less likely to result in harmonization among bidders compared to dynamic auctions (USAID 2019). According to IRENA-CEM (2015), the supply and demand curve in a static seal-bid auction can be matched due to the simplicity and low transaction costs of this type of auction. This encourages smaller players to participate in the process. In addition, earlier statements indicate that the supply and demand curves are known in this type of auction (GIZ 2015, Held et al. 2014), which is also supportive for the early auction. Argentina, Mexico, Ukraine, Hungary, and Spain have followed static seal-bid bid auction type with PAB pricing rule (del Rio & Menzies 2021, Anatolitis & Grundlach 2020, Bartek-Lesi et al. 2020, Menzies et al. 2019, del Rio 2019). According to Maurer and Barroso (2011), static seal-bid auctions are straightforward and have lower participation costs because they are easy to understand. This makes them a good choice for countries that implement auctions for the first time.

Again, the **ceiling price** is a maximum price above which bids will be disqualified. The presence of ceiling prices in auctions serves to intensify competitive dynamics while also constraining potential auction results, aiding bidders in their determination of whether or not to engage in the bidding process. Disclosing the ceiling price to bidders in advance prevents otherwise qualifying projects from being rejected simply because bidders did not know the ceiling price. The disclosure of the ceiling price also gives bidders more planning security and reduces allocation risk (AURES II 2021_b, USAID 2019). The ceiling price allocation process can prevent excessive prices and may prevent collusion and price manipulation. High ceiling prices attract more participants, though potentially weaker ones. This process can help the government to acknowledge upfront that there is a risk whether the auction scheme fulfills its intended role (achieve low cost) or not (Gephart 2017, del Rio 2017, IRENA-CEM 2015). The auctioneer needs to decide whether the ceiling price should be disclosed prior to the auction. Full disclosure tends to involve a slightly greater degree of transparency, but limited competition may result in bids that are just below the ceiling price. Maintaining the ceiling price undisclosed can result in disqualification of otherwise sound bids that are only slightly higher than the ceiling price. By introducing a ceiling price, there is an upfront acknowledgement of a risk that the auction scheme may not fulfill its intended role of achieving low prices and that; as a result, the auctioned volume will not be fully contracted. In South Africa, the disclosure of the ceiling price combined with the lack of a strict volume cap resulted in high prices. The subsequent rounds, with undisclosed ceiling prices and well-defined volume caps, led to significantly lower prices. The intense competition in the Indian auction meant that the "anchoring" caused by the disclosed price caps was of little concern (IRENA-CEM 2015).

Renewable energy (RE) generators can sell energy directly in a country's wholesale market through a remuneration type known as a **contract for differences (CfD)**. CfDs entail that generators must reimburse any disparity between their agreed-upon price and the prevailing market rate, should the market rate prove to be lower. Sliding FIPs come in two forms: symmetric, also known as two-sided CfD, and asymmetric, or one-sided CfD. A symmetric sliding FIP, akin to a two-sided CfD, offers developers maximum revenue security by fully insulating them from market exposure risk and the participants bid for a discount (%) from a given tariff level. Conversely, an asymmetric FIP, in contrast to its symmetric counterpart, results in reduced levels of guaranteed revenue (AURES II 2021_b). These generators are also able to participate in ancillary services and harmonizing markets. CfD auctions provide zero premium payments, enabling generators to engage in the market without relying on public subsidies, thus conserving public funds. Although CfDs may include a premium portion if market prices are exceptionally low, currently, amidst high price conditions, no premiums are being paid. However, historically, premiums were paid during earlier periods, and there remains the possibility of their reinstatement if prolonged periods of low or zero prices persist in the future. Neuhoff et al. (2018) mentions in the context of a CfD that participants are expected to propose a price range that reflects their LCOE while considering the anticipated market value. In the case of the sliding premium on CfD, the premium is determined by the average electricity price, shifting the risk to the regulator (Ragwitz et al., 2012). Moreover, the price risk associated with the sliding premium is considered to be minimal (Noothout et al., 2016).

4.3.2 Technology neutrality

Technology-neutral RE auctions are competitive bidding processes without any formal restrictions on the participation of available technologies, in which neither negative nor positive technology-specific discriminatory rules exist. This design (1) minimizes generation cost; (2) ensures compliance with applicable regulation demand-no technology discrimination; and (3) encourages more actors to participate as more technologies are included. Finally, if the aim of auction is to minimize costs, a technology-neutral auction can be initiated, allowing competition between technologies, therefore favoring the more mature and cost-competitive one (del Rio 2017, Mora et al. 2017, Wigand et al. 2016, GIZ 2015, IRENA-CEM 2015). As per RE auctions toolkit by USAID (2020_a), a recent example of this type of auction, which uses bidding on premiums to renewable generators selling into the wholesale electricity market, is the successful technology-neutral auction held in Finland in 2019. In this auction, 1.36 terawatt hours (TWh) of energy was contracted at an average premium of €2.51 (2.95 USD) per TWh. "*In 2017, Chile introduced technology-neutral auctions that included both conventional and RE plants. Bidders bid into hourly and seasonal time blocks, reflecting different power system needs. This design enabled RE projects to win 100% of the offered capacity*" (USAID, 2019; p. 15). The report also says that technology neutral auction deals for lowest generation cost, deducting windfall profits by removing incentives and more competitive bidding with less lavish technology. Furthermore, Creti et al. (2016) place emphasis on technology diversified auction that promotes diversified energy mix, which is an essential feature of a reliable system.

In 2019, Finland held a technology-neutral auction for 1.36 terawatt hours (TWh) of energy, with an average contracted premium of 2.51 EURO/TWh. RE developers competed in this auction using a **PAB (pay-as-bid)** system (USAID 2020a). The system offers suitable economic signals and aligns with the functioning of the forward and future markets anticipated to arise.[65] Pay-as-bid auctions however typically not used for two-sided auctions as day-ahead electricity auctions in the electricity industry, but rather for one-sided auctions as cross-border capacity auctions (Csercsik, 2020) whereas the **PAC (Pay-as-clear)** principle operates on the premise of the market clearing price (MCP). Under this principle, standard hourly bids are accepted based solely on the MCP, with payment determined by the MCP rather than the bid price. The MCP is typically computed to optimize total social welfare (TSW), which is the aggregate utility of consumption minus production costs (Madani, 2017). However, due to non-convexities, a uniform MCP may not always be attainable, leading to the occurrence of paradoxically rejected block orders (Madani, 2014). Further, PAC is useful for the sufficient competition in the electricity market.[66]

[65] https://www.ofgem.gov.uk/sites/default/files/docs/2012/10/pay-as-bid-or-pay-as-clear-presentation.pdf
[66] https://www.ofgem.gov.uk/sites/default/files/docs/2012/10/pay-as-bid-or-pay-as-clear-presentation.pdf

On the contrary, the use of fixed premium remuneration, also known as a form of support auctioned, can reduce bid prices in an auction due to the guarantee of constant revenues. This decreases the risk of premium and cost of capital (CoC) for participants. It also encourages competition, as both small and large players are likely to participate in the auction (del Rio 2017, Förster & Amazo 2016, GIZ 2015). It is mentionable that in case of fixed premium, bidders get a fixed amount of premium payment.

4.3.3 Long-term planning

Long-term schedule for **regular/systematic auctions** lessens the risks of investors, which improves the financing conditions and reduces RE generation cost, in addition, regular auctions encourage participation in the auction. The literatures show that regular/systematic auction alleviates the risk of underbidding, and it smooths the widespread expansion of the supply chain in that the equipment manufactures can set their venture strategy consequently (del Rio 2017, Fitch-Roy 2015, del Rio & Linares 2014). Along with the previous statement, AURES II (2021_a) states that a higher auction frequency can bring a result of lower WACC[67].

Systematic auction schedule decreases risk and increases investors' confidence, reduces bid prices, encourages technological progress, thereby reduces technology prices, prevents underbidding as bidders do not need to bid aggressively in a given round to secure a contact, gives room to the potential investors to enter into the market, and follows a learning by doing process (Guadarrama 2018, Hochberg & Poudineh 2018, Mora et al. 2017, IRENA 2016, Wigand et al. 2016, IRENA-CEM 2015). For improving the long-term planning among project developers, well-made auction occurrences are considered (Dukan & Kitzing 2021, IRENA-CEM 2015). For example, the National Solar Mission in India aimed to support the development of the solar power sector and committed to a systematic auctioning scheme. Between the first and second round, the total capacity offered in the bids increased by 100%, the percentage of projects installed in a timely manner increased from 89% to 100%, and the price dropped by 28%. In California, four auctions were planned from the very beginning to be carried out in the timespan of two years, with predetermined demand levels (although those quantities were later revised upwards). In Germany, one of the

[67]The weighted average cost of capital (WACC) is the average rate that a business pays to finance its assets. It is calculated by averaging the rate of all the company's sources of capital (both debt and equity), weighted by the proportion of each component.

main features of the newly designed auction is longer-term planning and a pre-commitment to a schedule. Nine auctions were planned over the course of 2015-2017. The reason for having a systematic auctioning scheme is to ensure a continuous renewable energy project pipeline, while, at the same time, to test different design elements in different auction rounds (IRENA 2017, IRENA-CEM 2015). For reducing the projects' levelized cost of energy (LCOE) and bid price, a long-term contract is an important tool (Apostoleris et al. 2018, Lilliestam & Pitz-Paal 2018). This contract design feature lessens the investment risks and CoC (Lilliestam & Pitz-Paal 2018, Förster & Amazo 2016, Wigand et al. 2016, GIZ 2015, IRENA-CEM 2015) and enhances competition (GIZ 2015). **Long term contract or support period** expands the confidence of the investors (del Rio 2019, del Rio 2017). The support period varies from 10-20 years. 20 years is good for risk minimization and enhancement of the bankability of the project (IRENA-CEM 2015). Reducing competition can be achieved by modifying the auction volume in accordance with the project pipeline across multiple auction rounds (AURES II 2021_b). However, different reports of AURES II under the literature review part found a 15-year support period.

4.3.4 Contribution of auctions to local development

For local industrial development, RE auction scheme may be seen as an opportunity and for this, policymakers need to focus on the localization of production activities (Hansen et al. 2020, Bayer et al. 2018, Hochsteller & Kostka 2015). The Argentinian RE projects that source more than 60% of the equipment and electro-mechanic components locally were eligible to receive tax credits equal to 20% of the amount of equipment purchased locally (Menzis et al. 2019). Hansen et al. (2020) treated **local content requirements** (LCRs)[68] as a focal tool in RE auction schemes motivating local industrial development by specifying the use of locally produced content. Mentioning the Brazilian case, they claim that if the domestic steel industry is well-developed, it can contribute a congenial atmosphere as a steel supplier for producing steel turbine tower. del Rio (2017) mentions that for making LCR effective, a minimum level of domestic manufacturing capability might be needed, and the auctioneer should overview the local technological market. For manufacturing equipment of RE technologies on the relevant future market

[68]LCRs define as the percentage of the total project cost secured locally through both equipment and services along with locally produced components, civil engineering work and consultancy fee (IRENA 2013, Hansen et al. 2020). According to UNCTAD (2014), LCR typically falls under specific laws or regulations, obligating foreign investors and companies to meet a minimum threshold for acquiring goods and services from local sources.

size, capacity-based volume auction is highly preferable, and it can encourage innovation and supply chain improvement (del Rio 2017, del Rio et al. 2016). Numerous nations incorporate design elements that encourage smaller actors' participation or involve local communities in project ownership. These measures aim to enhance competition levels and promote social acceptance of investments in renewable energy (Steinhilber & Soysal 2016). Projects awarded in Morocco have reported the benefits achieved due to the inclusion of socio-economic development goals as qualification requirement. Morocco's 'Noor-Ouarzazate' RE project consisted of four phases. Phase-I indeed sourced 30–35% of the project cost in local components and services. Throughout the four phases, 70% i.e., 6,430 Moroccans were employed and a third of the jobs were sourced locally from the region of Ouarzazate. Yet again, 'Renewable Energy Independent Power Producer Procurement Program (REIPPPP) in South Africa consisted of seven rounds that attracted 14.64 billion USD by March 2019. When it comes to local content, **3.27 billion USD were spent locally out of total spending of 90.3 billion USD. In terms of job creation, the REIPPPP has created a total of 40,134 job-years for South African citizens. The procurement was surpassed with local equity shareholding across all around reaching 52%**. The REIPPPP contributes to Broad Based Black Economic Empowerment (BBBEE) and the creation of Black industrialists and Black South Africans means owning on average 33% of the projects (IRENA 2019). In the Canadian context, a prerequisite in the second round involved guaranteeing a minimum of 25% equity ownership by indigenous individuals, a condition that had to be upheld for a duration of at least three years (Menzies et al. 2019).

LCR has a contributory role in NIMBY syndrome. In this connection, del Rio (2019) argued for local community support. Botta (2019) argues that for reducing/abolishing the "not in my backyard" (NIMBY)[69] syndrome, there is an obligation to offer a fixed percentage of project shares to local residents. This step not only mitigates the risk but also ensures financial gains to promote RE and expands support. Formulating a suggestion, AURES II (2021_c) states an obligation to provide a

[69]Nimby is a characterization of opposition by residents to proposed developments in their local area, as well as support for strict land use regulations. It carries the connotation that such residents are only opposing the development because it is close to them and that they would tolerate or support it if it were built farther away. The residents are often called Nimbys, and their viewpoint is called Nimbyism [https://www.rechargenews.com/transition/the-six-paradoxes-slowing-down-the-energy-transition/2-1-732488].

strategic plan with estimation on the impact of the installation on the local employment and industrial value chain.

Kuntze and Moerenhout (2013) point that LCRs can also function as a valuable political instrument for attaining legitimate environmental objectives, especially within the renewable energy industry. Nations incorporating LCRs in this field encompass Brazil, Canada, the United States, South Africa, and various others. The discourse surrounding LCRs in this context implies that substantial financial backing for renewable initiatives may not garner public support without corresponding local advantages. This field is exceptionally intricate, as it must address the dual task of accomplishing climate change mitigation on one front and ensuring energy security on the other (IEA— World Bank 2013). However, while there are apparent advantages associated with these policy objectives, the detrimental consequences of LCRs often surpass their immediate advantages over time.

Linking with the LCR feature, in a **location/site-specific auction**, the government selects the project site and may partially or fully pre-develop it. The government sets a target volume for the auction and bidders compete for the right to construct their projects at the chosen site. This type of auction can improve coordination between project construction and necessary grid expansion, and it can also reduce risks and costs for bidders. However, if the pre-development work is not done properly, it could negate these benefits. For example, in Zambia's first auction round, problems with the project sites selected by the government resulted in additional development work after the projects were awarded (USAID 2019). Site-specific auction probably reduced risk and transition costs for producers, which were reflected in the lower price level (AURES II 2021_b, del Rio et al. 2019). Furthermore, the auction was organized in specific areas with very good RES and after an extended time without a scheme, the demand was higher. Portuguese 1400 MW capacity auction and Mexican auction were implemented in this way (del Rio et al. 2019, del Rio 2019). This feature helps bidders by lessening uncertainty and obtaining good regional/local development. Referring to the Mexican scenario, del Rio (2019) suggested the country government developing the project site. Otherwise, due to land regulation/permission procedure, the project might be delayed. Mentioning some country-specific examples, Szabó et al. (2020) says that off-shore wind initiatives, which are typically site-specific auctions, have recently demonstrated significant cost reductions in the UK, Denmark, and Germany.

Furthermore, in the Netherlands, the most recent projects necessitated no external financial assistance.

4.4 Risk and Efficiencies of Auction Schemes

The recent trade-off between effectiveness and efficiency, to drive the effectiveness of the auction scheme, **pre-qualification** and **penalties** perform as influential implementation instruments for a higher realization rate (Matthaus 2020, Gephart et al. 2017). These two features of auction scheme can improve the administrative procedures for volume-based generation (del Rio 2017). **Auction volume** can be defined in terms of capacity (MW), generation (MWh), or budget (million EURO/USD). So far, **capacity caps** have been the most common (Kitzing et al., 2019). A high auction volume may attract additional actors to take part and thus upsurge competition, and accomplish lower prices (Schmidt et al., 2019). "*Many believe that because attractiveness for developers is strong, larger amount of electricity should be auctioned. Large projects would have fared well due to their more favorable economics of scale"* (Bartek-Lesi et al. 2020, p. 20). AURES II (2021_b) suggest avoiding too big or large volume auction for maintaining competition. AURES II (2021_c) also suggest capacity volume; but highlight delivering a minimum amount of energy every year. According to IRENA-CEM (2015), for experiencing wild energy growth and speedy capacity adding in any economy, volume auction is highly acceptable. However, target setting must be collaborated with government policies for RE deployment and technical capabilities of the existing system to absorb the RE. There are three ways to determine the auction volume: (1) under a fixed volume method; (2) in a price-sensitive demand curve mechanism; and (3) in a multi-criteria volume setting method. Among the three ways, the first one has been the most common option implemented worldwide and seems to be reasonably functional. Fixed volume approach is beneficial for its simplicity, transparency, and offering guidelines to the bidders. Furthermore, a **multi-unit auction** format is highly recommended when the effectiveness of the project or actor diversity is prioritized, and when the auction volume is distributed to more than one project developer, it reduces the non-compliance risk of the project (del Rio 2017). This feature improves both cost-effectiveness and deployment-effectiveness by boosting competition and differentiating developer-specific risks (Shrimali et al. 2016). According to Szabó et al. (2020), auctions contribute to **dynamic efficiency** by fostering the advancement and cost reduction of emerging technologies, thereby facilitating their gradual adoption over time. Given that most nations are striving to meet their renewable energy objectives at minimal expense, and numerous technologies have already attained significant deployment levels, auctions play a crucial role. Moreover, achieving **static efficiency**, (also known as efficiency gain) entails fulfilling predetermined targets at the lowest feasible overall cost. Estimating this cost floor is challenging due to various factors beyond auction design, such as market prices, balancing and system integration expenses, and forecast obligations, all of which can influence auction bid prices. Several EU case studies have highlighted efficiency gains in terms of contracted prices or discounts secured during the period spanning 2016 to 2020 compared to preceding periods.

Prequalification requirement lessens actor diversity, and it is considered as an essential tool for ensuring the quality and realization of the support project (AURES II 2021_a, Menzies et al. 2019). Putting emphasis on prequalification requirement for encouraging a high level of competition in auction scheme, AURES II (2021_b) and Menzies et al. (2019) placed focus on **bid bond** and **performance bond** as a prequalification requirement criterion in the auction feature. Bid bond is basically a financial form of a bank guarantee. It ensures to meet the contractual obligations and it is included for the guarantee of the potential payment of the penalty. If the bidder wins the award but the project is delayed or remains incomplete, the payment will not be refunded. On the contrary, performance bond assists to sustain the realization schedule and project standard for the project developers. It is refundable to the bidders. Sometimes performance bond is not loyal for the small actors. Bid bond acts as a confirmation of land ownership and grid connection agreement, lowering the possibility of project non-realization and protecting strategic fake bids (Anatolits & Grundlach 2020). Matthäus (2020) suggests regulators to impose financial pre-qualification in the auction design as the form of bid bond for aiming high realization rate of the project and more sustaining bids. As too much bid bond enhances qualification risk for small bidders, bid bond and performance bond should be lowest/minimum per megawatt (MW) for expediting the competition in the early auction (AURES II 2021_b, Anatolits & Grundlach 2020).

The project report of AURES II (2021_b) highlights that pre-qualification criteria pertain to the **essential project documentation** necessary for potential bidders to engage in an auction. This usually encompasses a comprehensive project overview, confirmation of grid access, land ownership verification, and environmental impact evaluations. These criteria serve to enable bidders to offer more accurate pricing by providing insights into site-specific conditions and associated expenses. Moreover, they enhance the probability of successful project completion for awarded contracts. Furthermore, **strict material requirement** reduces competition but increases realization rate. In the initial stage, lenient material requirement is suggested for balancing realization rate and competition (IRENA-CEM 2015, IRENA 2013). It is imperative for governments to give greater emphasis and dedication to monitoring and disclosing realization rates (Szabó et al. 2020).

Design elements such as **penalties for failure of commissioning of projects** help in two ways — firstly, manage underbidding risk; and secondly, establish cost and deployment effectiveness and the auction can be said a successful one (Shrimali et al. 2016). In addition, for proving the seriousness of the bids and participating in the tendering process, penalty should be imposed (Held et al. 2014). It also helps to prevent the risk of underbidding (Rosenlund & Jaana 2016, IRENA-CEM 2015). AURES II (2021_b) proposed imposing gradual and proportionate penalty based on the extension of commissioning delay of the RE project. On the other hand, the report focused on avoiding unrealistic completion time as it creates a high risk for paying a penalty. Comfortable accommodating lead time to submit a bid helps bidders to reduce uncertainties and attracts more bidders. Sometimes it facilitates speculating the equipment prices (Hochberg & Poudineh 2018, del Rio 2017, IRENA-CEM 2015, del Rio & Linares 2014). Simultaneously, when the project developers get a **long lead time** to realize the projects, the project developers can negotiate with the manufacturers, which requires low bid prices (Debrotkova et al. 2018) and lower risks from delayed projects and corresponding penalties (Hochberg & Poudineh 2018). Further, **counterparty** refers to the entity (such as a national government or utility) that receives the remuneration. Having a trustworthy counterparty enhances investor trust, leading to lower bid prices due to decreased risk premiums (IRENA 2017, IRENA-CEM 2015).

An **international support** (like World Bank) may initially help a country to implement an auction scheme for reducing financial costs and participation risks that may lead towards higher completion levels and lower bid prices. Auctions should be tailored perfectly, where LCR, prequalification requirements, and penalties should be included. Nevertheless, it should be remembered that good auction tailoring does not need to defend developers from all risks, it rather escorts developers to evaluate the risks immersion in taking part in an auction. The steadier a certain policy outline around renewables is, the less menace is tangled for renewable inventors to endow in project development (AURES II 2021$_b$). Bid price might be higher when the contract is made by local currency because it diminishes the capability of the developers' for raising debt. Furthermore, risks and CoC are amplified due to exchange rate fluctuation (Dobrotkova et al. 2018, IRENA 2017, IRENA-CEM 2015). Although adjustment to inflation and indexation of currency reduce the risks of investment and bid (Förster & Amazo 2016, Wigand et al. 2016), globally it is practiced not to do any adjustments and to do the contract in USD. Under the contract transferability condition, the non-implemented projects or part of the projects might be apprehended by other actors. Sometimes contract transferability can condense the bid price as some actors want to take part in the secondary market and hence competition can be reduced (Gephart & Klessmann 2017). It is recommended that the first auction should not have any multifaceted structures like requirements for forecasting and reactive power compensation equipment. The leading purposes of early auction creators are testing investors' interest and risk allocation approaches, simple energy-only auction, and setting the baseline for price discovery (USAID 2020$_a$). These together will set the early frameworks of the auction design.

The author examined several pieces of literature under sub-head 4.2 and developed a SWOT analysis (*Table 6*) of the RE auction technique. The SOWT[70] analysis has a longstanding history as a tool for strategic and policy planning in economic contexts. Recently, it has also found application as a strategic planning aid in other sectors (Goffetti et al., 2018). To address the research question of this paper, which aims to establish an auction model with diversified paybacks for developing countries like Bangladesh, conducting a SWOT analysis of the auction scheme would be beneficial for policy planning and decision making.

[70]SWOT is an acronym for Strengths, Weaknesses, Opportunities, and Threats. A SWOT analysis is a strategy used by businesses for measuring and evaluating their overall performance, and that of competitors, in an objective manner. The first two parameters, strengths and weaknesses, involve internal factors and the other two, i.e., Opportunities and Threats, are related to external influences.

Table 6 *SWOT Analysis for Auction Scheme*

Strength	***Weakness***
• *Economical and cost-effective;* • *Static and dynamic efficiency;* • *Market independence & flexible mechanism;* • *Elicit interest among developers;* • *High level of transparency;* • *Balances cost and effectiveness;* • *Effective for high level RE deployment target;* • *Ensures competitive RE price;* • *Stable revenue guaranteed for the investors;* • *Works in volume and budget limitation condition;* • *Reduces/abolishes government subsidy;* • *Helpful to gain other policies*	• Underbidding risk; • High investment cost for the bidders; • Risk for not winning the bid; • Needs a specific number of bidders
Threat	***Opportunity***
• *Possibility of lack of competition;* • *If proposal is not granted, it may carry a higher risk for investors;* • *All selected projects may not be carried out;* • *Market power exercised by the market players*	• Local industrial development; • Creation of new market; • Local employment generation; • Encourages innovation and improves local supply chain; • Higher project realization rate; • Increases the ownership of local people to RE projects, which will help to get local support

Source: Author's own creation reviewing the auction-based literatures

For overcoming threats and weaknesses like 'lack of competition', international cooperation (such as support from World Bank), expanding the number of bidding body created by concerned government, disclosing auction volume, and 'ceiling price' auction feature may help. When there is a possibility of low competition, 'ceiling price' helps limit the risk of higher support cost. Higher risk for investors for not accepting the proposal, relaxed/lenient prequalification requirement and flexible penalty terms may help to overcome the situation. Carrying out all selected projects, prequalification requirements, imposing penalty, dialogue with bidders and international cooperation may help. Again, a higher number of bidders, variety of bidder and enhancing the bidding body created by the concerned government may remove the threat of 'market power exercised by market players' (del Rio 2017, Shrimali et al. 2016, Tiedemann et al. 2016, del Vos & Klessmann 2014).

The auction mechanism employed in renewable energy (RE) projects is frequently hailed for its economic vitality, owing to its competitive compensation structure that typically aligns closely with the bidders' actual expenses. This approach facilitates the more effective expansion of capacity. The reasons for adopting an auction mechanism their mentions are: enhancing competition among the developers, reduction of government information asymmetry, and more precise planning in relation to capacity, which is to be connected to the grid and budget expenditure. Further, renewable energy auction/tender scheme is a market-oriented mechanism where the agreed quantity of power purchasing deal is being settled by the direct interaction with the buyer and the seller at the lowest cost; but the auction design feature should be tailored according to the need of the specific country. As per the reviewed literatures under chapter four, other support schemes are the subsidized schemes and those are not fit for robust deployment of RE. The SWOT analysis of auction scheme identifies some overcoming paths for the threats and weakness of this scheme. Some country-specific examples are the perfect scenarios to overcome those threats and weaknesses for tailoring a time bound auction scheme. Following those would be a scope to design a fruitful auction scheme.

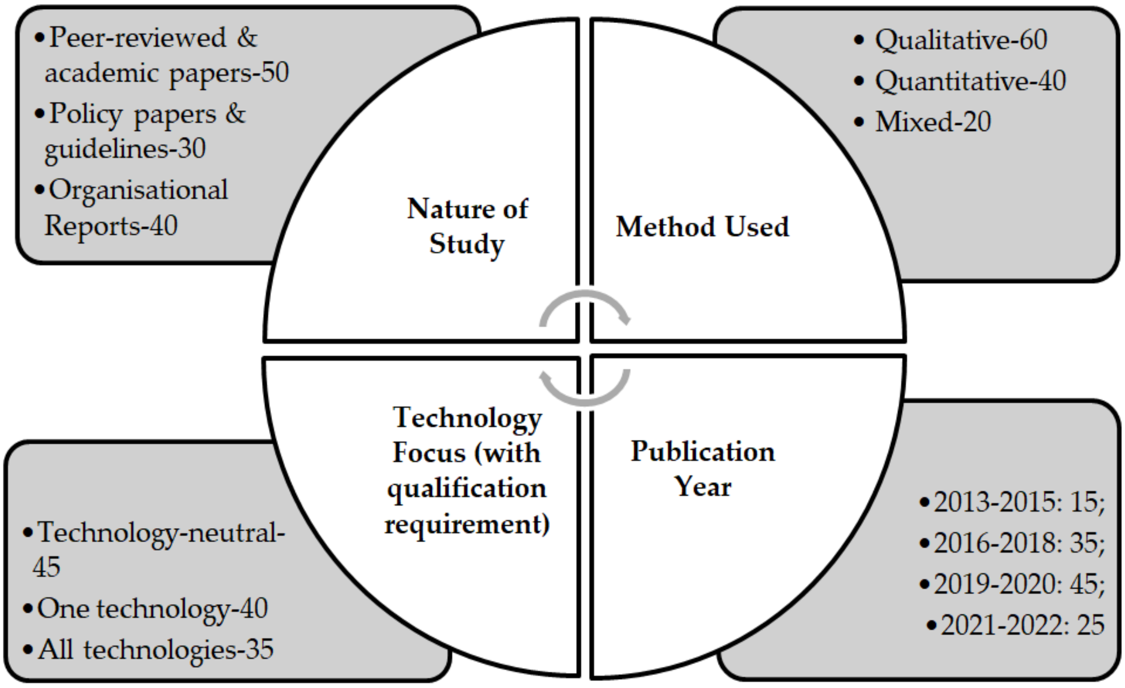
5 MATERIALS AND METHODS OF THE RESEARCH ON AUCTION MODELS

The research is both in qualitative and quantitative in nature. For the qualitative part, i.e., for testing the suitable auction design process, it has been a piloted systematic literature review focusing on three aims: first, to find out the potentiality of auction; second, to identify the design features of the auction and third, to find out the gains of the auction following some country-specific empirical evidence. For examining how auction is used in relation to cost-effective renewable energy deployment, a systematic literature review was completed, which comprised a reproducible search and applied explicit criteria for the inclusion and exclusion of studies (Sovacool et al. 2018). Based on the views of the Petticrew and Roberts (2006), a semi-structured approach was conducted.

In the abstract database Scopus, the peer-reviewed literature was poised assembling in a keyword search and ‘renewable energy auction design’ was the wide-ranging regulated hunted key. At the next step, snowball sampling round was trailed up for the cited articles in the preliminary phase (Cooper 1998). Furthermore, some country-specific policy reports, guidelines, organizational reports, and policy papers have been added here, which will help to give feedback about the literature of auction design and paybacks that were produced in a list of articles of 180 studies.

Out of these studies, highlighting a link among auction design, gains, and country-specific evidence, the list was compressed into 120 studies, summarized in *Figure 8*, which comprises the nature of study, its technology focus, its year of publication, and usage of method. Most of the studies were qualitative in nature. Based on the 120 studies, a compiled list was made concentrating on the features of auction design, auction pricing rule, technology specificity, location specificity, auction volume, and the outcomes of the auction. Specifically, how an auction design features with systematic schedule mingled with socio-economic development instrument under qualification requirement resulting diversified gains was searched by the qualitative screening of the studies (*Figure 9*). A complied matrix of auction was formed based on the reviewed literatures. Finally, a feasible auction scheme was formed for the developing countries like Bangladesh, highlighting the benefits of different auction features.

Figure 9 Compressed Qualitative Summary



Source: Author's creation based on the characteristics of articles

The literatures focused on the different sources of recent timeframes as the hype of the RE and the auction scheme mostly started after 2000's. Therefore, the qualitative part has been structured in this scenario as if the up-to-date insights could be underlined. The process followed above was conducted under the grounded theory of qualitative method.

Grounded theory is a qualitative research approach that allows the researcher to investigate a particular phenomenon or process through the collection and analysis of real-world data. This methodology can lead to the development of new theories that are grounded in empirical evidence.[71] Grounded theory is a methodology in qualitative research that aims to generate new theories and deductions through the analysis of data. The process begins with data collection through various means, followed by an analysis to identify key concepts. These concepts are then compared and used to develop preliminary theories, which are continually refined through further analysis until sample saturation is reached, meaning no new information challenges the theory. The researcher's interpretation of data is guided by the framework description, while the data

[71] https://www.google.com/search?sa=X&rlz=1C1GCEA_enBD1014BD1015&sxsrf=AJOqlzVTGHpTnkcnyvVD1B8OjWaUTF9QTA:1673654594787&q=What+is+grounded+theory+in+simple+terms%3F&ved=2ahUKEwj9_eSc4cX8AhWxl4sKHTgmDfYQzmd6BAgXEAU&biw=1280&bih=577&dpr=1.5

description is the researcher's method for organizing and structuring the data, as well as creating a conceptual model that can be compared to new observations (Glaser 1992, Strauss and Corbin 1990). According to the views of Bryant and Charmaz (2007), grounded theory, a methodology first introduced in the seminal work of the authors, emphasizes the generation of theory from data through an inductive process. This approach challenges the traditional method of deductively testing or refining theory and suggests that there may be alternative, valid ways of understanding the world, such as through the use of qualitative methodology.

Keeping in mind the renewable energy auction in the qualitative part, the author became interested in checking empirical evidence on whether the expansion of renewable energy is impactful positively or negatively on some selected variables (as a part of diversified gains) for some selected countries which are adopting auction scheme very recently to robust deployment of renewable energy (solar & wind). In line with the previous statement, it is mentionable that the author also tried to test the auction scheme on the renewable energy generation by the inclusion of auction as a dummy variable in the planned theoretical model. As the main motive of the auction scheme is to generate energy with low cost, the author intended to quantify the renewable (solar and wind) energy generation cost in Bangladesh as a sample (Bangladesh does not follow auction scheme yet) at the second phase of the quantitative part.

5.1 Theoretical Model

Firstly, under a quantitative segment for constructing the theoretical model, the paper has a focus on the postulation of a prolonged Cobb-Douglas function (1) pointing to the broad economic activity (Moyer et al. 2013, Thompson 2006) with capital (K_t), labor (L_t) and energy (E_t) plus damages (D_t) due to greenhouse gas (GHG) emission, which is indicated as:

$$Y_t = (1-D_t)\, A_t\, L_t^{1-\alpha-\beta} * K_t^{\alpha} * E_t^{\beta} \qquad \ldots\ldots\ldots\ldots (1)$$

Here, A_t is a technology-parameter reliant on time. All the countries in the European Union (EU) are shifting their economy towards green economy and for lowering the GHG to mitigate the D_t damages, they are picking up renewable energy sources (RES) for electricity by diminishing FF-based sources, highlighting the 'net zero emission target by 2050'. In connection with the target, the countries are practicing the RE auction scheme for robust deployment of RE; side by side reducing dependency on FF-based energy generation. D_t is elucidated and connected with the transition from FF-dependent energy to green energy sources, increased utilization of renewables, and the mitigation of CO2 emissions. For the sake of the theoretical model and quantitative analysis of the paper, the author has differentiated between globally and locally practiced variables and the author has selected some EU countries (such as Greece, Italy, Poland, Portugal, Romania, Spain) whose economies are open in nature, have close geographic similarities, coastal regions, allowing for a consistent load factor for planned solar and wind generation potentiality and has followed an RE auction scheme for the last few years to chase the net zero target. Furthermore, many nations have encountered debt crises at various points, affecting their ability to secure external funding. These countries represent the emerging economies within the EU.

In the model, the sovereign spread ($10Y_{i\text{-}US,t}$) variable is considered because capital accumulation (i.e., K_t) and funding scenario for the selected countries are extremely settled by the world market sentiment, which may be steered by the home-grown monetary policy. In this regard, for explaining the comparative affluence of funding, the sovereign spread between the i^{th} trial state and the 10-year bond of US have been measured as benchmark for unfolding the comparative comfort of funding – where higher values signify liquidity scarcity (Shimbar and Ebrahimi 2020, Capelle-Blancard et al. 2019).

In the case of output (Y_t), less strong economies do not play a vigorous role and they are not price takers from the global market and for this, the author planned to use a gravity-proxy that generally explains the gap between the GDP of sample countries and the global economy ($GDP_{i\text{-}w,t}$). Here it is mentionable that the higher values of ($GDP_{i\text{-}w,t}$) indicate the relative smallness.

Due to robust disposition of RE by following an auction scheme, the EU countries are lessening their dependency on FF-based electricity generation ($E_{ff,i,t}$) and the economy becomes more energy-efficient. Side by side, the economies emit less carbon dioxide ($CO2_{i,t}$) locally for consuming/producing less electricity based on FF by which GHG has negative impact on the economy in the form of various damages (D_t). Nevertheless, it needs to be pointed out that the damages are not solely acknowledged by the local CO2 emission ($CO2_{i,t}$).

To denote the exogenous shocks in the model, the author augmented West-Texas Intermediate oil price ($P_{WTI.i,t}$) to represent the situation of FF pricing; an IMF dummy ($d_{IMF,i,t}$) variable that indicates country-specific emergency periods when i^{th} country required funding from the IMF. Witnessing the benefits of auction and auction features compare to other support schemes, an auction scheme dummy ($d_{AS,i,t}$) variable is to epitomize the support instrument for installing RE robustly by the sample countries. Notably, the systematic auctioning schedule ensures a continuation of RE project in the pipeline and helps to add more RE in the system (IRENA 2017, IRENA-CEM 2015) and facilitate competition and drive down prices of renewable energy in the market (Maurer & Barroso 2011).

In this paper, the author categorized RE into two main groups: solar and wind energy ($R_{GEN\ s\text{-}w,i,t}$). These two types of RE generation do not emit any direct CO2 after the asset is bent and fitted.[72] The usage of higher-level RE can indicate the impression of circular economy and the higher the consumption of RE ($R_{COM\ S\text{-}W,i,t}$) lessens the usage of FF. It is noteworthy that the author positions the consumption of renewable energy on the right side of the model. Firstly, the renewable generation of the sample countries demonstrates strong grid connectivity. And secondly, *"…increasing the use of RES did not have a long-term positive impact on CO2 emissions. The main explanation for this was the use of traditional biomass, which directly increased such emissions. This missing decrease in CO2 emissions can be explained with the initial findings of Jevons (1865) and its later amendments"* (Somosi et al. 2024, p.7) — thus, there may be instances where the generation and consumption of renewable energy are not synchronized, potentially leading to environmental harm (D_t). However, the paper focuses on the identification of the country-specific factors in RE to comprehend the i^{th} country's capability to encounter the net zero emission target by 2050 under the applied Cobb-Douglas specifications following the below mentioned theoretical model:

$$\Delta \ln R_{GEN\ s-w,i,t} = \text{Constant} + \alpha_1 \Delta \ln 10Y_{i-US,t} + \alpha_2 \Delta \ln GDP_{i-w,t} + \alpha_3 \Delta \ln E_{ff,i,t} + \\ + \alpha_4 \Delta lnR_{COM\ s-w,i,t} + \alpha_5 \Delta \ln CO2_{i,t} + \beta_1 \Delta \ln P_{WTI,i,t} + \beta_2 d_{IMF,i,t} + \beta_3 d_{AS,i,t} + \varepsilon_t \qquad --(2)$$

Based on the set model, the expected outcome is: in all-purposes high sovereign spread level can hamper investment, reasoning sluggish economic growth and thus low level of CO2 discharge for deploying RE by reducing dependency on FF-based electricity generation ($\alpha_1<0$), Nevertheless, an extreme liquidity scarcity can distract funding from green energy venture as well ($\alpha_1>0$). This assorted symbol points to the deficiency of market impartiality for a green monetary policy. When the underlying

[72] https://www.carbonbrief.org/solar-wind-nuclear-amazingly-low-carbon-footprints

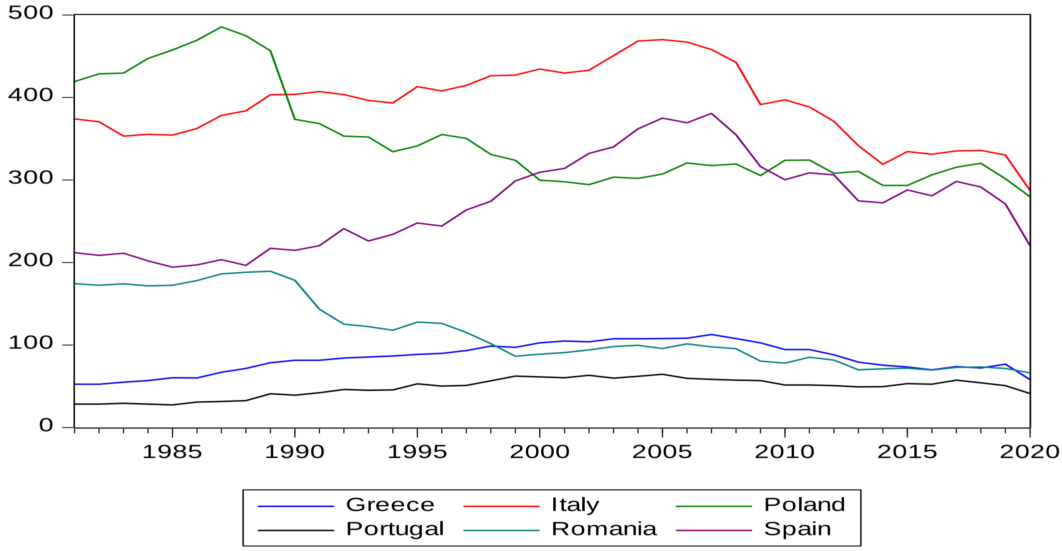
economy has a lesser portion in the global economy, the worth of the gravity-proxy is higher. As economic productivity depends on energy practice, this variable should have optimistic stimulus on CO2 emission (α_2>0); but the condition is to attain a country at a certain post-industrial level of growth. As higher level of RE-generated electricity reduces the gradual dependency on FF-based electricity, energy consumption from RES has an analogous effect as RE still has a small stake in energy blend (α_3>0; α_4>0). For the substitute of FF, RE usage by mentionable solar and wind energy can potentially reduce the CO2 emission (α_5<0). We see that the variables GDP, RE consumption and CO2 emission (i.e., α_2, α_4, α_5) have capability to methodically diminish the GHG in the set model.

5.2 Data and Methods

5.2.1 Data

The selected EU countries started to emit a large amount of CO2 after 1982, aligning with the global scenario and the growing trend has continued since 2010 with some hindrances, only when there were some experiences of recession (*Figure 10*). After the tremendous attention to green energy, the paper analyzes the phenomenon of how the countries' economic, financial, and industrial sectors are performing by keeping the carbon-neutrality target in the prime position in future.

Figure 10 *CO2 Emission (million tons)*

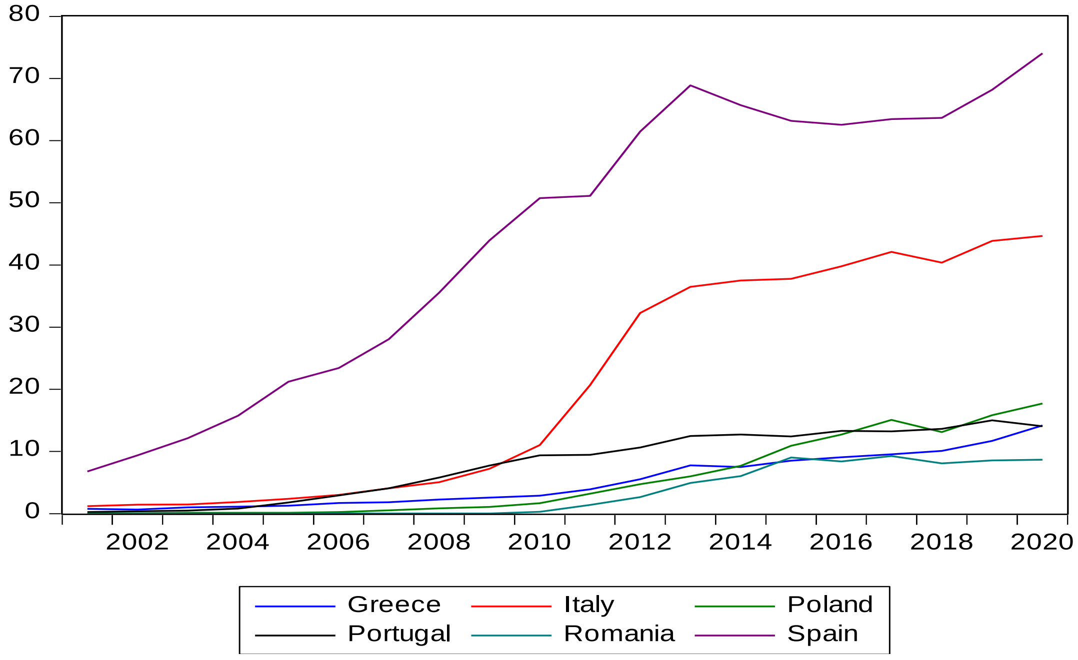


Source: Author's edition, bp Statistical Review of World Energy July 2021[73]

[73] http://www.bp.com/statisticalreview

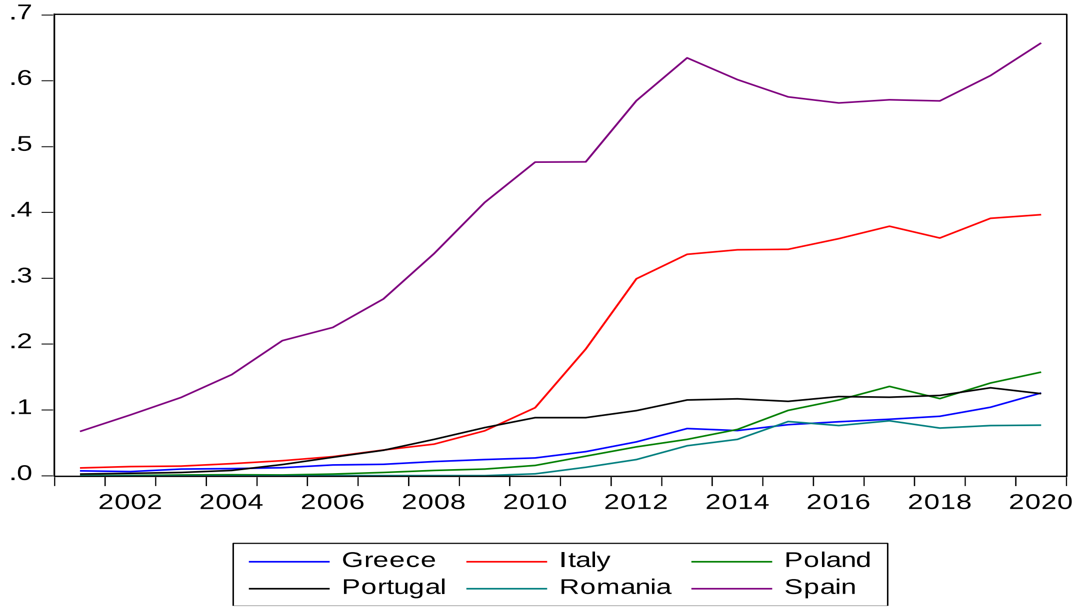
RE generation, especially solar and wind, started to rise in the selected countries in the 2000s and the increasing production has the inspiration to consume more RE and this inspiration requires reducing persistent dependency on the FF-based energy generation (*Figure 11 to Figure 13*).

Figure 11 Total Solar & Wind Generation (Terawatt-hour)



Source: Author's edition, bp Statistical Review of World Energy July 2021[74]

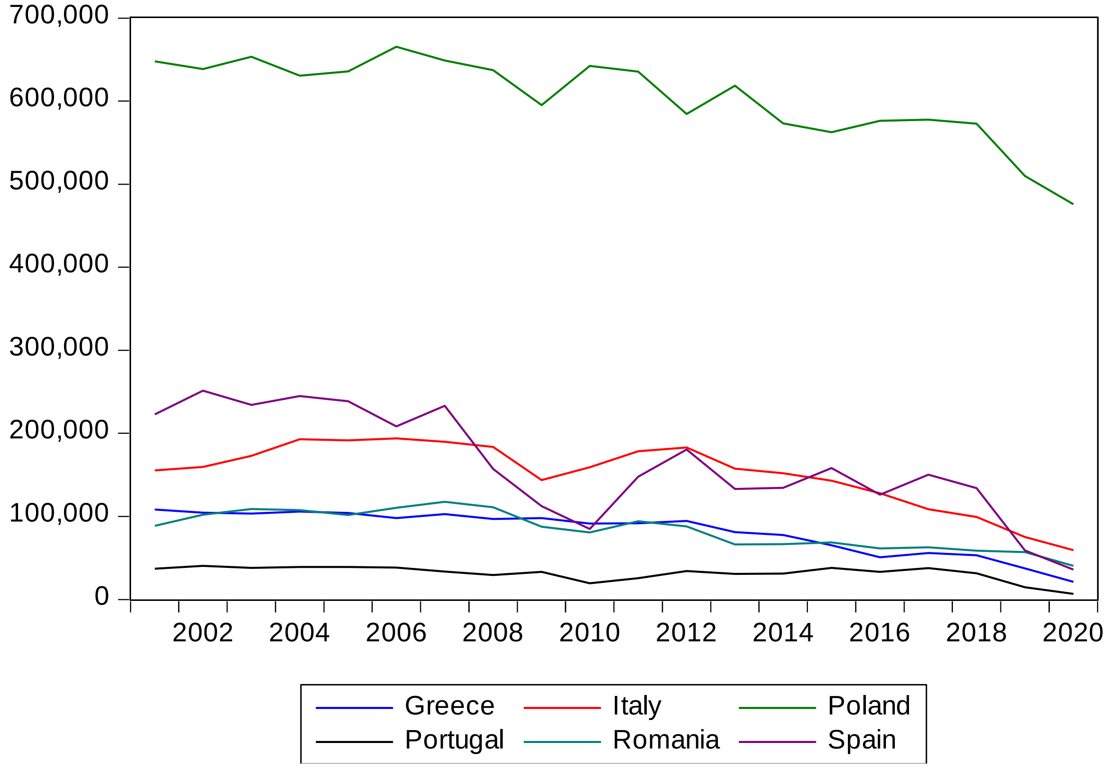
Figure 12 Total Solar & Wind Consumption (Exajoules)



Source: Author's edition, bp Statistical Review of World Energy July 2021[75]

[74] http://www.bp.com/statisticalreview
[75] http://www.bp.com/statisticalreview

Figure 13 Fossil Fuel-based Energy Generation (Gigawatt-hour)



Source: Author's edition, bp Statistical Review of World Energy July 2021[76]

It can be claimed that the above-mentioned figures are satisfying our assumption primarily, i.e., a higher level of RE generation increases the level of RE consumption, and, on the other hand, it reduces the dependency on FF-based energy generation, and it also lessens the emission of CO2.

In first section of the paper, the author analyzed the annual data between 2001 and 2020 as the robustness of RE basically started over this period. Comparatively, six developing and open economies (Greece, Italy, Poland, Portugal, Romania, and Spain) of the EU are considered as a sample for verifying the assumed theoretical model (i.e., equation 2) where the auction scheme is practiced after 2012 (most of them followed it from or after 2016) for vigorous deployment of RE. For a stipulation of homogenous load-factor for premeditated solar and wind generation potential, all the selected countries are pigeon-holed by similar climate, costal belt, and geographical position. Moreover, most of the countries were affected by developing debt crisis in different times, which is directing their acquaintance towards external funding conditions. It

[76] http://www.bp.com/statisticalreview

needs to be mentioned that the author selected those countries as sample for the study scope because the countries have close geographical scenarios, open economies, potential for RE deployment, are following RE auction or about to adopt an RE auction scheme for robust deployment of RE, faced debt crisis in different times, and took part in different programs of IMF. Bangladesh shares some geographical and coastal similarities, debt-related challenges with the countries that have been chosen, and it also has significant potential for generating electricity from solar and wind sources. Also, the country is an open and potentially growing economy in Asia.

Table 7 *Data Sources*

Name of the variables	Sources
Renewable generation (solar and wind) ($R_{GEN\ s\text{-}w,i,t}$)	bp Statistical Review of World Energy July 2021
Sovereign Spread ($10Y_{i\text{-}US,t}$)	Refinitiv Eikon database
Gravity ($GDP_{i\text{-}w,t}$)	World Bank
Fossil fuel based energy generation ($E_{ff,i,t}$)	Eurostat
Renewable consumption (solar and wind) ($R_{COM\ s\text{-}w,i,t}$)	bp Statistical Review of World Energy July 2021
Carbon dioxide emission ($CO2_{i,t}$)	bp Statistical Review of World Energy July 2021
WTI oil price ($P_{WTI,i,t}$)	bp Statistical Review of World Energy July 2021
IMF dummy ($d_{IMF,i,t}$)	IMF country report
Auction scheme dummy ($d_{AS,i,t}$)	AURES II reports

Source: Author's edition

The energy sectors are retrieved from the database of bp Statistical Review of World Energy, financial data are obtained from Refinitiv Eikon database, and world Bank database is the source of GDP data (*Table 7*). As the selected EU countries have taken part in various IMF programs, only the general resources account was measured when the payout occurred from IMF towards the i^{th} state. It is to be noted that the paper does not reflect the poverty reduction and growth trust due to other reasons. Furthermore, the paper takes account of the auction scheme practiced by the sample countries for at least a single time.

Table 8 Descriptive Statistics and Unit-root Tests

	$CO2_{i,t}$	$E_{ff,i,t}$	$GDP_{i\text{-}w,t}$	$10Y_{i\text{-}US,t}$	$R_{COM\ s\text{-}w,i,t}$	$R_{GEN\ s\text{-}w,i,t}$	$P_{WTI,i,t}$	$d_{AS,i,t}$	$d_{IMF,i,t}$
Mean	10.35002	-0.026552	-0.003473	-0.06373	1.539328	6.218036	0.01376	0.194175	0.116505
Median	10.37727	-0.021017	-0.00112	-0.2902	1.750746	6.431424	0.089275	0.00000	0.00000
Maximum	10.44307	0.840846	0.057437	24.3555	3.075278	7.799048	0.326308	1.00000	1.00000
Minimum	10.14681	-0.706975	-0.05911	-23.5253	-0.65332	3.971268	-0.64980	0.00000	0.00000
Std. Dev.	0.077858	0.238875	0.022535	3.868075	1.090909	1.12139	0.278028	0.397498	0.322398
Skewness	-0.97728	0.322562	0.138542	0.43251	-0.32797	-0.32337	-1.00919	1.546274	2.390649
Kurtosis	3.106358	5.877313	5.506677	29.67932	1.896296	1.893788	3.03858	3.390964	6.715201
Jarque -Bera	16.44426	37.31655	27.29587	3057.96	7.074491	7.046921	17.49004	41.70087	157.3476
(P)	0.000269	0.000000	0.000001	0.00000	0.029093	0.029497	0.000159	0.000000	0.000000
Unit-root test									
Levin, Lin & Chu t*	-6.6991	-8.39954	-2.91101	-5.24036	-8.18219	-8.19192	-8.26709	-4.5737	-2.5898
(P)	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048
Observations	103	103	103	103	103	103	103	103	103

Source: Author's edition, EViews 10

As it was mentioned earlier, the robustness of RE started in the 2000s and afterwards and not all the sample countries occupied RE from that period, so due to the missingness of data, the panel data can be considered unbalanced, which is measured by the panel VAR model (*Table 8*). On the other hand, there is no unit-root in the data and the standard deviation and mean of the data are time-invariant and for this, the VAR satisfies the stability condition. It is highlighted that the panel unit root test, also known as the stationarity test, is used to determine whether a panel data set is stationary or non-stationary. Stationarity is an important assumption for many statistical analyses, including regression analysis, because it ensures that the underlying relationships between variables are constant over time. If a data set is non-stationary, the results of any analyses may be unreliable.

According to the results, all variables, except GDP and FF-based energy generation, are non-stationary at the level with individual effect and individual linear trend effect. However, $CO2_{i,t}$, $10Y_{i\text{-}US,t}$, $R_{COMs\text{-}w,i,t}$, $R_{GENs\text{-}w,i,t}$, $WTI_{i,t}$, $d_{AS,i,t}$, $d_{IMF,i,t}$ are found to be stationary at the level with only an individual linear trend effect. Nevertheless, when those come to the first difference, all of the variables ($CO2_{i,t}$, $E_{ff,i,t}$, $GDP_{i\text{-}w,t}$, $10Y_{i\text{-}US,t}$, $R_{COMs\text{-}w,i,t}$, $R_{GENs\text{-}w,i,t}$, $WTI_{i,t}$, $d_{AS,i,t}$, $d_{IMF,i,t}$) are found to be integrated of order one, i.e., I(1) process. Since the pooled data is stationary in the first difference, the series is reliable for further investigation and analysis (Rao 2007).

5.2.2 Method

In the Vector Auto Regression (VAR) model, the variables are in the form of time series and auto-correlated, the model is appropriate for handling such time series and autocorrelation problems. Furthermore, the VAR model considers the dynamic and causal relationships among economic variables, which is a benefit that classical regression models cannot ensure. For this, VAR is suitable in policy analysis (Kumar and Paramanik 2020). Panel VAR models attempt to show the dynamic interdependencies present in the data using a minimal set of restrictions and impulse response analysis or policy counterfactuals can be built in a comparatively straightforward way including the relevant exogenous shocks. The panel VAR has the same structure of VAR model, where it is assumed that all variables are endogenous and interdependent; but a cross sectional measurement is supplemented to the depiction (Canova and Ciccarelli 2013). VAR is able to process even a lesser amount of time series variables, where a priori endogeneity is presumed for individual variable and their dynamics are taken into interpretation. This dynamic interpretation of a set of *N* time series variables $y_t = (y_{1t},\ldots, y_{kt})'$ can be defined simply by the below mentioned basic VAR model form (3) (Gábor et al. 2020, Lütkepohl-Kratzig 2004):

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + \varepsilon_t \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where y_t is the model variables for the (*Nx1*) vector, F_i is the matrix which contains (*NxN*) autoregression coefficients and the $\varepsilon_t = (u_{1t}, \ldots, u_{Kt})'$ is the unobserved error term vector with (*Nx1*) Gaussian distribution where $\varepsilon_t \sim (0, E(u_t, u_t'))$ is a positive definite covariance matrix. Optimal lag length of the model is nominated by the Schwarz (or Bayesian) information criteria (SC), Akaike information criteria (AIC), and Hannan–Quinn information criteria (HQ) to check steadiness and asymptotic normality of the data. After that the standardized condition for stability is tested to see whether the modulus values are smaller than one, which infers the invertible explanations and the explanations of infinite order-vector moving averages (Gábor et al. 2020, Lütkepohl 2005).

At the time of forming the equation (3), quite a few boundaries of the parameters are conceivable: the short-term restrictions can be casted off to explain the arrangement of shocks in the case of Cholesky's formation. On the other hand, the long-term restrictions can be described by the shocks for Blanchard-Quah's formation. For doing this, firstly we need to familiarize with the structural version of the shorten VAR form (4) (with a time lag ρ and three variables with structural coefficients A and A^s):

$y_t = A_1^s y_{t-1} + \cdots + A_p^s y_{t-p} + Bu_t$, where $\varepsilon_t = A^{-1}Bu_t$ and $S = A^{-1}B$. ……..(4)

It is our assumption that the value of certain coefficients is zero and u_{1t} affects instantly the other variables simultaneously, while u_{2t} affects only the variables 2 and 3 simultaneously and u_{3t} only the third in Cholesky's restriction (5):

$$\varepsilon_t = Su_t = \begin{vmatrix} s_{11} & 0 & 0 \\ s_{21} & s_{22} & 0 \\ s_{31} & s_{32} & s_{33} \end{vmatrix} \begin{vmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{vmatrix} \quad \text{.............................} \quad (5)$$

In the long-term restriction method proposed by Blanchard and Quah (1989), the impact of a shock is only evaluated in the row of the F-matrix where the affected variable is located. The accumulated effect of the shock over time is assumed to be zero, and ψ the long-term multiplier (F = ψS) is:

$$(1 — A_1 — \ldots A_p)^{-1}\, \varepsilon_t = \psi_{\varepsilon t} = F_{ut} \text{ and } F = \begin{vmatrix} f_{11} & 0 & 0 \\ f_{21} & f_{22} & 0 \\ f_{31} & f_{32} & f_{33} \end{vmatrix}, \text{while } S = \begin{vmatrix} s_{11} & s_{12} & s_{13} \\ s_{21} & s_{22} & s_{23} \\ s_{31} & s_{32} & s_{33} \end{vmatrix}. \quad (6)$$

The structure of the *F*-matrix unfolds the long-term possessions and in the EViews 10 econometric program it is determined by the loading order of the variables into the VAR model, assuming that there is a shock which affects every variable, and the end variable of the order is the one which affects itself only. The construction of the *F*-matrix (*Table 9*) was determined by the paper's theoretical model provided by the highest global influence for the exchange rate as an external balance proxy variable and the smallest local for the liquidity.

Table 9 *Structure of the F-matrix containing the Long-term Effects*

		Shocks								
		$CO2_{i,t}$	$E_{ff,i,t}$	$GDP_{i-w,t}$	$10Y_{i-US,t}$	$R_{COM\ s-w,i,t}$	$R_{GEN\ s-w,i,t}$	$P_{WTI,i,t}$	$d_{As,i,t}$	$d_{IMF,i,t}$
Variables	$CO2_{i,t}$	f_{11}	0	0	0	0	0	0	0	0
	$E_{ff,i,t}$	f_{21}	f_{22}	0	0	0	0	0	0	0
	$GDP_{i-w,t}$	f_{31}	f_{32}	f_{33}	0	0	0	0	0	0
	$10Y_{i-US,t}$	f_{41}	f_{42}	f_{43}	f_{44}	0	0	0	0	0
	$R_{COM\ s-w,i,t}$	f_{51}	f_{52}	f_{53}	f_{54}	f_{55}	0	0	0	0
	$R_{GEN\ s-w,i,t}$	f_{61}	f_{62}	f_{63}	f_{64}	f_{65}	f_{66}	0	0	0
	$P_{WTI,i,t}$	f_{71}	f_{72}	f_{73}	f_{74}	f_{75}	f_{76}	f_{77}	0	0
	$d_{As,i,t}$	f_{81}	f_{82}	f_{83}	f_{84}	f_{85}	f_{86}	f_{87}	f_{88}	0
	$d_{IMF,i,t}$	f_{91}	f_{92}	f_{93}	f_{94}	f_{95}	f_{96}	f_{97}	f_{98}	f_{99}

Source: Author's Edition in EViews 10

For screening the stable and long-run relationships among the variables, the paper tests the co-integration with Johansen test. If the test disqualifies getting such a relationship, then it is not proof that one does not exist; it only suggests that one may not exist (Dinh 2019). As for the use of a specific econometric method, called Panel Dynamic Ordinary Least Squares (DOLS), it is to estimate the long-run equation of a model. The method is used because the variables in the model are integrated of order one (I(1)) and it shows if there is a co-integrating relationship among them (Stock and Watson 1993). Furthermore, the impulse response analysis is a vital stage in econometric analysis, which is used in the VAR model. The functions under this analysis are considered as the effect of a unit shock on a given model variable where the shock of variable *i* is to variable *j* and ceteris paribus. Again, for a definite time horizon, variance decomposition denotes the breakdown of the prediction error variance. The decomposition process specifies the short-term and long-term influence of certain variables, i.e., the percentage of the uncertainty of variable *i*, which is to be accredited to the j^{th} shock after period *h* (Dinh 2020).

5.3 Levelized Cost of Energy (LCOE) Model

Investments in RE require significant capital, typically involving substantial initial investments alongside minimal operational expenses. Consequently, the levelized cost of energy (LCOE) for such projects can be notably influenced by fluctuations in the cost of capital (CoC) (Đukan et al. 2019). The significance of the cost of capital for the LCOE of different renewable power generation technologies cannot be overstated. The impact of a lower WACC in certain regions holds more sway over the LCOE than the influence of higher solar radiation levels or wind flows found in southern countries (Ondraczek et al. 2015). Ondraczek at al. (2015) also mentions that in nations where the expense of capital is elevated, there is likely to be a more pronounced shift of wealth from public coffers or electricity consumers, whoever shoulders the burden of the subsidy, to these entities, several of which have an international presence.

In the second step, under the quantitative segment, LCOE model was used. LCOE quantifies the average cost of producing a unit of electricity in a given power plant and represents the average minimum price at which electricity needs to be sold to break even (Reichelstein and Sahoo 2015). LCOE calculations for comparison purposes often employ a simplified formula, typically considering WACC (weighted average cost of capital) instead of a specific return target and cash flow level, without incorporating debt or tax considerations. This approach is chosen due to the lack of information regarding country-specific taxes or project-specific leverage ratios, which are not relevant for the comparative analysis.[77] The decrease in the WACC has already shown notable effects on the LCOE.[78]

Lowering the WACC to 5% within OECD nations could potentially decrease the weighted average LCOE by approximately one-fifth (IRENA 2020$_c$). In specific nations like Kenya, Ondraczek (2014) discovered that the responsiveness to the cost of capital or the discount rate is approximately 0.6. Therefore, a 10% alteration in the discount rate results in an approximately 6% adjustment in the LCOE. One way to gauge if auctions are more responsive to LCOE reductions compared to other support mechanisms, such as FITs, is by examining the price fluctuations following the implementation of these schemes. In numerous countries like Germany, Greece, Poland, and Hungary, prices have notably decreased, suggesting that competitive RES-E auctions have proven to be more effective than previous support frameworks (Szabó et al. 2020).

The sample study area of this paper is Bangladesh; but the LCOE data for the sample country are not available in the international database, thus, for the sake of analysis, the LCOE has been calculated from the generation cost of renewable energy from three solar and one on-shore wind power plants implemented/under implementation under utility-scale (IPP model) to compare with two other Asian countries— India and the Philippines, which are following an RE auction scheme, to

[77] https://www.greenmatch.ch/en/knowledge-center/how-to-calculate-the-levelized-cost-of-energy-lcoe/
[78] https://bvgassociates.com/lcoe-weighted-average-cost-capital-wacc/

understand the factual cost of energy portrayal in Bangladesh. The analysis aims to validate our hypothesis three (*H3*), which posits that Bangladesh experiences higher LCOE. It also seeks to ascertain the ceiling price through examining the auction features within the renewable energy auction model under investigation. The base data for Bangladesh were collected from the companies through the author's personal communication[79]. To calculate the LCOE, the initial investment, i.e., the total average cost of building and operating the power plant over its entire life is divided by the total electricity production of the plant over its entire life (equation 7).

$$\mathrm{LCOE} = \frac{\text{Initial Investment} + \sum_{t=1}^{n} \frac{\text{O \& M Expenditure}_t}{(1+\mathrm{CoC})^t}}{\sum_{t=1}^{n} \frac{\text{Electricity Generated}_t}{(1+\mathrm{CoC})^t}} \qquad \text{.......... (7)}$$

Here,

Initial Investment = the initial cost or capital cost/mega-watt (MW) (CAPEX) at t = 0

O & M Expenditure_t = inflation adjusted operation & maintenance cost/MW and each year (OPEX)

Electricity Generated_t = electricity generated in mega-watt-hours (MWh) per MW each year corresponding to the annual full-load hour (FLH)

n = the lifetime of the plant

t = year

CoC = cost of capital/the discount rate privately

The results for Bangladesh are shown in *Table 14* (solar) and *Table 15* (on-shore wind) along with the data for two selected countries which have been practicing auction scheme for a few years/recently, while Bangladesh is not yet in the auction field. It is mentionable that the data for India collected from the International Energy Agency (IEA-NEA 2020) database and the Philippines from PV Magazine[80].

[79] Mr. Md. Bellal Hossain, email to author, 30 December 2020

[80] https://www.pv-magazine.com/2022/03/25/philippines-sets-ceiling-price-of-0-069-kwh-for-upcoming-renewables-auction/

6 RESULT AND ANALYSIS

The VAR model and LCOE model were selected to know the effect of auction scheme for RE generation in some selected countries along with some pre-fixed variables. Therefore, here the author tried to explain the results based on the dataset followed by the analysis of the result.

6.1 Result and analysis of theoretical model

The missing data can make the dataset unbalanced due to the missingness of the data; but this is considered in the panel VAR model. The VAR was estimated following the EViews 10 where standard errors are in '()' and t-statistics in '[]' (*Appendix 1*). At the time of the analysis, there was no unit root in the data. In that the mean and standard deviation of the data were time-invariant and the model met the stability condition. The model used in this paper applied the lag length by the 'lag order selection criteria' where lags were set 0-2 for meeting the stability condition. The model is selected by AIC (*Table 10*), which suggests an optimal lag of 2 (as AIC is -30.21685* that is lowest in the table). Thus, at this point, the panel VAR has no statistical errors. The paper did not get any inverse roots of the characteristics polynomial that lied outside the unit circle (i.e., all moduli were smaller than 1), which also gratified the stability condition of the VAR model (*Table 11*).

Table 10 *VAR Optimum Lag Selection Criteria*

Lag	LogL	LR	FPE	AIC	SC	HQ
0	472.6552	NA	3.04E-16	-10.19022	-9.941897	-10.09004
1	1190.871	1278.581	2.53E-22	-24.19496	-21.71169	-23.19312
2	1545.867	561.7520*	6.44e-25*	-30.21685*	-25.49864*	-28.31335*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Author's Edition, EViews 10

***Table 11** Roots of Characteristic Polynomial*

Root	Modulus
0.989778 + 0.068498i	0.99215
0.989778 - 0.068498i	0.99215
0.313466 + 0.897844i	0.95099
0.313466 - 0.897844i	0.95099
-0.473067 + 0.775998i	0.90883
-0.473067 - 0.775998i	0.90883
-0.018682 + 0.847597i	0.8478
-0.018682 - 0.847597i	0.8478
0.620595 - 0.362401i	0.71866
0.620595 + 0.362401i	0.71866
-0.318443 + 0.574107i	0.65651
-0.318443 - 0.574107i	0.65651
0.641105 - 0.119862i	0.65221
0.641105 + 0.119862i	0.65221
-0.389409 + 0.074997i	0.39657
-0.389409 - 0.074997i	0.39657
-0.207841 + 0.105042i	0.23288
-0.207841 - 0.105042i	0.23288

Source: Author's edition, EViews10

The co-integration shows the statistical significancy of the independent variables at 5% significance level. In the long run, the independent variables are impactful to the dependent variable because all the values of the trace statistic and Max-Eigen statistic are greater than that of the respective critical values for the selected nine variables (Dinh 2019) (*Table 12*).

Table 12 *Johansen Co-integration Test*

Trace test denotes 9 co-integration eqn.(s) at the 0.05 level				
Hypothesized		**Trace**	**0.05**	
No. of CE(s)	**Eigenvalue**	**Statistic**	**Critical Value**	**Prob.****
None *	0.993419	1179.733	179.5098	0.0001
At most 1 *	0.984435	752.7342	143.6691	0.0000
At most 2 *	0.829253	398.9036	111.7805	0.0000
At most 3 *	0.647891	248.6599	83.93712	0.0000
At most 4 *	0.518611	159.9356	60.06141	0.0000
At most 5 *	0.440246	97.79391	40.17493	0.0000
At most 6 *	0.266717	48.47194	24.27596	0.0000
At most 7 *	0.174544	22.10289	12.3209	0.0009
At most 8 *	0.06594	5.79821	4.129906	0.0191
Max-eigenvalue test indicates 9 co-integrating eqn.(s) at the 0.05 level				
Hypothesized		**Max-Eigen**	**0.05**	
No. of CE(s)	**Eigenvalue**	**Statistic**	**Critical Value**	**Prob.****
None *	0.993419	426.9988	54.96577	0.0001
At most 1 *	0.984435	353.8307	48.8772	0.0001
At most 2 *	0.829253	150.2437	42.77219	0.0000
At most 3 *	0.647891	88.72425	36.63019	0.0000
At most 4 *	0.518611	62.14171	30.43961	0.0000
At most 5 *	0.440246	49.32197	24.15921	0.0000
At most 6 *	0.266717	26.36904	17.7973	0.0020
At most 7 *	0.174544	16.30468	11.2248	0.0059
At most 8 *	0.06594	5.79821	4.129906	0.0191
*denotes rejection at the 0.05 level; **MacKinnon-Haug-Michelis (1999) p-values				

Source: Author's edition, EViews10

The DOLS model has a high R-squared value of 99.49%, which indicates that a large proportion of the variation in the dependent variable is explained by the independent variables. Finally, it is mentioned that based on the results of this DOLS model, all the independent variables have positive impact on the RE generation, i.e., on the dependent variable. Here, automatic leads and lags specification are based on AIC criterion (max=*) and in the long-run variances (Bartlett kernel, Newey-West fixed bandwidth) used for individual coefficient covariances (Table 12).

Table 13 *Panel Dynamic Least Squares (DOLS) where Dependent Variable* $\boldsymbol{R_{GENs\text{-}w,i,t}}$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
$R_{COM\ s\text{-}w,i,t}$	0.962123	0.003774	254.9363	0.0000
$10Y_{i\text{-}US,t}$	0.009223	0.001467	6.28823	0.0001
$GDP_{i\text{-}w,t}$	6.119255	1.007774	6.072049	0.0001
$E_{ff,i,t}$	0.119211	0.012129	9.828591	0.0000
$CO2_{i,t}$	0.451066	0.002716	166.0995	0.0000
$P_{WTI.i,t}$	0.021176	0.008826	2.399314	0.0374
$d_{IMF,i,t}$	0.048034	0.010755	4.466369	0.0012
$d_{As,i,t}$	0.050520	0.003548	14.2401	0.0000
R-squared	0.994859	Mean dependent var		6.282465
Adjusted R-squared	0.983034	S.D. dependent var		1.066118
S.E. of regression	0.138867	Sum squared resid		0.192841
Long-run variance	1.97E-06			

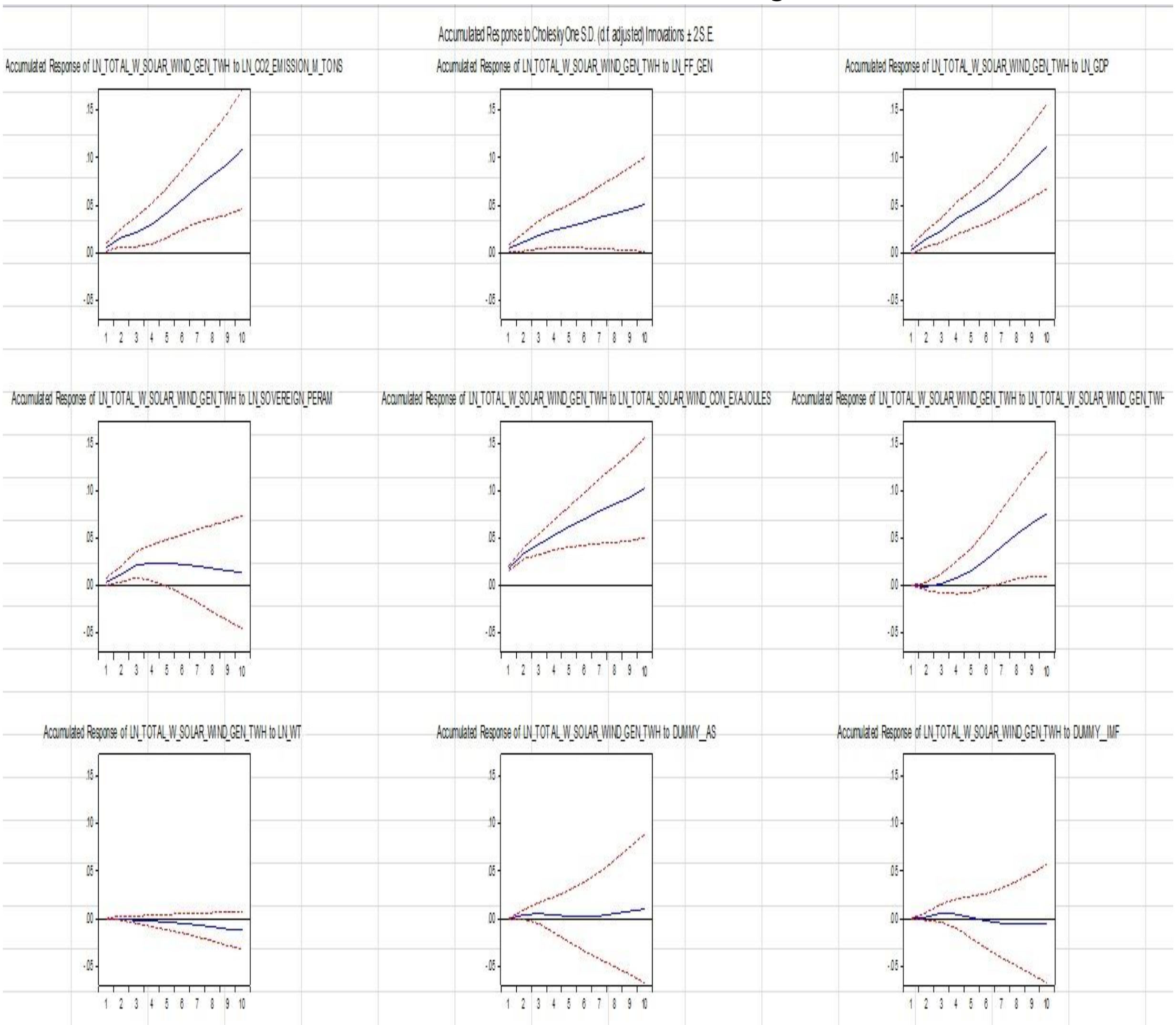
Source: Author's edition, EViews10

Impulse responses present the progress of each variable's stimulus on the total RE (solar & wind) generation in time with a 95% (±2 standard error) confidence intervals (*Figure 14*). Firstly, the behavior of the dependent variable was checked, i.e., RE generation at the initial period, i.e., the trend of RE generation was increasing or decreasing. The trend was found positive. After that the impulse response of the other variables have positive effect on RE (solar & wind) generation.

The CO2 emission, GDP and RE (solar & wind) consumption have the highest significant impact, meaning that if more RE is generated, CO2 emission will be reduced highly; it will be positively impactful to the country's GDP as the value of coefficient of $GDP_{i\text{-}w,t}$ is 6.119255, which is the highest value under *Table 13* and RE (solar & wind) consumption will be enhanced, which will help the sample countries to reach the carbon neutrality target in 2050. In addition, if the RE generation increases, then the auction scheme will play a significant role on the robustness of the generation as slower positive nature of auction dummy is produced in the impulse response. Thus, the regularity of the auction scheme is a potential tool to ensure the high quantity deployment of RE and its diversified gains.

Sovereign spread maintained a significant positive influence up to 7 years, meaning that the relatively high premium diverts financial resources toward the usage of fossil fuels for a certain period; after that it will motivate the usage of their renewable counterparts. Meanwhile, fossil fuel-based energy generation has a slightly significant impact on the total RE generation up to 10 years; later on, the level of significance is found negative, meaning that the change of energy-mix will affect the country's fossil fuel-based energy generation more significantly in the long run. Again, West-Texas Immediate oil price found slightly significant in the short run; after that it is found negative meaning a gradual improvement of RE in the long run, the FF-based energy generation will not be able to craft too much adverse impression to the economy due to the gradual depletion of the energy generation from that part. Finally, the IMF dummy has a slower positive nature up to 5 years; after that the negative trend means that up to 5 years funding support might be needed from the outsider for RE generation. However, when the full-phased market auction will come into the RE market, the funding support level will be lessened gradually.

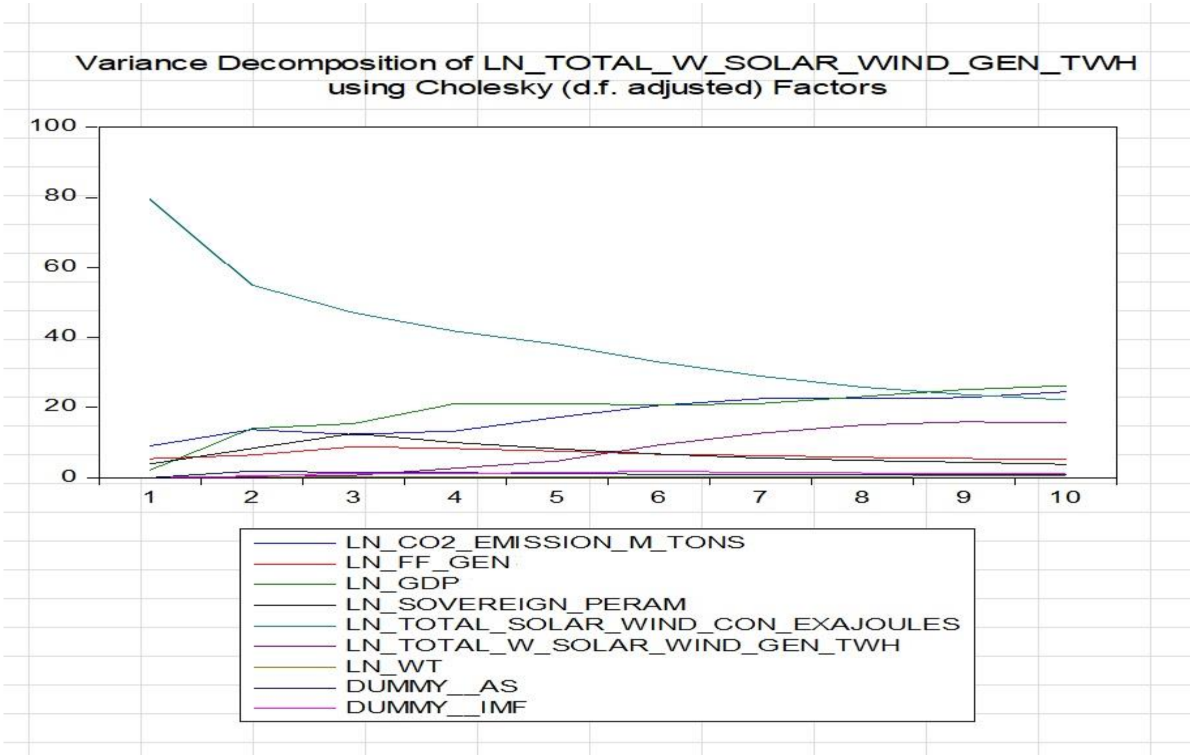
Figure 14 Accumulated Impulse Response Functions of the Total RE (solar & wind) Generation to Model Variables on the Long Run



Source: Author's edition, EViews10

For considering the percentile oscillation in a time series attributed to the particular variables at designated time horizons, variance decomposition underlines that a major part (~60%) of total RE (solar & wind) generation is explained by the model in the long run (*Figure 15)*. The variance decomposition (see *appendix 2*) of renewable energy (RE) generation, specifically solar and wind, reveals that RE consumption (solar and wind) exerts a significant impact, accounting for ~40% on average. Meanwhile, CO2 emissions contribute ~18%, and economic activities contribute ~19%, indicating a moderate effect. Other variables demonstrate marginal effects ranging from ~1% to ~7%, with notable influence observed in factors such as sovereign spread and electricity generation from fossil fuels, which exhibit a relevance of ~7%. It is important to note that although the auction technique currently shows a marginal effect of ~1%, its influence is steadily increasing each year. Reinforcing our previous results, the data points out the importance of generating more energy from renewable sources and inclusion of those into the energy mix will stop the further growth of CO2 emission, expanding RE consumption and reducing fossil fuel-based energy generation. These results are parallel with our previously described anticipations at the theoretical model part.

Figure 15 Variance Decomposition of Total Renewable Energy (solar & wind) Generation Using VAR Factors



Source: Author's edition, EViews10

After analyzing the data for the period 2001-2020 for the countries in question, the results remark that the panel VAR model soothes the stability condition. The paper gets a positive influence of each concerned variable on RE generation — more significant variables are CO2 emission, GDP and RE consumption and sovereign spread. The extended Cobb-Douglas function for the six EU countries is used in this segment of the paper keeping total RE (solar & wind) generation as a dependent variable. The panel VAR model was used to scrutinize the exogenous shocks (i.e., practicing auction scheme, IMF funding requirement at the countries' crisis session and environment for fossil fuel pricing), where the shocks affect all the considered variables. The paper highlights the sample countries' ability to align with the carbon neutrality goal under the Cobb-Douglas function for high level deployment of RE (solar & wind) for systematic auction scheme. Thus, the satisfaction of *H1* and *H2* is evident upon analysis of the theoretical model. The inclusion of Renewable Energy (RE) in the energy mix brings benefits to emerging and open economies. Additionally, the ongoing contribution of auctions showcases features that can potentially establish beneficial auction mechanisms for developing countries such as Bangladesh.

6.2 Results and analysis of LCOE model

Comparing with two auction scheme practicing countries in Asia, the LCOE is higher in Bangladesh and the country has not implemented auction scheme yet. Thus, the LCOE is higher here; for example, the 340 MW utility-scale solar PV project recently signed in Bangladesh has a set LCOE under PPA at 100.00 USD/MWh. In contrast, the Philippines have set the LCOE at 69.00 USD/MWh for its 1260 MW solar PV plant. Moreover, in Bangladesh, a 7.4 MW power plant, established on government-provided free land, has an LCOE of 45.41 USD/MWh. India, on the other hand, has set its LCOE at 35.60 USD/MWh for a 35 MW plant (*Table 14*).

On the other hand, for the case of utility scale on-shore wind plant (*Table 15*), India established the LCOE at 35.91 USD/MWh for the construction of a 65 MW plant. Conversely, Bangladesh opted for a different approach (PPA), determining the LCOE at 54.19 USD/MWh for a 55 MW plant where the project included partial land value; not the full. This indicates that Bangladesh's LCOE is approximately 34% higher compared to India's, despite the latter having a plant with a 15% higher capacity (65 MW). Additionally, noteworthy is the CoC or discount rate; Bangladesh applied a 12% CoC for its two solar and one onshore wind plants, which exceeds the prevailing global trend.

Table 14 *LCOE Results (for utility-scale solar PV)*

Country	Plant size (MW)	Construction costs (USD/MWh)	Refurbishment costs (USD/MWh)	Decommissioning costs (USD/MWh)	Total capital costs (USD/MWh)	Discount rate	LCOE (USD/MWh)
India	35	31.65	0	0.26	**31.91**	0.07	**35.60**
The Philippines	1260	63.48	0	1.15	**64.63**	0.07	**69.00**
Bangladesh*	**7.4 (no land cost included)**	**42.33**	**0**	**2.12**	**44.45**	**0.12**	**45.41**
	50 (IPP model)	**59.61**	**0**	**5.96**	**65.57**	**0.12**	**70.62**
	340 (IPP model)	**90.71**	**0**	**9.06**	**99.77**	**0.12**	**100.00**

Source: IEA-NEA 2020

*Base data for Bangladesh for analysis were collected through author's personal communication

Table 15 *LCOE Results (for utility-scale on-shore wind)*

Country	Plant Size (MW)	Construction costs (USD/MWh)	Refurbishment costs (USD/MWh)	Decommissioning costs (USD/MWh)	Total capital costs (USD/MWh)	Discount rate	LCOE (USD/MWh)
India	65	31.92	0	0.27	**32.19**	0.07	**35.91**
The Philippines	380	63.48	0	1.15	**64.63**	0.07	**69.00**
Bangladesh*	**55 (IPP Model) [partial land cost included]**	**45.92**	**0**	**0**	**45.92**	**0.12**	**54.19**

Source: IEA-NEA 2020

*Base data for Bangladesh for analysis were collected through author's personal communication

Discount rate (CoC) influences the LCOE significantly, because if the rate is high, then the LCOE will be enhanced and vice versa. For instance, if the CoC was 6%, then the LCOE for India's 35 MW solar PV would be 32.92 USD/MWh, i.e., only a reduction of 3.68 USD/MWh for a 1% reduction of CoC (IEA-NEA 2020). The same scenarios (for both total capital and CoC) are depicted in the on-shore wind energy case that also proves the findings of Ondraczek (2014). The adoption of auction techniques globally has resulted in a noticeable reduction in the Levelized Cost of Energy (LCOE), signaling the increasing affordability of renewable energy. Nevertheless, in Bangladesh, where the consistent application of this method is lacking, the LCOE seems relatively elevated compared to other countries, aligning with the aforementioned third hypothesis (*H3*).

Therefore, RE auction scheme is a helpful tool and will be a helpful toolkit in the RE market to ensure low-cost energy with other positive returns. Nevertheless, the auction obviously has to be tailored properly according to the requirements of the country. Furthermore, for reducing the discount rate, the public entities are responsible to initiate different steps for the generators and the investors as it has an impact on launching the targeted amount of renewable energy in any country for hurtling the global net zero aim.

7 DISCUSSION AND DECISION OF THE RESEARCH

Auction rules typically include guidelines for bidding, clearing, and pricing. Bidding refers to the structure of agreements and when they can be submitted. Clearing involves comparing bids to determine the winner and allocation of the product. Pricing determines the final cost at which the deal will be completed (Maurer & Barroso 2011). The access to energy is no longer a binary marvel; it is the quality energy access high up on the energy ladder (Csereklyei et al. 2017, Burke 2013) and not the mere quantity that is related to the economic development. In many places, RE technologies have proven valuable and sometimes vital. They play a significant role in sustaining current economic growth and have recently been instrumental in pushing the energy access boundaries around the world. The global scenario is changing rapidly, with the share of renewables in the energy mix increasing globally. According to the IEA monthly electricity statistics report from the end of 2020, global RE production was 3,269.1 terawatt-hours (TWh) in 2020, 7.5% higher than in 2019. The share of renewable electricity in the mix was 31.6% in 2020, up from 28.6% in 2019. Wind and solar production were mainly responsible for the increase in renewables, up by 95.8 TWh or 11.6% and 73.0 TWh or 20.2% respectively in 2020 compared to 2019. Since 2018, wind production has increased by 20.1% and solar production by 28.4%, showing the dynamic growth of the wind and solar power sector.[81]

The growing emphasis on environmental issues increases public and private awareness as well as the support of the topic. There is increasing pressure on the industry to meet such needs. Fossil fuel-based power generation could also lose its earlier role in the energy mix due to price reductions in constantly increasing power generation from RE. This can be partially explained by the theory of learning curves. Although FF-based power generation may gain price benefits from higher efficiency or smart technologies, the RE market is moving at a much faster pace. Wright (1936) provided a framework for forecasting cost declines due to cumulative production. Moore (1965) – referring to the transistor market development – predicted it would double every two years because of time. Others later explained the cost reductions by economies of scale (Goddard 1982) or combined the abovementioned factors with each other (Swanson 2011[82], Nordhaus 2009, Sinclair et al. 2000). Clean technology cost

[81] The official webpage of the International Energy Agency.

[82] Swanson (2011) also formulated a "law" specifically for the clean energy market. He projected a 20% drop in the price of solar PV modules for every doubling of cumulated shipped volume.

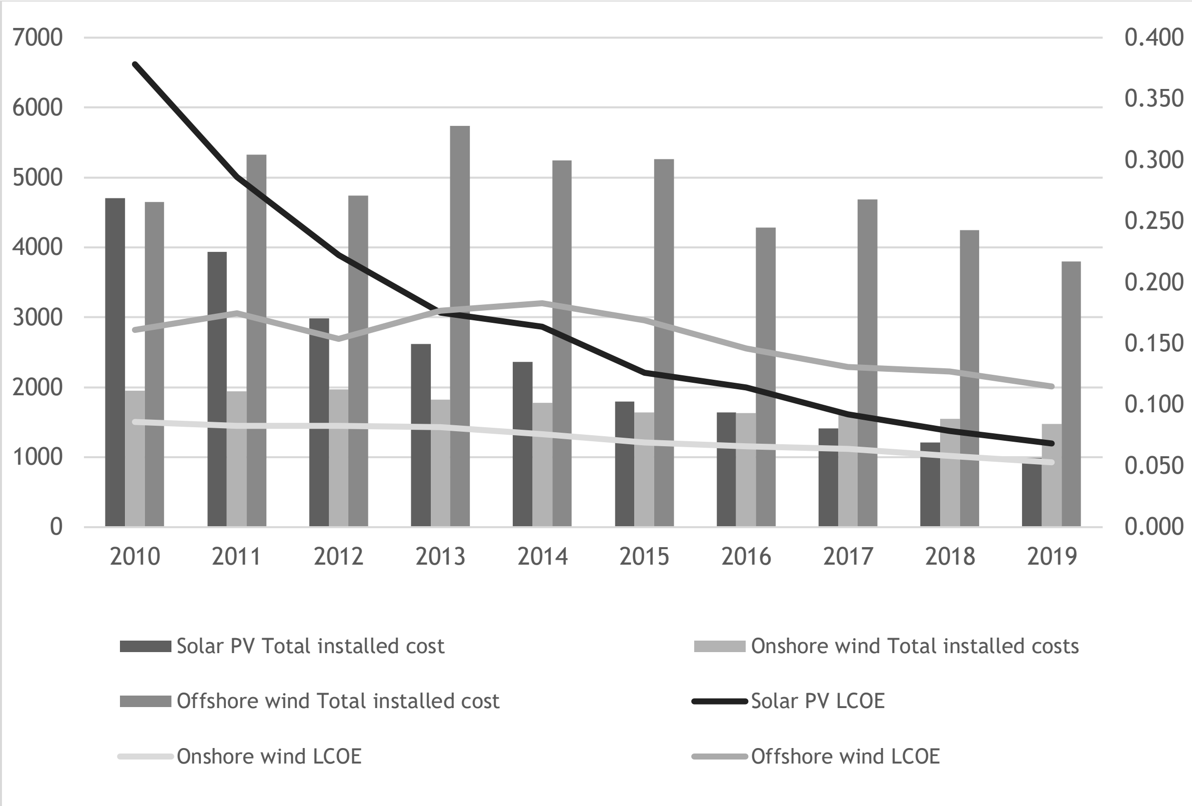
reductions arise from fundamental physics and lower input material costs from scale as well as lower labor costs through manufacturing automation and lower waste driven by higher efficiency. All these cost reductions appear naturally due to manufacturing scale and vertical integration rather than performance improvements. Thus, the advances in clean technology are a function of experience and production, closely related to “learning by doing”.

Besides the learning curve-indicated technological progress, the new channels of support for RE generation have also contributed to the drastic fall in RE prices, thereby improving the accessibility of energy for wider consumer groups. However, finance and sustainability are the most important design criteria for investing in RE. Studies show that significant results can arise from all support channels (Izgec et al. 2017), especially if designed carefully (del Río et al. 2021), while others also emphasize that support schemes may differ in their effect, depending on their design (Lilliestam et al. 2021). The features of cost-effectiveness, enabling real price discovery regarding the project and resulting in a lower support level mean that many countries worldwide are shifting from feed-in tariffs to a competitive auction process (Kreiss et al. 2017).

The impacts of the learning curve and the various support channels work together and strengthen each other, enabling lower prices to be the prime motivation for the further advocacy of auction schemes globally. The auction mechanism for RE offers competitive prices and faster project execution, it is easier to scale up for multiple projects and rounds, thus attracting multiple bidders.

The levelized cost of energy (LCOE) is used to analyze global price trends. It quantifies the average cost of producing a unit of electricity in a given power plant and represents the average minimum price at which electricity needs to be sold to break even (Reichelstein and Sahoo 2015). The following figure (*Figure 16*) illustrates the trends of average total installed costs (USD/kW) and the levelized costs of energy (LCOE, in 2019 USD/kWh) witnessed in the last decade from 2010 to 2019.

Figure 16 Global Weighted Average of Total Installed Cost (USD/kW) and LCOE (USD/kWh) of solar PV, on-shore & Off-shore wind (2010-2019)



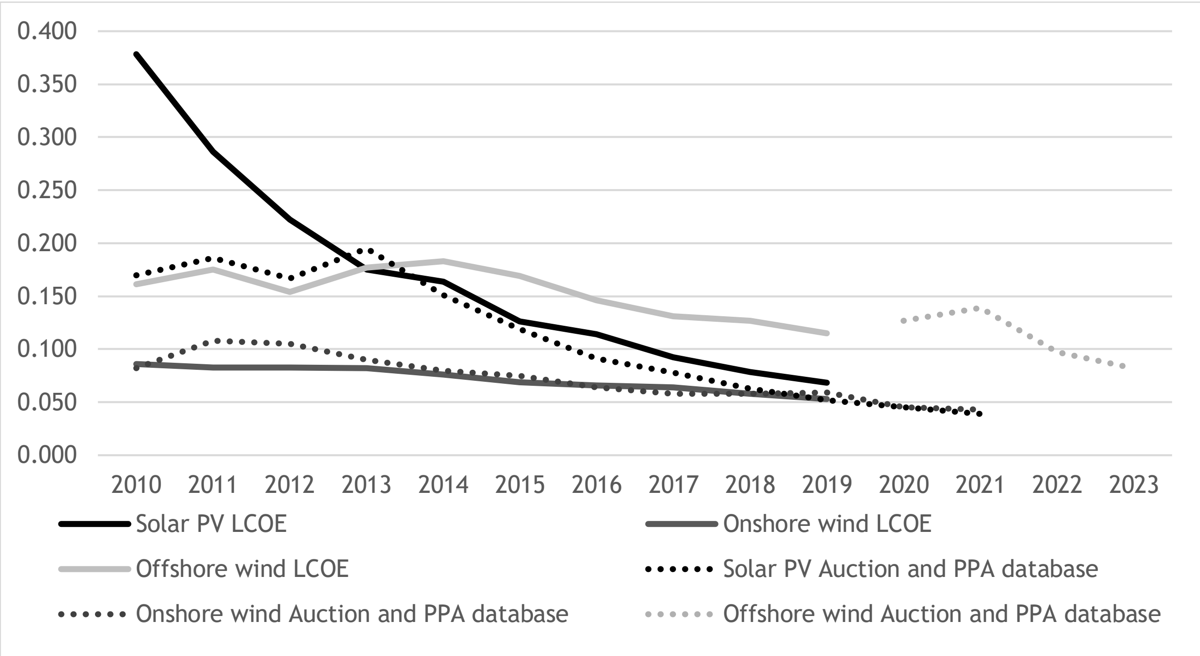
Source: Author's construction based on IRENA official data[83]

From 2010 to 2019, the global average contracted price for solar energy dropped by 78%. Similarly, the wind price also fell; however, compared to solar, the reduction rate did not reach the same level and the weighted average price of wind dropped only by 33% (IRENA 2019). In 2020 the IRENA report says, the total per kilowatt (kW) installed cost was 883 USD for solar photovoltaic, 3185 USD for offshore wind and 1355 USD for onshore wind.[84] The reduction in technology costs in this time resulted in global RE experts and decision-makers firmly accepting the auction scheme as a medium to shape the market price of renewables in their precise framework and circumvent inventors' windfall earnings. The final set of average prices is influenced not just by the technological advancements leading to reduced prices of renewable energy (RE) sources, but also by the support systems in place. Research indicates that fiscal incentives for RE investments have contributed to a significant decrease of 16-33% in the Levelized Cost of Energy (LCOE), as observed even in a developing nation such as Colombia (Castillo-Ramírez et al., 2017).

[83] https://www.irena.org/Statistics/View-Data-by-Topic/Costs/Global-LCOE-and-Auction-values
[84] https://www.irena.org/Data/View-data-by-topic/Costs/Global-Trends

The IEA (2019$_b$) also stated that the use of competitive auctions has accelerated cost reductions for some renewable technologies, notably solar PV, onshore wind, and offshore wind. However, these prices cannot be followed consistently, as each country and technology have different resource potentials, financing conditions, and a different set of auction designs. IEA data show that from 2017 to 2020, the average auction prices for solar PV and wind were both higher for Europe than in other regions/countries worldwide. *Figure 17* shows that the prices at solar and wind auctions have decreased significantly in the last decade.

Figure 17 Global Weighted Average of LCOE and PPA/Auction Prices (in 2019 USD/kWh)



Source: Authors' construction based on IRENA official data[85]

The auction and PPA database indicates the cost of electricity from solar photovoltaic decline to USD 0.039/kWh in 2021, 43% lower than the global weighted-average cost in 2019 whereas onshore wind decline to USD 0.043/kWh in 2021, 19% lower than the global weighted-average LCOE in 2019 and offshore wind decline to USD 0.082/kWh in 2023, 29% lower than the global weighted-average LCOE in 2019.[86] There was a notable price decrease for onshore wind in Brazil from 28.96 USD/MWh in December 2017 to 18.58 USD/MWh in April 2018. For solar PV, 17 GW

[85]LCOEs usually reflect higher values. According to the IEA, the three main reasons, among others, are: auction prices may not always represent full costs, aggressive bidding of certain players and current auction prices only reflect a small portion of the market.

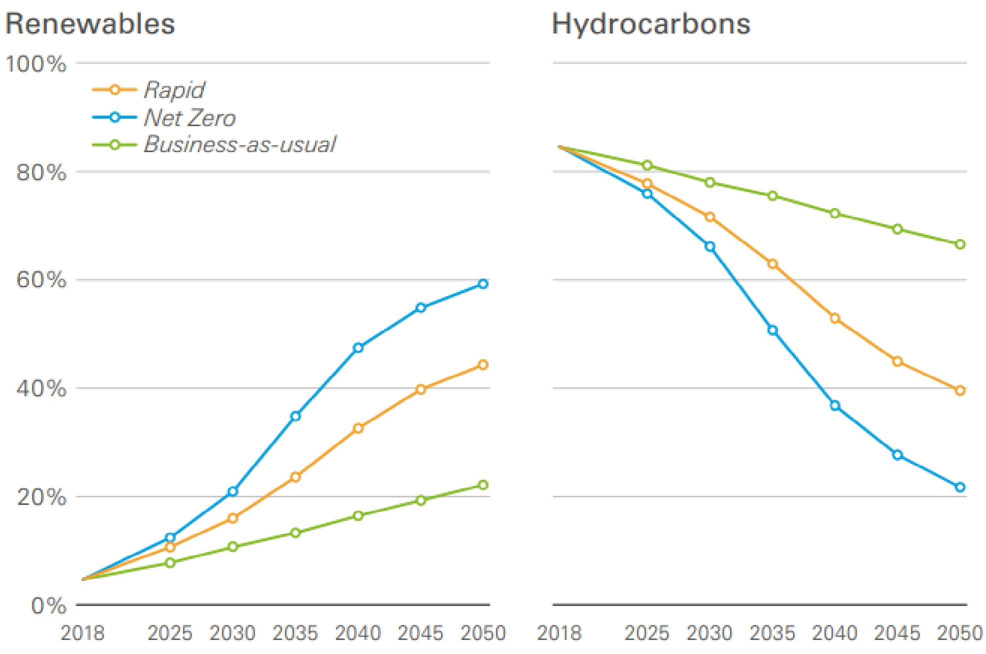
[86] https://www.irena.org/Data/View-data-by-topic/Costs/Global-Trends

capacity was solely owed by India at an average price of 42.3 USD/MWh and the Philippines received bids for a 50 MW capacity at a low cost of 43.9 USD/MWh (IRENA 2019).

It should be acknowledged that comparisons between LCOEs and auction prices remain an important challenge. However, limited information is available on contract-winning projects, which makes it difficult to state whether these tender-determined prices will become benchmarks for future costs of RE generation.

The deployment of renewable energy is driven by a combination of factors, including the economic benefits of RE, the decreasing costs of RE technologies, concerns about pollution and climate change, goals for accelerating RE deployment, advances in RE technology, the actions of corporations and investors to reduce their carbon footprint, and public support for RE (IRENA – GCGET 2019). These trends are leading to an increased integration of clean energy into the economy, as demonstrated by its contribution to a country's GDP. The qualitative and quantitative analyses of this paper both are the proof of this as well. The use of renewable energy has been rapidly increasing and the fossil fuels are in declining mode under 3 different future scenarios such as rapid, net zero, and business-as-usual (*Figure 18*). Adoption of policy support is tremendously facilitating its steady marching.

Figure 18 The World's Energy Transition Projections (% of primary energy)



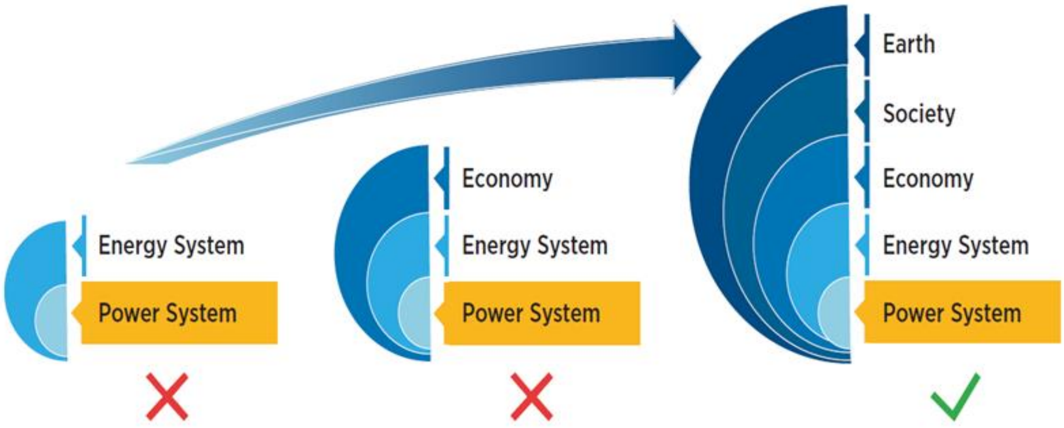
Source: bp Energy Outlook (2020), p. 64

However, to achieve targets related to climate change, energy access, air pollution, and energy security, the adoption of clean energy needs to accelerate. The framework for achieving these goals is outlined in the clean energy policy (IEA 2018). Supporting the IEA's statement, Pegels et al. (2018) mention that *"Green energy policy encompasses any policy measure aimed at aligning the structure of a country's energy sector with the needs of sustainable development within established planetary boundaries- both in terms of the absorption capability of ecosystems and the availability of natural resource"* (p. 27). The goal of renewable energy (RE) support policies is to increase capacity and production. These policies are becoming more widespread globally, with many countries having at least one RE target. The number of countries promoting RE through direct policy support has tripled (IRENA-IEA-REN21 2018). To be effective, energy policies should be:

(1) Structured to foster innovative technologies towards profitability (Altenburg & Lütkenhorst 2015);
(2) Designed for the long term to cover the long-lasting transformation process (Pegels et al. 2018); and
(3) Selectively chosen to provide direction and control technological progress (Falck et al. 2011) to expand innovation and dispersion (Altenburg & Lütkenhorst 2015).

The shift towards green or clean energy from conventional sources requires a reevaluation of power system organization, planning, and operation. The power system is not isolated (*Figure 19*), but rather intertwined with the energy system, economy, society, and the environment, with multiple interactions and feedbacks between these systems (IRENA 2020_a). To maximize the potential of solar and wind energy technologies, and to promote energy democracy, high volumes of clean energy must be deployed using these technologies (Burke & Stephens 2018, Angel 2016).

Figure 19 The Embedded Power System Transition to Clean Energy



Source: IRENA (2020$_b$), p. 6

Clean energy policies have a significant impact on the expansion of clean energy and other diversified benefits. Böhringer et al. (2013) found that clean energy policies have diverse effects on the labor market, electricity prices, and coal energy subsidies, leading to suitable policy implications. Mu et al. (2018) found that China's renewable energy policy led to an increase in employment due to the expansion of solar PV and wind power generation. Oh et al. (2020) found a positive correlation between renewable energy policies, renewable energy generation and GHG emission reduction. The European Commission changed its state aid guidelines for the energy sector in 2014, implementing competitive bidding as the main scheme for providing state aid for RE expansion from 2017 (Botta 2019, Leiren & Reimer 2018).

The concept of energy transition which induces the response of energy democracy emerged as a politically loaded call for today to a process, an outcome or a goal depending on the context it is used (Szulecki & Overland 2020). It is linked with energy justice, energy sovereignty, energy citizenship, and energy decolonization, which are cohesive with political prerogatives within the discussion point for clean energy transition (Burke & Stephens 2018). It is important to note that energy democracy and energy transitions are primarily political (Laird 2013), and this system of politics used to pilot clean energy transitions will significantly stimulate the opportunity for additional democratic prospects (Mitchell 2009).

Achieving true energy democracy involves giving the public and communities the power and ownership of renewable energy systems, such as land, renewable generation facilities, micro-grids, and small to medium-scale storage technologies. This also requires implementing policies and principles that promote capacity building at the community and regional levels. To achieve this goal, we must focus on enhancing democratic practices and ensuring positive outcomes. Currently, the centralized politics of fossil fuels coexists with decentralized energy systems. However, the transition to renewable energy, distributed generation, and democratic politics are all hindered by the current centralized energy politics. To overcome this challenge, greater emphasis should be placed on decentralizing energy politics to align with the decentralized nature of renewable energy systems (Burke & Stephens 2018).

Historically, the possession and control of fossil fuels have played a significant role in determining geopolitical power. The threat of oil embargos or gas shortages has led to the formation of alliances and even wars, and those with access to oil reserves have amassed great wealth. However, as the world shifts towards clean energy, a new set of nations and regions will rise to power. Some have even referred to it as a "clean energy space race." Those who excel in the development and implementation of clean technology, export renewable energy, or reduce their dependence on fossil fuels stand to benefit in this new energy landscape, while nations heavily reliant on exporting fossil fuels such as the Middle East or Russia may see a decline in their power and influence (Bordoff & O'Sullivan 2022, Hook & Sanderson 2021, Burke & Stephens 2017, Mitchell 2013, Mumford 1934). Sometimes for discouraging RE, electricity prices in today's energy markets do not accurately shown the genuine expenses associated with conventional power plant electricity generation. Consequently, they do not serve as a valid benchmark for comparing the costs of electricity generated from RES, although such comparisons are frequently made. This can lead to an inaccurate perception of renewable energy as being significantly more expensive than its actual cost (Nestle & Brugger 2014).

Renewable energy (RE) has significant geopolitical consequences that set it apart from conventional fossil fuels, as outlined in the report of IRENA-GCGET (2019). Four specific reasons for this are highlighted in the report:

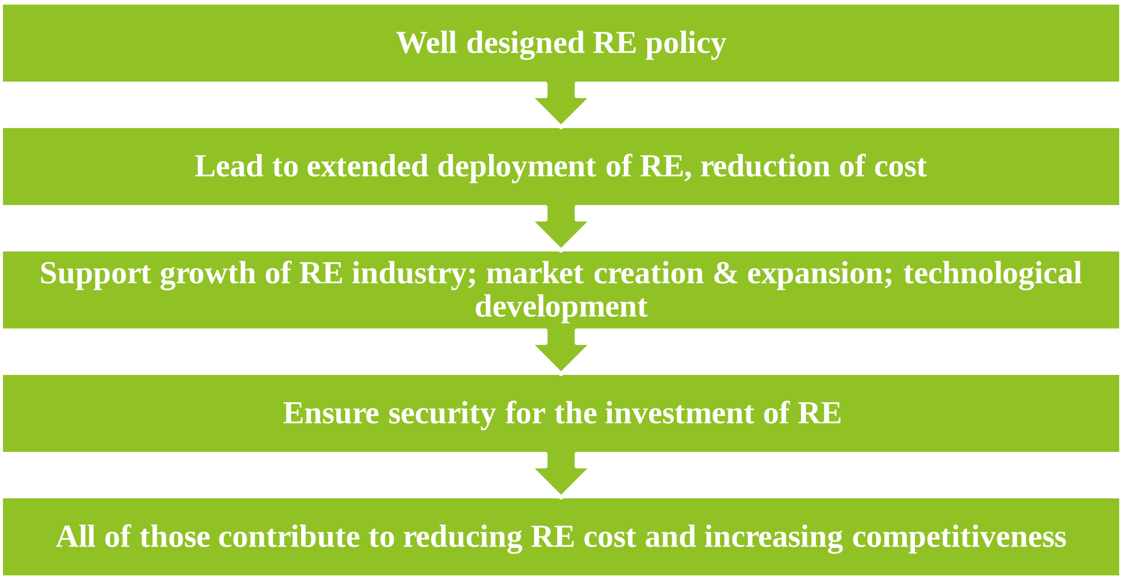
(1) Unlike fossil fuels, RE sources are widely available in various forms in most countries, weakening the power of traditional energy chokepoints;
(2) RE sources are typically flow-based, rather than stock-based like fossil fuels, making them difficult to interrupt and less prone to depletion;

(3) RE can be utilized at various scales and lends itself well to decentralized forms of energy production and consumption, which can have democratizing effects;

(4) RE sources, especially solar and wind, have near zero marginal cost and experience cost reductions of about 20% for every doubling of capacity, making them capable of shifting the balance of geopolitical power.

According to Rennkamp et al. (2017), middle income countries can implement renewable energy (RE) policies with sufficient domestic political support. They also note that the structure of economic incentives, private sector participation, policy uncertainty, policy strategy, and base load power are some of the main political arguments against RE policies. Mazzucato (2013) adds that green energy policies can change the market scenario, lower prices, and create a conducive atmosphere for profit making if policies are favorable, putting pressure on the government for investment. He also argues that long-term investment will not be effective if there is an unpredictable political environment. Powerful interest groups, such as large energy companies, may influence the outcome of government entities' supervisory efforts through lobbying, potentially undermining the intended aims of incentive schemes. Developing countries' governments may be particularly vulnerable to this due to weak monitoring systems, lack of transparency, and poor capabilities (Pegels et al., 2018). Therefore, according to Groh & Möllendorff (2020), framework conditions, political orientation, a feasible target, and a perfectly tailored support scheme are the prime catalysts of the perceived importance of the policy goals. The flow chart of *Figure 20* shows the gains from the well-designed RE policy:

Figure 20 Gains from Well-designed RE Policy



Source: Author's own creation from reviewed literatures

Thus, a well-designed RE policy is able to contribute to the reduction of RE cost and enhancing competitiveness. Bangladesh, like many other nations, is experiencing rapid economic growth and also making efforts to address its vulnerability to climate change. To achieve these goals, it is crucial to incorporate sustainable and renewable energy sources into the country's long-term development plans. A well-defined vision and structured strategies are essential for the advancement of any sector, and this applies to the growth of renewable energy as well. To successfully meet renewable energy targets, a specific plan, budget, timeline, and a balance between application and productivity are necessary.

As the world's fossil fuel resources dwindle and environmental issues exacerbate, it is essential for countries like Bangladesh to plan for the future. Advancements in technology will likely lead to decreased costs for renewable energy (RE) in the coming years. The global energy landscape is changing rapidly and RE's share in the overall energy mix is increasing. To promote sustainable and accessible energy for all by 2021, Bangladesh has implemented various measures, such as:

- Large-scale grid-tied solar PV projects,
- Solar home systems,
- Mini-grids,
- Irrigation pumps,
- Net energy metering for rooftop solar PV systems,
- Solar-powered drinking water systems,

- Telecom towers, streetlights, and
- Charging stations.

These measures align with global efforts to expand the use of RE. Despite efforts to increase the use of renewable energy (RE) in Bangladesh, only 650 MW of electricity from RE had been added to the energy mix by June 2020. The main obstacles to achieving RE targets within the specified timeframe are inconsistent policies and a lack of effective action. To achieve the RE target outlined in the "Draft National Solar Energy Roadmap of Bangladesh 2021-2041," the following targets should be set (as outlined in *Table 116*). It should be noted that the power generation target from renewable energy sources (RES) would need to be coordinated with the potential reduction in greenhouse gas emissions calculated in scenarios where Bangladesh's grid emission factors reach 0.67 tons/MWh by 2041.

Table 16 *Proposed RE Production and Expected CO2 Emission Reduction Target for Bangladesh*

Scenario		**Unit 2020**	**Unit 2021-2030**	**Unit 2031-2041**	**Cumulative**
BAU (10%)	Capacity (MW)	650	1,961	3,493	6,104
	GHG ($MtCO_2$)	570,679	2,049,673	3,650,884	6,271,236
Medium Case (20%)	Capacity (MW)	650	3,922	6,986	11,558
	GHG ($MtCO_2$	570,679	4,099,346	7,301,768	11,971,793
Higher Medium Case (35%)	Capacity (MW)	650	5,086	15,547	21,283
	GHG ($MtCO_2$)	570,679	5,315,475	16,250,168	22,136,322
High Case (50%)	Capacity (MW)	650	9,743	19,711	30,104
	GHG ($MtCO_2$)	570,679	8,092,984	22,692,337	31,356,000

Source: Author’s own compilation based on the ‘Draft National Solar Energy Roadmap 2021-2041’ for Bangladesh

The advancements in renewable energy technology worldwide are significant and are expected to continue at a rapid pace. This means that achieving ambitious goals in this field is becoming increasingly feasible. Bangladesh will not be the out of the boundary of that feasibility—just it needs consistency and well-designed RE policy. In Bangladesh, for example, it is suggested that the overall electricity load demand should be divided into three categories: 60% base load, 20% intermediate load/day-peak, and 20% evening-peak. If we do so, then the proposed target under *Table 16* will not be a tough goal. The way forwards for chasing these specific targets are outlined in *Table 17*.

Table 17 Justification of RE Target Setting in Bangladesh and Pathway to Meet

Scenario	Cumulative Target (till 2041 linked to *Table 16*)	Justification to fit with RE Target and pathway to meet that target
Business as Usual (BAU) 10% of RE of total electricity production	• 6104 MW RE • 6271236 $MtCO_2$ emission reduction	In accordance with various policies (i.e., energy policy, power sector master plan 2016) set by the government of Bangladesh, the 10% RE will be added into the energy-mix
Medium case 20% of RE of total electricity production	• 11558 MW RE • 11971793 $MtCO_2$ emission reduction	Currently around one fifth of the intermediate load, which is the demand during the daytime, is met by liquid fuel. The cost of liquid fuel per unit is HFO 0.19 USD and LNG 0.13 USD. The goal will be met if the cost of generating one kWh of renewable energy, specifically solar, is below 0.10 USD. Recent global trends indicate that the cost of generating renewable energy is below 0.10 USD/kWh. As of now, there are 16 rental and quick rental power plants operating in Bangladesh with a total capacity of 1109 MW, and their per kWh generation cost is 0.099 USD. However, their contract is set to expire in 2024. The government's decision to continue operating these rental and quick rental power plants is uncertain due to environmental concerns. If the contract is not extended, this capacity can be fully replaced with renewable energy sources.
Higher medium case 35% of RE of total electricity production	• 21283 MW RE • 22136322 $MtCO_2$ emission reduction	As per the various analyses, Bangladesh will see rapid economic progress and industrialization in the coming years, which could increase the electricity demand in the evening that could shift the evening-peak demand for electricity. If this occurs, it is possible that a target of 35% of total demand (20% day-peak demand and 20% evening-peak demand) could be met by renewable energy sources such as solar and wind power through generation cost below 0.10 USD/kWh. This would require significant investment in the development and implementation of renewable energy technology and infrastructure, as well as ongoing efforts to improve energy efficiency and reduce demand. Additionally, the government should take initiatives to pledge auction scheme, prepare the electricity market for competition, provide subsidies (if requires) and support to the renewable energy sector to make it more economically viable.
High case 50% of RE of total electricity production	• 30104 MW RE • 31356000 $MtCO_2$ emission reduction	To achieve the target of total demand, Bangladesh needs to adopt a gradual approach of updating their policies, upgrading the technology, expanding renewable energy sources, integrating the grid, and encouraging the use of variable renewable energy (VRE) sources

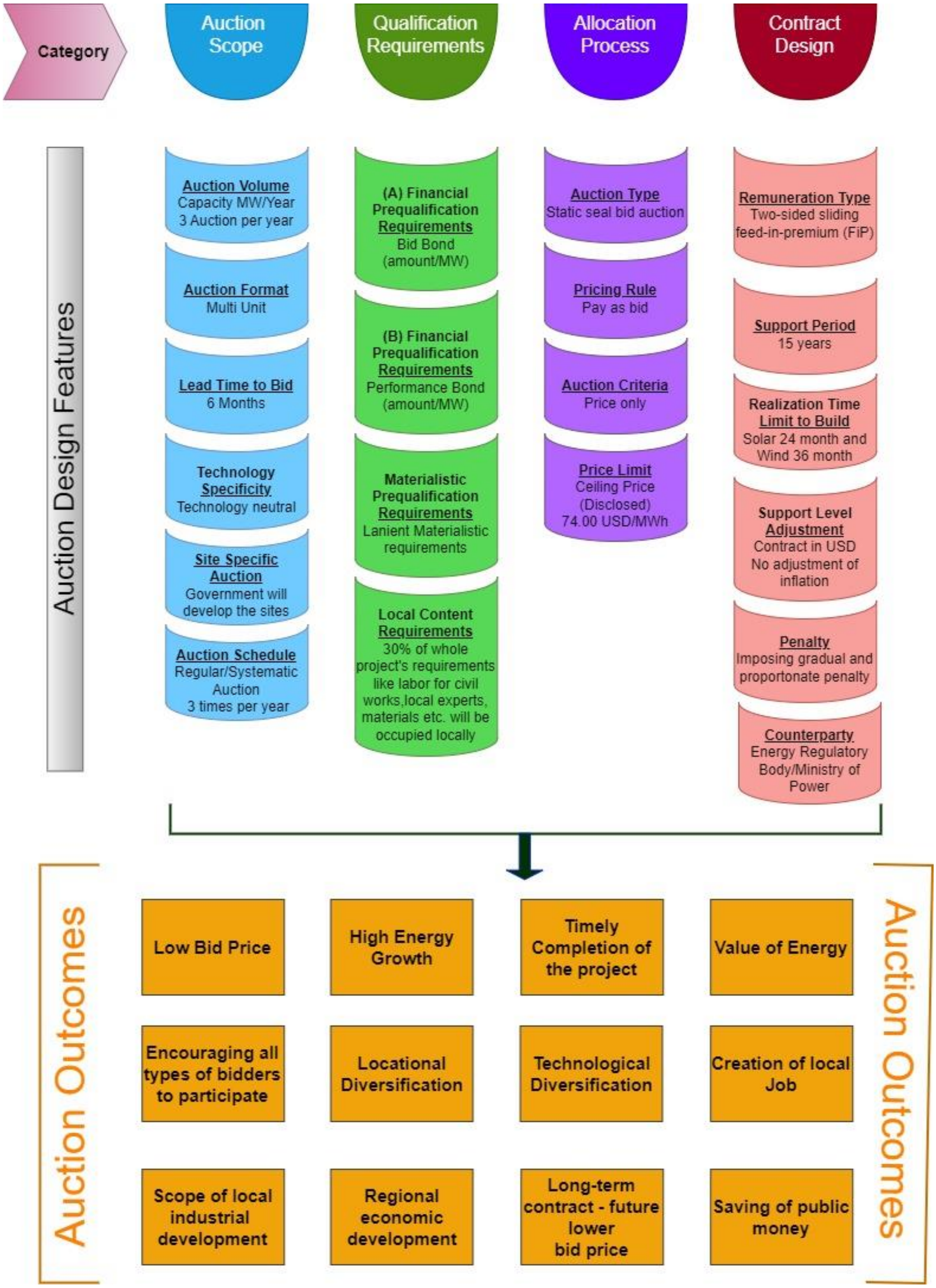
Source: Author’s own creation

It was mentioned earlier that despite the presence of potentiality, the energy market still lacks rationality. The exploitation of high-cost energy sources instead of utilizing available options leads to a wastage of vast amounts of money. To achieve a safe, secure, stable, and low-cost energy supply, it is necessary to make timely policy decisions to establish such sources as other developed and developing countries. While the country aims to achieve these goals, it is not yet reflected in practicality.

According to the reviewed literature, auction design elements can effectively guarantee diverse returns both directly and indirectly along with competitive low-cost energy. Auctions have been shown to be an efficient means of attracting new participants and aligning supply and demand when competition is desirable and feasible. They have had significant impacts in multiple economic industries (WBG 2014). *Table 18* evaluates the advantages and prospective benefits revealed in the outcomes of past renewable energy auctions associating with the paybacks for Bangladesh.

A renewable energy auction model has been proposed (as per *Figure 21*) for the developing countries like Bangladesh (which is supposed to be a new entrant in the auction scheme and targeted 20% or above of total generation, i.e., 11,558 MW electricity generation from RE sources by 2041) for robust deployment of low-cost sustainable energy with lower subsidy by ensuring more rivalry; high realization rate of the projects with varied technology and balanced grid expansion; safeguarding expanded economic pay-backs.

Figure 21 Renewable Energy Auction Model and Outcomes for the Developing Countries



Source: Author's own creation from reviewed literatures and Conceptual Framework

Table 18 *Further Explanations of Proposed Auction Design Features and its Outcomes for Bangladesh*

Category	Auction Design Features	Paybacks/gains/outcomes
AUCTION SCOPE	**Auction Volume:** Capacity (MW/year) [*Government's yearly target should be divided into 3 parts as there will be 3 auctions per year. Considering the high case (i.e., 50%) for 2021-2030, per auction will be called 325 MW. So, in this 10-year, the total added capacity will be 325x10x3=9750 MW. After gaining the experiences from the competitive auction and gradual development of the technologies, for 11-year (2031-2041), the total added capacity will be 600x11x3=19,800 MW*]	• supporting high energy growth and fast capacity addition; • attracting more bidders, thus increasing competition and attaining a lower price; • offering guidelines to the bidders due to its simplicity and transparency; • encouraging private investment
	Auction Format: multi-unit auction	• reducing non-compliance risk; • improving cost & deployment effectiveness via boosting competition & differentiating developer-specific risk
	Lead time to bid: 6 months	• attracting more bidders; • helping to speculate equipment prices; • helping bidders to reduce auction uncertainties
	Technology Specificity: Technology neutral *[All technologies can join in]*	• promoting diversified energy-mix; • offering more competitive bidding within less expensive technology; • minimizing generation costs; • ensuring compliance with the applicable regulation demands; • ensuring stability and reliability of the grid; • improving the value of energy; • enhancing the dispatchability; • removing incentive by reducing windfall profit

Category	Auction Design Features		Paybacks/gains/outcomes
	Location Specificity: Site specific [*site/geographical location will be selected and developed by the government*]		• allowing better coordination among project construction, required grid expansion and land acquisition; • balancing the electricity expansion areas; • reducing risks and costs (transition costs) for producers; • lessening uncertainty and obtaining good regional development; • faster project execution; • attracting new market entrants
	Auction Schedule: Regular/systematic auctioning schedule [*3 times per year*]		• bringing a result of lower WACC • promoting better guidance for placing the grid infrastructure; • ensuring a continuation of renewable energy project in pipeline; • decreasing risk, increasing investors' confidence and reducing the bid price; • technological progress and reduced technology prices through learning by doing process; • preventing underbidding as other projects are in the pipeline
QUALIFICATION REQUIREMENT	**Prequalification Requirement (financial)**	**Bid Bond (amount/MW)** [*To encourage bidders and investors, a bid bond equivalent to 1% of the whole investment cost for whole MW is required for the initial five years. Following market maturity, starting from the sixth year, the bid bond increases to 1.5% of the investment cost*]	• confirmation of land ownership and grid connection agreement, lowering the possibility of project's non-realization, meeting contractual obligations and protecting fake bids (by bid bonds); • sustaining the realization schedule and standard of the project (by performance bond); • encouraging a high level of competition; • lenient prequalification requirement lessens the risk for investors

Category	Auction Design Features		Paybacks/gains/outcomes
		Performance bond (amount/MW) **[***Successful projects are required to provide a performance bond of 3% of the calculated whole investment cost for the initial five years, which represents a 2% increase from the bid bond. Following market maturity, starting from the sixth year, the performance bond increases to 5%. It's important to note that the performance bond must be in the form of a bank guarantee.]*	
	Lenient Prequalification Requirement (material): detail project description, environmental assessment, etc.		
	Local Content Requirement: 30 percent of the local content (*like local employment, local labor for civil works, locally manufactured materials, etc. and then the investor will get a specific percent of tax credit by the authority*)		• encouraging innovation and supply chain improvement; reducing local risk (NIMBY syndrome); • ensuring local industrial development as a socio-economic development instrument; • creating new employment generation, gearing up empowerment locally and/or nationally; • facilitating regional economic development
ALLOCATION PROCESS	**Auction Type:** Static seal-bid auction *[Conducted to determine the supported price in USD/MWh. Support is granted to bidders who submit the lowest offers until either the volume or budget constraints are met]*		• straightforward and easy to understand; • lower participation for the bidders; • supply and demand are matched here; • small actors can participate in bidding process; • less vulnerable to collusion compared to dynamic auction

Category	Auction Design Features	Paybacks/gains/outcomes
	Pricing Rule: Pay-as-bid (PAB)	• offers actual bid price for each market generator; • minimizing the cost of RE by discovering the real demanded price; • favoring more financially viable projects; • wider acceptance from a social and political standpoint; • pathway for solving RE policy paradox
	Award Criteria: Price only [*Bidders who submit the most competitive pricing are awarded the opportunity to undertake the project, provided that neither the energy limit nor the budget constraint is surpassed*]	• lowering bid price compared to multi-criteria auction; • preventing underbidding
	Price Limit: Ceiling price (disclosed) [*Proposed* ***ceiling piece is 74.00 USD/MWh****. For more explanation see the* ***appendix 3***]	• leading significant lower prices; • preventing excessive prices, collusion & price manipulation, thus giving bidders higher planning security; • attracting more participants even potentially weaker ones; • helping government acknowledge upfront potential risk if the auction scheme may not fulfill its intended role; • giving bidders more planning security and reducing allocation risk
CONTRACT DESIGN	**Remuneration type/form of support auctioned:** Contract for differences (CfD) [*two-sided sliding FiP. For more explanation see the* ***appendix 3***]	• zero premium payment to the generators as RE generators participate in ancillary services and market balancing; • Sometimes pay premium if market price is too low; • savings of public money; • strong signal for value of energy; • Higher revenue guarantee can motivate the bidders to enter into the market; • RE generators can sell energy directly to the wholesale market that helps the generators to be self-reliant for the future

Category	Auction Design Features	Paybacks/gains/outcomes
	Support Period: 15 years [*may be more depending on the goal and technological maturity of the specific country*]	• enhancing the confidence of investors that influence to offer low cost for auction by a long-term support period; • reducing LCOE, investment risks and CoC; • enhancing competitions
	Realization Time Limit to build: Solar-24 months & Wind-36 months	• reducing risk for paying penalty with realistic realization time; • negotiating with manufacturers for low bid price; • helping to guess technology price
	Penalty: Gradual and proportionate penalty should be imposed based on the commissioning delay of the project [*If the project fails to meet its completion deadline, the promoter forfeit the performance bond. In later stage, if the project remains incomplete one year after the deadline, it forfeits its eligibility for support, and the promoter is barred from participating in renewable energy auctions for a period of two years*]	• proving the seriousness of the bidders; • managing underbidding risk; • establishing cost and deployment effectiveness.
	Counterparty: Ministry of Power/Energy Regulatory Body (such as Bangladesh Energy Regulatory Commission)	• escalation the self-reliance of the financiers • lessen bid price by sinking the risk premia
OTHER	**Support Level Adjustment:** No adjustment for inflation. Contract will be done in USD	Signing contract in local currency- • increasing bid prices; • reducing the capability of developers for rising debt; • due to exchange rate fluctuation, risk & CoC increased

Source: Author's own creation based on the reviewed literatures and the outcomes of the research

Upon satisfaction of *H1* and *H2* in the analysis of the theoretical model, the inclusion of Renewable Energy (RE) in the energy mix brings benefits to emerging and open economies. Additionally, the ongoing contribution of auctions showcases features that can potentially establish beneficial auction mechanisms for developing countries such as Bangladesh. Analyzing the theoretical model, the adoption of auction techniques globally has resulted in a noticeable reduction in the LCOE, signaling the increasing affordability of renewable energy. Nevertheless, in Bangladesh, where the consistent application of this method is lacking, the LCOE seems relatively elevated compared to other countries, aligning with the author's third hypothesis (*H3*).

Therefore, the introduction of RE auctions holds the potential for significant benefits for Bangladesh mentioned in *Table 18* and *Figure 21*. After reviewing the benefits, the nation can attain a competitive bidding price, substantial energy expansion, timely project execution, energy value appreciation, broadening participation in the bidding process, local and technological variety, fostering local employment opportunities, advancing local industries, promoting regional economic growth, establishing enduring partnerships for future cost reductions, and prudent utilization of public funds. By this our fourth hypothesis (*H4*) is validated by the presence of existing qualification requirements in the auction model in Bangladesh and the final auction model can be set as per *Figure 21*.

According to *Table 18 and Figure 20*, it is recommended to implement unsolicited auctions in the renewable energy sector to allocate projects. The first auction will have a simple design, lacking requirements for forecasting or compensation equipment for reactive power. The main objectives of the initial auction organizers, as stated by USAID (2020_a), are to gauge market interest and initiate the process of determining prices. The report says that France quoted 88 MW for solar PV in its first year, India quoted 208 MW, Greece quoted 40 MW for its pilot solar auction, and Poland quoted 8 MW for wind and 70 MW for solar.

A country's initial auction goals typically include: (1) evaluating investor interest and risk allocation strategies, (2) conducting a straightforward energy-only auction, and (3) establishing a baseline for price discovery. These objectives help to establish the foundation for the auction design. In order to effectively achieve the auction goals, the designers should prioritize the auction features listed in *Table 18* and also consider other relevant fields listed in *Table 19*.

Table 19 *Fields of Auction Design with the Participants' Responsibility*

	Fields of auction design	**Responsible participant**
1	land risk (i.e., land development, land allocation, site selection)	government
	bidding, investment, and operation risk	participants
2	calling auction for high voltage power generation from RE (i.e., hub-based RE)	government
3	enhancing competition and efficiency of public sector, building a public entity that will participate in the auction process along with private entities	government
4	the qualification requirements must be easy but should also focus on the benefits of local socio-economic development	government
5	emphasizing timely completion of RE projects	government

Source: Author's compilation based on the literature and case study review

Using auction systems as a mechanism for allocating resources and attracting private investment can play a key role in achieving the previously discussed target of 20% and above of total demand from renewable energy sources by 2041, thus moving towards 100% carbon-free energy generation.

8 CONCLUSION AND POLICY IMPLICATION

Auctions have a track record of success in various economic sectors where competition is feasible and desirable. They attract new players and efficiently match supply and demand. They also increase the transparency of the procurement process, reducing the likelihood of challenges in the future as political and institutional landscapes change. This is also applicable to the energy sector, as market competition in well-designed, transparent auction schemes has been seen to drive significant cost reductions.

The use of auctions for renewable energy support is driven by two main arguments: first, they allow for the allocation of support at a competitively determined level, reflecting the true costs of the selected projects. Secondly, they enable a non-discriminatory and competitive approach to controlling the volume of renewable energy deployment, avoiding first-come-first-served schemes, and thus controlling support budgets. These arguments can appeal to policymakers who are facing growing support commitments that can put a burden on consumers/taxpayers. However, there is strong empirical evidence that the benefits of auction schemes outweigh these arguments in many aspects.

Auction schemes have been an effective tool for supporting the development of renewable energy and sharing grid connection capabilities over the past decade. The integration of renewable energy and storage is a new dimension in this area. Renewable energy sources are becoming economically competitive with fossil fuels in many assessments and are also a more environmentally friendly and sustainable option for reducing greenhouse gas emissions. As the world community addresses the challenge of reducing the carbon footprint through sustainable economic development, it is becoming increasingly important to effectively implement policies and strategies for sustainability and energy security. The utilization of renewable energy sources can diversify energy supply and reduce the risks associated with fluctuations in oil prices. Bangladesh, due to its vulnerable geographic location, rising sea levels, and increased frequency of climate-related natural disasters, has been recognized as particularly susceptible to the impacts of climate change. Therefore, there is a feasible and potential option for transition towards low-cost clean energy. Establishing achievable goals for renewable energy production and creating a comprehensive plan, including identifying the best locations for solar and wind energy, are crucial for maximizing its potential.

In the future, the use of auction mechanisms is likely to make renewable energy even cheaper than fossil fuel-based energy. This will be the main driving force in the energy industry. The expansion of renewable energy will lead to an expansion of connections both backwards and forwards. India is an example of this. Implementing a systematic auction scheme will ensure a steady pipeline of renewable energy projects but the auction scheme must be tailored to the specific countries.

The quantitative findings of this paper examine the impact of renewable energy generation on some selected variables. The highest significant impact was proved on CO2 emission, GDP, and renewable energy consumption. Thus, the green economy is the ‘contributory economy’ globally with related arenas. Also, it will lessen the influence of fossil fuels by lowering down its generation scope. Furthermore, the quantitative approach found the promising impact of the auction on the renewable energy generation. The quantitative verdicts of the paper, which scan the impression of different auction design features on outcomes, can assist policymakers in understanding the potential benefits of different design choices for early auction and help them weigh the pros and cons of different auction designs and qualification requirements.

Getting a meaningful effect on sovereign spreads and implementing a green monetary policy could be beneficial. This policy entails more favorable refinancing, collateral conditions, or asset purchase programs for green bonds. Interest-free credit or low-interest credit (2%-3%) may also serve as a supportive tool. Furthermore, this might be helpful to reduce the discount rate and this rate will directly mollify the LCOE of the countries like Bangladesh, where discount rate is higher compared to the global average.

Volume auctions can be highly effective in managing fast-paced growth and expansion of energy capacity in an economy. However, it is crucial to align the target setting with government policies for renewable energy deployment and the current system's technical capabilities for absorbing this energy. By utilizing technology-neutral, location-specific volume auctions, in conjunction with socio-economic development tools and qualification criteria, it is possible to achieve diverse benefits for economies with untapped renewable energy potential, which have not yet implemented auction schemes.

To attract more investors to renewable energy generation, policymakers are reducing subsidies for fossil fuels. During this transition, consumers should be encouraged to be energy efficient and conserve energy. According to Szabo (2022), natural gas can serve as a transitional fuel due to its comparatively cleaner features compared to coal, liquefied natural gas (LNG), and high-speed furnace oil (HFO). Furthermore, it is crucial to diversify energy sources and it is a reminder. To ensure energy security and a sustainable future, countries must prioritize its energy security and cannot rely solely on one source to meet its growing demand, thus requiring a diversification of energy sources.

Kunze & Becker (2015) and Hall & Klitgaard (2012) introduced the concept of energy technological politics, which posits that the utilization of centralized energy sources, such as fossil fuels, results in the centralization of economic and political power. This theory is the foundation for the energy democracy movement, which advocates for the use of renewable energy sources to promote decentralized forms of power and politics. The energy democracy movement argues that renewable energy sources, which are more dispersed, promote decentralization and strengthen democracy, in contrast to centralized energy sources, which lead to weaker democratic systems. The connection between energy and politics is commonly described as a balance between centralization and decentralization. Fossil fuels, being centralized sources, result in centralized political power and weakened democracy, while decentralized sources like solar and wind energy promote distributed political power and stronger democracy. These theoretical connections emphasize the significance of energy choices in shaping political systems. Therefore, a successful transition to clean energy requires both political support at the systemic level and backing from the local community. This will not only result in an economically sustainable outcome, but also drive the future development of renewable energy. Hence, decisions made at the central level play a crucial role and the decision should come from the sustainable energy policies (short, medium, and long term). In other words, sufficient legal regulations are appreciable regarding clean energy production.

A holistic approach to the energy sector's future requires the participation of leaders from major countries to develop a framework that aligns with the changing energy landscape. Institutions like the International Energy Agency (IEA), OPEC, and commodity exchanges have been instrumental in shaping the hydrocarbon industry. However, the transition to renewable energy requires new organizations, political agreements, and frameworks that consider the viewpoints of various stakeholders from both public and private sectors. Failure to do so could lead to geopolitical conflict, creating winners and losers.

During the climate summit, there were signs of disagreement regarding the promised $100 billion in aid for developing countries that was pledged by wealthy nations in 2009, with a deadline of 2020. This commitment has yet to be fulfilled and even this large sum is a fraction of the estimated $1 trillion to $2 trillion required annually for investments in clean energy in developing and emerging market economies, in order to reach net-zero emissions by 2050 (Bordoff & O'Sullivan, 2022). As the urgency and costs of de-carbonization increases, the inability of wealthy nations to provide aid to poorer countries will likely become a major source of geopolitical conflict, particularly as developing nations are disproportionately affected by damages they did not cause. Therefore, wholehearted support both in the form of technology and funding is critically required for the poorer and developing nations for aligning them perfectly with the net-zero vision.

In addition to the findings of this paper, there are several supplementary recommendations that developed countries have implemented to support the expansion of renewable energy. These include:

- Conducting reliable and comprehensive mapping of renewable energy resources, such as solar and wind, to take full advantage of them;
- Using innovative technologies such as energy storage, upgrading the capacity of existing network elements and implementing demand side management;
- Encouraging the development of independent aggregators for energy communities, to facilitate the exchange of energy in day-ahead and intra-day markets;
- Implementing policies such as mandatory solar home systems and net metering for new buildings, industries, and commercial establishments;
- Designating a single point of responsibility for achieving renewable energy targets within a specified timeframe;
- Developing meteorological centers to support high-accuracy forecasting for the national load dispatch center;
- Introducing policies for large-scale energy storage systems for peak shifting and load balancing, and reducing the variability of renewable energy generation;
- Connecting renewable energy deployment to distributed renewable energy systems;

- Developing regional cooperation in the renewable energy sector, such as through the formation of a Renewable Energy Coordination Group, to facilitate more cost-effective trading of renewable energy across a broader area;
- Establishing a quality control department for standardizing renewable energy accessories;
- Introducing green tariffs for the renewable energy sector;
- Encouraging the adoption of electric vehicles as a source of energy storage;
- Providing specialized education and training to improve the labor market in the renewable energy sector;
- Improving employment prospects in the green energy sector;
- Allocating subsidies and incentives for major expansion of the renewable energy sector.

'Current or at this moment solution' concept is not applicable for the energy sector; it is rather linked with long-term planning. Accordingly, developed countries apply energy planning for a long period. Most of the poorer and developing countries like Bangladesh have a wrong and inconsistent energy policy along with the existence of mismanagement in this sector.

In most cases, the countries did not prepare themselves for the alternative sources of energy. For this, when it comes to a discussion for 'alternative energy sources', the poorer and developing countries give unreasonable excuses for not implementing those. If the European Union moves towards the LNG market ignoring the Russian gas supply, then the market will certainly see the price hike of LNG, there is no doubt. Then the LNG will be a nightmare for the poorer and developing nations. In that case, the energy sector will not be benign and protected. Only self-reliance energy supply can assure us to become safe and secured. Therefore, a renewable energy auction scheme with socio-economic development criteria can help to ensure reasonable, safe, and secured energy with diversified gains.

9 LIMITATIONS AND FUTURE RESEARCH DIRECTION

It should be noted that the author selected only six countries from the European Union (EU), i.e., Greece, Italy, Poland, Portugal, Romania, and Spain as sample based on some selected variables and not all EU countries to test the theoretical model represented in *equation 2*. The selected countries have similar climate, coastal regions, and geographical locations, allowing for a consistent load factor for planned solar and wind generation potentiality. Additionally, most of these countries have faced debt crises at different times, impacting their access to external funding. Furthermore, the selected countries have some geographical and debt crisis similarities with Bangladesh, and it also has the potentiality for solar and wind power generation. Therefore, the author prioritized selecting the countries based on whether the auction scheme (considered as dummy variable in the theoretical model) is performing its role for robust deployment of RE or not as a new entrant in that scheme.

The study was limited and did not consider factors such as urbanization, energy efficiency, and technological advancement. While the overall development was accounted for through GDP, further research could include indicators that impact both energy consumption and CO2 emissions. Improving these areas can address the challenges posed by the Jevons paradox and variations in funding. Additionally, the paper did not pay a unique attention to burning topics like expansion of RE and its contribution to the regional economic development. Thus, a study can be completed on this topic as well. Further, the clean energy transition is facing the geopolitics by the pressure of the FF based resource rich countries. The pattern of geopolitics is different for the case of developing countries and developed countries. So, two separate researches can be addressed for the mentioned two types.

The study conducted an analysis of annual data from 2001 to 2020, as the robustness of renewable energy (RE) began during this time period. The auction scheme for the deployment of RE has been in practice in most of these countries since 2016 or later. Data availability is the main factor that prevents the inclusion of the data of recent years. The period after 2019 or 2020 is characterized by the introduction and spread of 'Coronavirus' disease over the world, which can be referred to as the post-covid era. Therefore, it is not clear about the impact of the Covid pandemic on the conduct of RE generation globally. Nevertheless, different reports mentioned that there was energy generation growth from the solar and wind sources. Actually, the author showed his intention to analyze the data in the stable economic situation rather than in the unstable period. Therefore, it is recommended that future studies should investigate the effect of the Covid pandemic on the conduct of renewable energy generation globally.

In relation with the data, it needs to be mentioned that the energy-related up to date data of Bangladesh is not available in the internationally authentic data sources like IEA/bp statistical data source/ IRENA, etc. For this reason, the author contacted various organizational officials in Bangladesh by email to collect data to analyze specifically for the LCOE model. Furthermore, some anomalies of the same data from different sources were found.

Another drawback exists in the quantitative part of the study, i.e., used models. The author used panel VAR model and LCOE model in the quantitative part. The author used those due to the advantages of the models. However, it needs to be noted that those models have some inbuilt disadvantage(s). For example, the limitation of the VAR model is that it assumes a one-way relationship, where the forecast variable is affected by the predictor variables but not the other way around. Again, along with many positive aspects, the limitations of LCOE model are oversimplifying cost, oversimplifying project context, and difficulty to accurately represent distributed systems. While some argue that LCOE does not account for the environmental impact and associated healthcare costs stemming from emissions, it still proves valuable when assessing generation costs from various sources.

The author used a prolonged Cobb-Douglas function, and the criticism of this function is that it imposes an arbitrary level for substitution possibility between inputs. In the same way, there are some critics of the statistical tools/software which the author used for this study. Overall, it can be said that the author used those models/equations/statistical tools that helped to satisfy the assumption of the author's presumed theoretical model justified by the reviewed literature. The author's main focus was to construct an auction model with diversified gains for developing countries like Bangladesh.

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APPENDICES

Appendix 1 Vector Auto Regression Estimates

	$CO2_{i,t}$	$E_{ff,i,t}$	$GDP_{i-w,t}$	$10Y_{i-US,t}$	$R_{COM\ s-w,i,t}$	$R_{GEN\ s-w,i,t}$	$P_{WTI.i,t}$	$d_{As,i,t}$	$d_{IMF,i,t}$
$CO2_{i,t}$ (-1)	0.424527	-11.28898	-1.07316	-60.15111	-1.002341	-1.023655	26.01742	10.45766	6.621081
	-0.26368	-4.90954	-0.29074	-85.0151	-0.51788	-0.51521	-4.66503	-8.45389	-5.58517
	[1.61000]	[-2.29940]	[-3.69111]	[-0.70753]	[-1.93547]	[-1.98688]	[5.57712]	[1.23702]	[1.18548]
$CO2_{i,t}$ (-2)	0.019793	11.81339	0.505749	80.24381	1.907333	1.933374	-31.42261	-11.27328	-6.867775
	-0.25387	-4.7268	-0.27992	-81.8508	-0.4986	-0.49603	-4.49139	-8.13923	-5.37729
	[0.07797]	[2.49923]	[1.80676]	[0.98037]	[3.82534]	[3.89770]	[-6.99618]	[-1.38505]	[-1.27718]
$E_{ff,i,t}$ (-1)	0.002175	-0.652449	-0.004101	1.095411	0.01469	0.014715	0.119798	0.038615	-0.119474
	-0.00572	-0.10652	-0.00631	-1.84461	-0.01124	-0.01118	-0.10122	-0.18343	-0.12118
	[0.38008]	[-6.12486]	[-0.65012]	[0.59384]	[1.30735]	[1.31638]	[1.18355]	[0.21052]	[-0.98589]
$E_{ff,i,t}$ (-2)	0.000521	-0.471954	-0.004781	3.003453	0.02539	0.025125	-0.019237	0.261495	0.049426
	-0.00537	-0.10004	-0.00592	-1.73224	-0.01055	-0.0105	-0.09505	-0.17225	-0.1138
	[0.09689]	[-4.71789]	[-0.80705]	[1.73386]	[2.40613]	[2.39343]	[-0.20239]	[1.51808]	[0.43431]
$GDP_{i-w,t}$ (-1)	0.38564	10.14662	0.168471	111.1343	1.232018	1.244455	-18.67313	-2.311088	-3.405184
	-0.19682	-3.66464	-0.21702	-63.4581	-0.38656	-0.38457	-3.48213	-6.31026	-4.16896
	[1.95935]	[2.76879]	[0.77630]	[1.75130]	[3.18711]	[3.23599]	[-5.36256]	[-0.36624]	[-0.81680]
$GDP_{i-w,t}$ (-2)	-0.112127	5.828466	-0.073944	-32.7445	0.182786	0.196323	-12.53775	-0.822561	-5.915796
	-0.12554	-2.33747	-0.13842	-40.4764	-0.24657	-0.24529	-2.22106	-4.02497	-2.65915
	[-0.89315]	[2.49349]	[-0.53418]	[-0.80898]	[0.74132]	[0.80036]	[-5.64494]	[-0.20436]	[-2.22470]
$10Y_{i-US,t}$ (-1)	3.17E-05	-0.00213	-3.66E-05	-0.268672	0.001594	0.001573	0.005142	0.001685	0.007538
	-0.00032	-0.00593	-0.00035	-0.10273	-0.00063	-0.00062	-0.00564	-0.01022	-0.00675
	[0.09950]	[-0.35896]	[-0.10424]	[-2.61525]	[2.54644]	[2.52712]	[0.91216]	[0.16489]	[1.11693]
$10Y_{i-US,t}$ (-2)	0.000343	-0.00044	-0.000136	-0.295388	0.001722	0.001718	0.005683	-0.000242	0.007773
	-0.00028	-0.00525	-0.00031	-0.09087	-0.00055	-0.00055	-0.00499	-0.00904	-0.00597
	[1.21826]	[-0.08391]	[-0.43698]	[-3.25064]	[3.11120]	[3.11998]	[1.13970]	[-0.02679]	[1.30204]
$R_{COM\ s-w,i,t}$ (-1)	-36.6218	14.35612	-35.70593	785.6674	7.664815	6.393925	-124.741	23.69728	18.27976
	-3.03849	-56.5742	-3.35031	-979.657	-5.96771	-5.93689	-53.7567	-97.4169	-64.3597
	[-12.0526]	[0.25376]	[-10.6575]	[0.80198]	[1.28438]	[1.07698]	[-2.32047]	[0.24326]	[0.28402]
M s-w,i,t	36.45198	-0.515412	36.42058	-909.0077	-8.014753	-7.663785	117.0236	-37.48283	-3.335131

	-2.82872	-52.6685	-3.11901	-912.023	-5.55571	-5.52702	-50.0454	-90.6915	-59.9165
	[12.8864]	[-0.00979]	[11.6770]	[-0.99669]	[-1.44262]	[-1.38660]	[2.33835]	[-0.41330]	[-0.05566]
$R_{GEN\ s\text{-}w,i,t}$ (-1)	36.68897	-13.87635	35.74194	-788.3102	-6.827383	-5.553909	127.8462	-23.37482	-16.55799
	-3.03764	-56.5584	-3.34937	-979.382	-5.96604	-5.93522	-53.7416	-97.3897	-64.3417
	[12.0781]	[-0.24535]	[10.6712]	[-0.80491]	[-1.14437]	[-0.93575]	[2.37891]	[-0.24001]	[-0.25734]
$R_{GEN\ s\text{-}w,i,t}$ (-2)	-36.4867	0.21368	-36.39668	905.6541	8.023511	7.671041	-119.7323	37.07576	2.11666
	-2.8309	-52.7092	-3.12142	-912.728	-5.56	-5.53129	-50.0841	-90.7616	-59.9628
	[-12.8887]	[0.00405]	[-11.6603]	[0.99225]	[1.44308]	[1.38685]	[-2.39062]	[0.40850]	[0.03530]
$P_{WTI,i,t}$ (-1)	-0.014827	0.115371	-0.015298	-0.921759	0.011897	0.011646	-0.719912	-0.562558	-0.194663
	-0.00684	-0.12742	-0.00755	-2.20651	-0.01344	-0.01337	-0.12108	-0.21942	-0.14496
	[-2.16648]	[0.90541]	[-2.02728]	[-0.41774]	[0.88508]	[0.87092]	[-5.94586]	[-2.56389]	[-1.34288]
$P_{WTI,i,t}$ (-2)	0.0195	-0.285376	0.021288	-0.052408	-0.04686	-0.048058	-0.236479	0.311472	0.009976
	-0.00649	-0.12075	-0.00715	-2.09088	-0.01274	-0.01267	-0.11473	-0.20792	-0.13736
	[3.00688]	[-2.36344]	[2.97712]	[-0.02506]	[-3.67906]	[-3.79277]	[-2.06114]	[1.49806]	[0.07262]
$d_{As,i,t}$ (-1)	0.004682	0.021227	0.004696	-0.728276	0.006832	0.006778	0.024259	0.425483	-0.004961
	-0.00379	-0.07059	-0.00418	-1.22228	-0.00745	-0.00741	-0.06707	-0.12154	-0.0803
	[1.23507]	[0.30073]	[1.12338]	[-0.59583]	[0.91752]	[0.91509]	[0.36170]	[3.50066]	[-0.06178]
$d_{As,i,t}$ (-2)	-0.004349	-0.013444	-0.006221	-0.212273	-0.008595	-0.008293	0.004449	0.024656	0.006565
	-0.00404	-0.07526	-0.00446	-1.30317	-0.00794	-0.0079	-0.07151	-0.12959	-0.08561
	[-1.07588]	[-0.17864]	[-1.39587]	[-0.16289]	[-1.08264]	[-1.05002]	[0.06222]	[0.19027]	[0.07668]
$d_{IMF,i,t}$ (-1)	0.008754	0.032619	0.014343	2.948826	0.011618	0.011404	0.135082	-0.041594	0.826649
	-0.00477	-0.08886	-0.00526	-1.53878	-0.00937	-0.00933	-0.08444	-0.15302	-0.10109
	[1.83429]	[0.36707]	[2.72545]	[1.91633]	[1.23947]	[1.22288]	[1.59979]	[-0.27182]	[8.17716]
$d_{IMF,i,t}$ (-2)	-0.004459	-0.085849	-0.009264	-6.019333	-0.016682	-0.016483	-0.08883	-0.101149	-0.176348
	-0.00484	-0.09012	-0.00534	-1.56061	-0.00951	-0.00946	-0.08564	-0.15519	-0.10253
	[-0.92131]	[-0.95257]	[-1.73586]	[-3.85704]	[-1.75472]	[-1.74284]	[-1.03731]	[-0.65179]	[-1.72004]
C	4.5444	58.323	8.6392	-741.2688	-14.44447	-14.12168	15.61053	-55.41238	69.02029
	-3.13636	-58.3966	-3.45823	-1011.21	-6.15994	-6.12813	-55.4883	-100.555	-66.4329
	[1.44894]	[0.99874]	[2.49816]	[-0.73305]	[-2.34490]	[-2.30440]	[0.28133]	[-0.55107]	[1.03895]

R-squared	0.975666	0.577316	0.825851	0.510897	0.999666	0.999687	0.689398	0.542738	0.677944
Adj. R-squared	0.969583	0.471646	0.782313	0.388621	0.999582	0.999609	0.611747	0.428422	0.597431
Sum sq. resids	0.006942	2.406473	0.008439	721.5911	0.026777	0.026501	2.172741	7.135304	3.114384
S.E. equation	0.009819	0.18282	0.010827	3.16577	0.019285	0.019185	0.173715	0.314804	0.207979
F-statistic	160.3795	5.463345	18.96879	4.17823	11969.49	12791.69	8.878202	4.747712	8.420217
Log likelihood	302.266	36.16431	293.3759	-223.3357	240.8407	241.3119	40.81318	-13.28929	24.43128

Akaike AIC	-6.225626	-0.377238	-6.030241	5.326059	-4.87562	-4.885976	-0.479411	0.709655	-0.119369
Schwarz SC	-5.701381	0.147008	-5.505995	5.850304	-4.351375	-4.36173	0.044835	1.2339	0.404877
Mean dependent	10.36947	-0.02659	-0.004457	-0.071848	1.760676	6.445407	-0.008065	0.21978	0.120879
S.D. dependent	0.056299	0.251514	0.023205	4.048778	0.94371	0.970535	0.278792	0.416392	0.327793

Determinant resid covariance (dof adj.)	1.17E-25
Determinant resid covariance	1.42E-26
Log likelihood	1545.867
Akaike information criterion	-30.21685
Schwarz criterion	-25.49864
Number of coefficients	171

Source: Author's edition in EViews 10

***Appendix 2* Variance decomposition of renewable energy generation ($R_{GENs-w,i,t}$) based on structural VAR factors**

Period	$CO2_{i,t}$	$E_{ff,i,t}$	$GDP_{i-w,t}$	$10Y_{i-US,t}$	$R_{COM\ s-w,i,t}$	$P_{WTI,i,t}$	$d_{AS,i,t}$	$d_{IMF,i,t}$	$R_{GEN\ s-w,i,t}$
1	9.065255	5.402705	2.161868	3.894515	79.454740	0.010062	0.000362	0.000052	0.010440
2	13.714170	6.446936	14.038720	8.324861	54.997130	0.029206	0.806064	0.481102	0.005976
3	12.297730	8.834090	15.439660	12.613090	47.076190	0.042211	0.996798	1.223846	0.988492
4	13.352680	8.333160	21.160730	9.980466	41.791510	0.838106	1.038280	1.020333	1.903030
5	17.226470	7.562052	21.190500	8.256186	38.031670	1.501809	1.218823	1.631722	3.082347
6	20.605170	6.689165	20.675370	6.749829	32.992130	3.394963	1.442491	2.011282	5.439600
7	22.543390	6.302723	21.168370	5.605469	28.958490	4.590679	1.517238	1.929017	7.683030
8	22.648530	5.801537	23.145120	4.906273	25.862720	5.312596	1.619985	1.690732	9.594212
9	22.861310	5.472324	25.126820	4.374330	23.746270	5.515236	1.484696	1.485058	10.501850
10	24.516790	5.199403	26.235340	3.817519	22.210880	5.465211	1.961896	1.279671	10.469120

Source: Author's edition, EViews10

Appendix 3 Explanation for Setting Ceiling Price and proposing CfD

Appendix 3.1 Bulk Electricity Sale Rate in Bangladesh[87]

Year	Total Generation Cost (USD/kWh) (a = b+c+d)	Bulk Sale Rate (USD/kWh) (b)	Subsidy (USD/kWh) (c)	Payment Delay (USD/kWh) (d)
2023-2024	0.11	0.064	0.02	0.026
2019-2020	0.051	0.047	0.004	-
2016-2017	0.05	0.044	0.006	-
2014-2015	0.054	0.045	0.009	-

**Conversion rate 1USD = 109.765 BDT.*

The weighted average LCOE for three utility-scale solar PV and one utility-scale on-shore wind projects, as indicated in *Table 14* and *Table 15*, was calculated to be 0.0676 USD/kWh. Currently, the bulk electricity sale price stands at 0.064 USD/kWh (excluding subsidies and payment delays). The author suggests establishing a ceiling price of 74.00 USD/MWh (0.074 USD/kWh). This proposed ceiling price represents a 36.55% increase compared to the LCOE of on-shore wind projects, a 26% decrease compared to the LCOE of a recently signed 340 MW utility-scale solar PV plant, and approximately a 16% increase compared to the current bulk electricity sale rate (excluding subsidies).

By setting the ceiling price at 0.074 USD/kWh, bidders are required to offer a discount percentage relative to the reference tariff. The fixed tariff, calculated as the reference tariff minus the discount, is then compared to a projected capture price. This capture price is determined by averaging the wholesale price weighted by solar generation. If the fixed tariff falls below the forecasted capture price, it results in a surplus within the system, whereas if it exceeds the forecasted capture price, a deficit occurs (Silva 2019). The ceiling price will limit the highest bid (Bartek-Lesi 2020). Additionally, the ceiling price of 0.074 USD/kWh is 0.01 USD/kWh lower than the current bulk electricity sale rate plus subsidy, which amounts to 0.064 USD/kWh + 0.02 USD/kWh = 0.084 USD/kWh. This ceiling price which is higher than that of weighted average LCOE of renewables and lower than that of whole sale electricity price (including subsidy) incentivizes bidders to enter the market initially (**with a 9.76% higher mark-up compare to previously implemented utility-scale RE projects**) and reduces the government's subsidy burden (**by 0.01 USD/kWh instead of 0.02 USD/kWh** in the case of bulk electricity sale rate).

Prior to engaging in day-ahead and intraday power market auctions, the annual **reference price** is determined by computing the weighted average of bulk electricity sale prices, inclusive of subsidies set by the relevant authority, and the weighted average LCOE

[87] Mr. Md. Bellal Hossain and Mr. Raju Ahmed, email to author, 20 February 2024

projected for the upcoming years, converted into USD/MWh. This reference price serves as the basis for evaluating the sufficiency of the support budget. Subsequently, **upon participation in the day-ahead and intraday power market auctions**, the **reference price** for each month is established as the average hourly price observed in the auction market. The precise premium is contingent upon the determined reference wholesale prices, whether prior to or following participation in the day-ahead and intraday power market auctions. Further, the value of each 'guaranteed remuneration' bid is determined based on the estimated annual production of solar and wind energy over a 15-year period. Similarly, each 'general remuneration' bid represents a positive cash flow for the contracting entity over the same 15-year duration (del Rio 2019).