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THE POTENTIALITY AND FEASIBILITY OF AUCTION DESIGN IN THE RENEWABLE ENERGY MARKET OF A DEVELOPING COUNTRY—THE CASE OF BANGLADESH

Theses of the Doctoral Dissertation

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University of Szeged
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1. Introduction

Depending more on fossil fuel-based power plants the developed countries released thousands of tons of carbon dioxide (CO2) and other Green House Gases (GHG) in the troposphere and 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. 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) with low-cost for gaining diversified pay-backs.

1.1 Relevance of the topic

RE technologies, in many parts, have verified themselves to be awfully treasured and from time to time vital. Making RE affordable and economical, the cost must be competitive and not putting further burdens to the country's economy. If RE prices become competitive, they will become affordable to the wider society. RE 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 future economic growth. The global scenario is rapidly changing, and the share of renewables in the energy-mix across the globe is expanding. Bangladesh, as one of the fastest growing economies of the world, is lying in this true case.

The present government's vision is to advance Bangladesh as a developing country by 2021 and a developed country by 2041. Within and beyond the time period, a massive development plan is highly recommended and one of the prime recommendations for Bangladesh is industrial development. However, the industrial development and especially certain sectors can highly energy intensive. Only a secured, reliable, and sustainable energy supply plays a pervasive role for keeping industrial growth and industrial production steady (Simelyli & Dudzeviciute 2017). The major part of the electricity in Bangladesh is produced by gas (57.36%), next 25.16% by heavy fuel oil (HFO), and 7.23% by high-speed diesel (HSD) (Power Cell, Bangladesh on June 2020). But due to the gradually declining of indigenous gas reserves and limited exploration of new gas wells, Bangladesh is steadily moving towards energy importing (like LNG, coal). The policy makers 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. In fact, the sources are not cost effective for the developing countries like Bangladesh. Other side, CO_2 emissions trend from fuel combustion in Bangladesh is upward moving—in 2014 it was 63.10 million tones (Mt) CO_2, 82 in 2018 and 89.30 MtCO_2 in 2019 (IEA 2019).

Bangladesh is the largest delta of the world and it has the potential to get electricity from solar (mostly) and wind. According to 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 daily basis (GHI≈ 4.5 kWh/m^2) which can be converted into reasonable sources of energy via either thermal or PV route.

Cost savings via energy efficiency and implementing competitive renewable energy programs has been pointed as potential fields to create win-win situation where emission reduction and economic development go hand in hand (Beg et al. 2002, Rennkamp et al. 2017). 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 tariff are determined through direct negotiation (between BPDB & Independent Power Producer-IPP); and for this RE price is higher compare to global trends.

So, the research will be a pathway for the developing countries like Bangladesh for achieving the carbon free green energy generation target within the stipulated period for meeting up the future safe & secured energy through a cost-effective auctioning scheme with diverse paybacks.

1.2 The objectives of the dissertation

The main purpose of the study is to build up a feasible auction scheme for the developing countries like Bangladesh mingled with socio-economic development instrument under qualification requirement that ensures diverse paybacks. To attain the main research purpose, obtain more accurate findings, and conduct proper research from the study, the following hypotheses construct the basis of the train of thought:

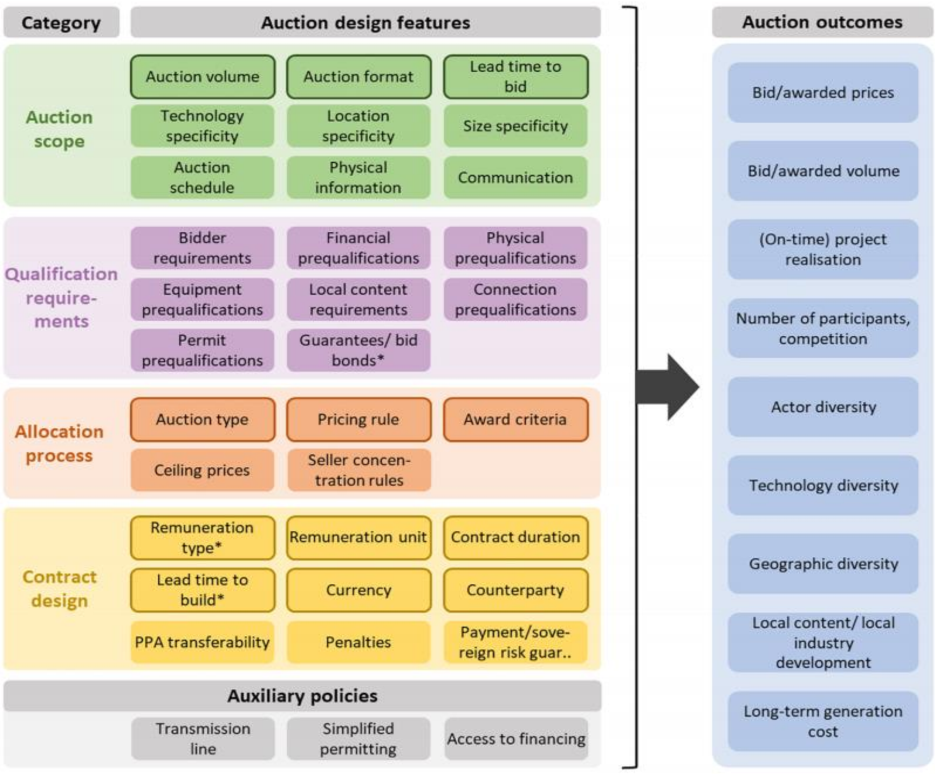
- *H1*: Last few years, the emerging and open economies are getting some benefits for adding electricity into their energy mix from RE sources.
- *H2*: There are auction features by which a potentially beneficial auction can be established for a developing country like Bangladesh due its persistent contribution.

• *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.

1.3 The conceptual framework of the dissertation

To address the research objectives and identified research issues, a conceptual framework were followed that served as a guide for developing a suitable auction outcome for the 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 (*Figure 1*). Further the author reviewed the various country-specific auction implementation reports of AURES II by del Rio & Menzies (2021), Bartek-Lesi et al. (2020), del Rio et al. (2019) for the auction features and outcomes. Further, the author reviewed different auction design features categorized by AURES (2015) and Fleck & Anatolitis (2023).

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

To assess the literatures in connection with the auction features of Haelg (2020) and others perform as the motivating tool-kit for the dissertation to get the final outcome, i.e., auction model for the developing countries like Bangladesh for sustaining the research issues.

1.4 The theoretical model of the dissertation

In this paper, the author categorized the 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. The usage of higher-level RE can care of the impression of circular economy and the higher the consumption of RE ($R_{COM\ S\text{-}W,i,t}$) and lessen the usage of FF ($E_{ff,i,t}$). 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:

$$\Delta \mathrm{lnR}_{\mathrm{GEN}\ s-w,i,t} = \mathrm{Constant} + \alpha_1 \Delta \mathrm{ln10Y}_{i-US,t} + \alpha_2 \Delta \mathrm{lnGDP}_{i-w,t} + \alpha_3 \Delta \mathrm{lnE}_{ff,i,t} + +\alpha_4 \Delta lnR_{COM\ s-w,i,t} + \alpha_5 \Delta \mathrm{lnCO2}_{i,t} + \beta_1 \Delta \mathrm{lnP}_{WTI,i,t} + \beta_2 d_{IMF,i,t} + \beta_3 d_{AS,i,t} + \varepsilon_t \quad --(1)$$

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 (α_1<0), Nevertheless, an extreme liquidity scarcity can distract funding from green energy venture as well (α_1>0). This assorted symbol points to the deficiency of market impartiality for a green monetary policy. When the underlying 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 last three variables have capability to methodically diminish the GHG in the set model.

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 postulates country precise emergency periods when i^{th} country required funding from the IMF and an auction scheme dummy ($d_{AS,i,t}$) variable to epitomize the support instrument for installing RE robustly by the sample countries.

1.5 The Levelized Cost of Energy (LCOE) model of the dissertation

Levelized cost of energy (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). 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).

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 2).

$$\text{LCOE} = \frac{\text{Initial Investment} + \sum_{t=1}^{n} \frac{\text{O \& M Expenditure}_t}{(1+\text{CoC})^t}}{\sum_{t=1}^{n} \frac{\text{Electricity Generated}_t}{(1+\text{CoC})^t}} \quad \text{……….. (2)}$$

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

2. Methodology

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 evidences. 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.

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. The author analyzed the annual data between 2001 to 2020 as the robustness of the RE basically started in these periods. Comparatively six developing and open economies (Greece, Italy, Poland, Portugal, Romania and Spain) of EU are considered as sample for verifying the assumed theoretical model (i.e., equation 1) where the auction scheme is being practicing after 2012.

As it is mentioned earlier that the robustness of RE started in 2000s and afterward and all the sample countries did not occupy RE from that period, so due to missingness of data, the author applied the panel vector auto-regression (VAR) model. 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). 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).

As the main motive of the auction scheme is to generate energy with low cost, the author intended to quantify the renewable (solar & wind) energy generation cost in Bangladesh as a sample (Bangladesh does not follow auction scheme yet) at the second phase of the quantitative part. Thus for the sake of analysis, the LCOE has been calculated from the generation cost of renewable energy from two solar and one on-shore wind power plants recently implemented/under implementation under utility-scale (IPP model) to compare with some countries such as Brazil, Canada, China, Finland, France, India, Italy, the Netherlands, and the USA, which are following an RE auction scheme, to understand the factual cost of energy portrayal in Bangladesh.

3. Theoretical background

In this section, the author initially will discuss the historic view point of auction and later on the author will discuss the state of art of renewable energy of auction scheme.

3.1 Historic view point and economic prospect of auction

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.[1] 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.

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).

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 auction and he used game theory[2] (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).

[1] https://magazine.artland.com/a-short-history-of-art-auctions/

[2] 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.

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 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-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).

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.

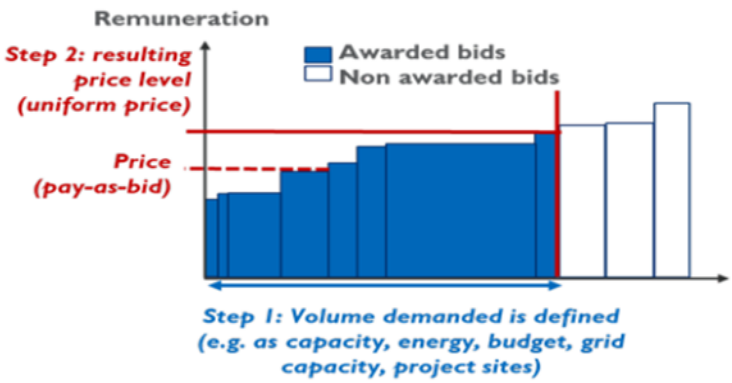
3.2 Current state of art of renewable energy auction

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. In other words, in the auction process, the government sets the auction volume that is demanded (step 1 in *Figure 2*). 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 2*) (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). 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 2020).

The auction scheme has the ability to **balance between cost and effectiveness** (Shrimali et al. 2016). The auction has demonstrated 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).

Figure 2 Price formation of auction



Source: USAID (2019), p. 5

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).

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. 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). Further, IRENA (2017) and IRENA (2013) highlight some avantages 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 project for high investment cost for bidders
- Underbidding risk

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’[3]. 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. For overcoming the situation, the authors suggest for auction (more specifically pay-as-bid auction[4]) for alternative price setting mechanisms as of receiving actual bid for each market generator, again up to the uppermost market clearing bid.

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). Hansen et al. (2020) treated local content requirement (LCR)[5] as a focal tool in RE auction schemes motivating local industrial development by specifying the use of locally produced content. LCR has a contributory role in ‘not in my yard’ (NIMBY) syndrome. In this connection, del Rio (2019) argued for the local community support. Botta (2019) argues that for reducing/abolishing the NIMBY[6] 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. Drawing a suggestion, AURES II (2021) states an obligation to provide a strategic plan with estimation on the impact of the installation on the local employment and industrial value chain.

[3]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]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.

[5]LCR defines 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).

[6]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].

Evaluating the literatures related to auction focusing on the SOWT[7] analysis of auction scheme the results are presented in *Table 1*. The SOWT 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.

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, then 'ceiling price' helps to 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, higher number of bidders, variety of bidder and enhancing the bidding body created by 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).

Table 1 SWOT analysis for auction scheme

Strength	***Weakness***
• *Economical & Cost effective;* • *Static and dynamic efficiency;* • *Market independent & flexible mechanism;* • *Elicit interest among developers;* • *High level of transparent;* • *Balance cost & effectiveness;* • *Effective for high level RE deployment target;* • *Ensure competitive RE price;* • *Stable revenue guarantee for the investors;* • *Works in volume and budget limitation condition;* • *Reduce/abolish government subsidy;* • *Helpful to gain other policies*	• Underbidding risk; • High investment cost for the bidders; • Risk for not winning the bid; • Need a specific number of bidders

[7]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 rest two, i.e., Opportunities and threats are related to external influences.

Threat	*Opportunity*
• *Possibility of lack of competition;* • *If proposal is not being granted, it may carry 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; • Encourage innovation and improve local supply chain; • Higher project realization rate; • Increase the ownership of local people to RE project which will help to get local support

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

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.

4. Results and theses

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. The panel VAR was estimated following the EViews 10.

4.1 Result and theses of the theoretical model part

At the time of 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 2*) 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 modulus were smaller than 1) which also gratified the stability condition of the VAR model.

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). 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 3*).

Table 2 VAR optimum lags 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 3 Panel Dynamic Least Squares (DOLS) where dependent variable $\mathbf{R_{GENs\text{-}w,i,t}}$

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			

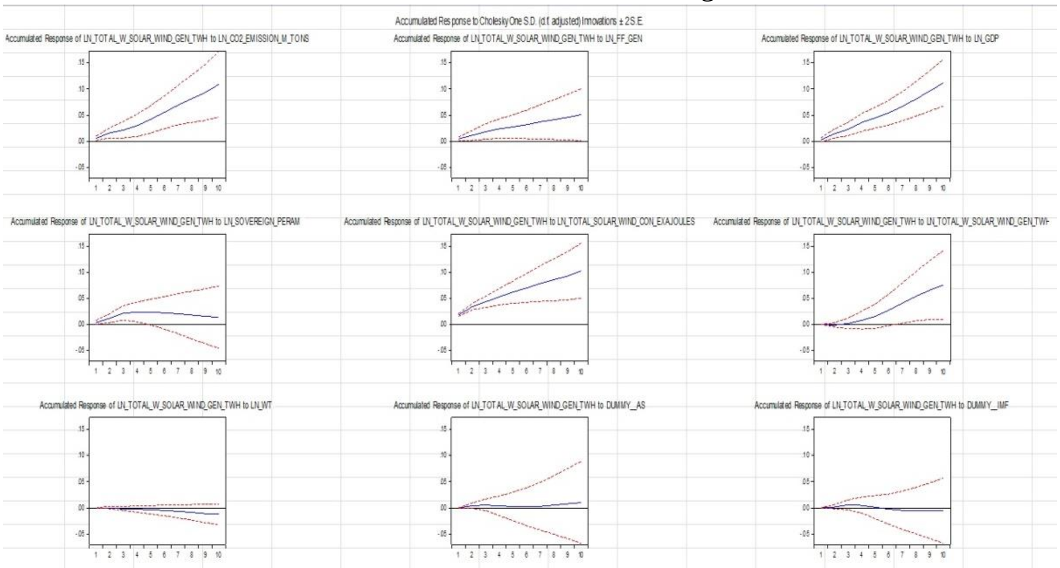
Source: Author's edition, EViews10

Impulse responses present the progress of each variable's stimulus on the total RE (solar & wind) generation in time with a 95% ($\pm$2 standard error) confidence intervals (*Figure 3*). 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 3* 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.

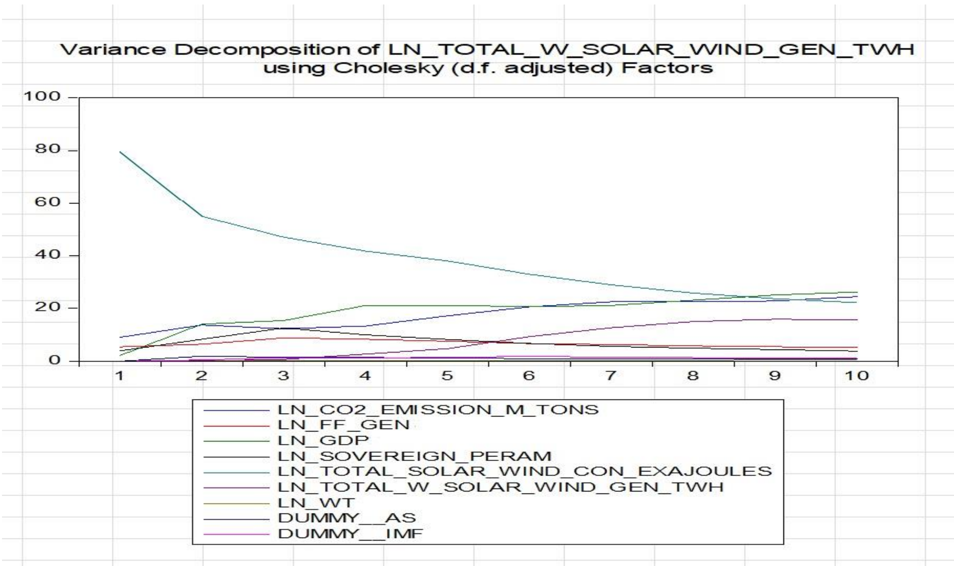
Figure 3 Accumulated impulse response functions of the total RE (solar & wind) generation to model variables on the long run



Source: Author's edition, EViews10

For considering the percentile oscillation in a time series attribute to the particular variables at designated time horizons, variance decomposition underlines that a major (~60%) of total RE (solar & wind) generation is explained by the model on the long-run (*Figure 4)*.

Figure 4 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. *H1* and *H2* are satisfied this section.

4.2 Result and theses of the LCOE model part

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. On the other hand, for the case of utility scale on-shore wind plant, 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).

Another notable segment is CoC/discount rate, 12% CoC was applied for each of the three solar and one on-shore wind plants for Bangladesh, which is higher than the current global trend. Discount rate (CoC) influences the LCOE significantly, because if the rate is high, then the LCOE will be enhanced and vice versa. So, our third hypothesis (*H3*) is satisfied due to the higher LCOE in Bangladesh not practicing auction technique like Inida and the Philippinies.

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.

5. Recommendations and conclusion

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.

Bangladesh, like many other nations, is experiencing rapid economic growth and is 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 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 4*). 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 4 RE target and justification of RE target setting in Bangladesh

Scenario	Cumulative Target (till 2041)	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 1 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

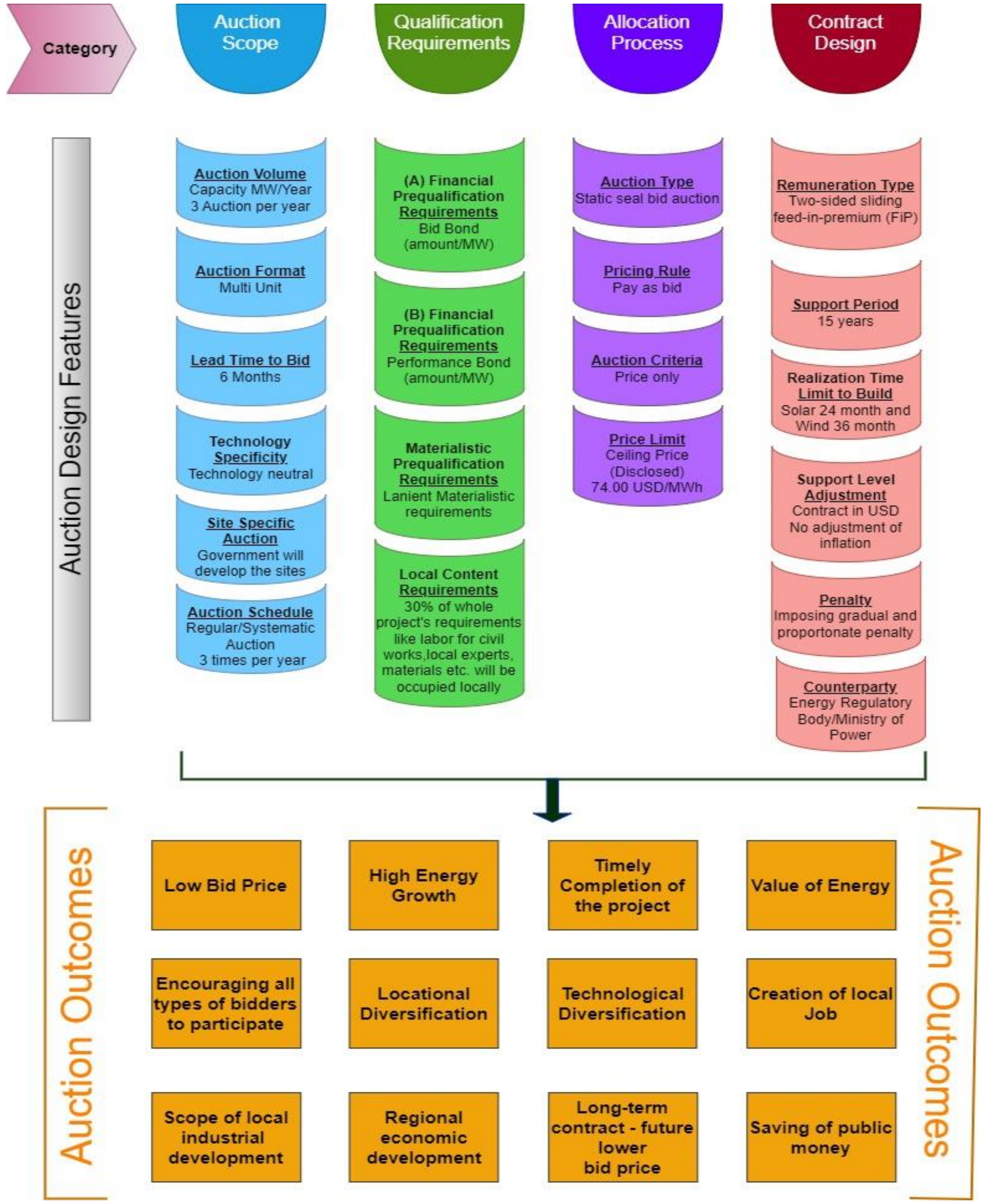
Scenario	Cumulative Target (till 2041)	Justification to fit with RE Target and pathway to meet that target
		concerns. If the contract is not extended, this capacity can be fully replaced with renewable energy sources.
Higher Medium case 35% of RE of total electricity production	• 21283 MW RE • 22136322 $MtCO_2$ emission reduction	As per various analyses, Bangladesh could see rapid economic progress and industrialization in the coming years, which 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, if the generation cost is below 0.10 USD/kWh. This would require significant investment in the development and implementation of renewable energy technology and infrastructure, as well as on-going efforts to improve energy efficiency and reduce demand. Additionally, the government should take initiatives to pledge auction scheme, prepare the electricity market for competition, and provide subsidies (if required) 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

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 5* and *Figure 5*. 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 5*.

Figure 5 Renewable Energy Auction Model and Outcomes for the Developing Countries



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

Table 5 Renewable energy auction model for the developing countries like 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: 06 months	• attracting more bidders; • helping to speculate equipment prices; • helping bidders to reduce auction uncertainties
	Technology Specificity: Technology neutral	• 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
	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

<table>
<tr><th>Category</th><th colspan="2">Auction Design Features</th><th>Paybacks/gains/outcomes</th></tr>
<tr><td></td><td colspan="2">Auction Schedule: Regular/systematic auctioning schedule [3 times per year]</td><td>• 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</td></tr>
<tr><td rowspan="4">QUALIFICATION REQUIREMENT</td><td rowspan="2">Prequalification Requirement (financial)</td><td>Bid Bond [amount/MW]</td><td rowspan="3">• 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</td></tr>
<tr><td>Performance bond [amount/MW]</td></tr>
<tr><td colspan="2">Lenient Prequalification Requirement (material): detail project description, environmental assessment, etc.</td></tr>
<tr><td colspan="2">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)</td><td>• 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</td></tr>
<tr><td rowspan="3">ALLOCATION PROCESS</td><td colspan="2">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]</td><td>• 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 compare to dynamic auction</td></tr>
<tr><td colspan="2">Pricing Rule: Pay-as-bid (PAB)</td><td>• 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</td></tr>
<tr><td colspan="2">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</td><td>• lowering bid price compare to multi-criteria auction;
• preventing underbidding</td></tr>
</table>

Category	Auction Design Features	Paybacks/gains/outcomes
	the budget constraint is surpassed]	
	Price Limit: Ceiling price (disclosed) [*Proposed ceiling piece is 74.00 USD/MWh*]	• 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*]	• zero premium payment to the generators as RE generators participate in ancillary services and market balancing; • no public subsidy, i.e., savings of public money; • strong signal for value of energy; • RE generators can sell energy directly to the wholesale market that helps the generators to be self-reliant for the future
	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	• 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

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 5* evaluates the advantages and prospective benefits revealed in the outcomes of past renewable energy auctions.

According to *figure 5*, 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), are to gauge market interest and initiate the process of determining prices. 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.

'Current or at this moment solution' concept is not applicable for the energy sector — rather long term planning is linked with the sector. The developed countries hold such long period's energy planning. Most of the poorer and developing countries like Bangladesh have wrong and inconsistent energy policy along with the existence of mismanagement in this sector. Most cases the countries did not prepare themselves for the alternative sources of energy. For this, when it comes a discussion for 'alternative energy sources' on the desk; then the poorer and the developing countries highlight unreasonable excuses for not being implemented those. If the European Union moves towards the LNG market ignoring the Russian gas supply, then surly the market will see the price hike of LNG, no doubt. Then the LNG will be a night mere for the poorer and the 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. So, renewable energy auction scheme with socio-economic development criteria can help by ensuring reasonable, safe and secured energy with diversified gains.

6. 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 1*. 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 data, it is needed to mention that the energy related up to date data of Bangladesh is not available in the international authentic data sources like IEA/bp statistics/IRENA data source, etc. For this reason, the author conducted various organizational officials in Bangladesh by email to collect data to analyze specially for LCOE model. Further, there were found some anomalies of same data from different sources. 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. Due to the advantages of the models, the author used those. But it needs to remind that those models have some inbuilt disadvantage(s). Again, the author used prolonged Cobb-Douglas function and the critic of this function is that the function imposes an arbitrary level for substitution possibility between inputs. In the same ways, there are some critics of the statistical tools/software those the author used for this study.

In fine, it can be said that the author used those models/equations/statistical tools that were helpful to satisfy the assumption of the author's presumed theoretical model justified by reviewed literatures. Author's main focus was to construct an auction model with diversified gains for the developing countries like Bangladesh.

References

Altenburg, T., and Engelmeier, T. (2013). Boosting solar investment with limited subsidies: Rent management and policy learning in India. *Energy Policy*, 50 (c), 866-874.

AURES (2015). *Overview of Design Elements of RES-E Auctions*. Auctions for Renewable Energy Support, Karlsruhe.

AURES II (2020). *Auctions for the Support of Renewable Energy: Lessons Learnt from International Experiences*. Auctions for Renewable Energy Support II, Karlsruhe.

AURES II (2021). *Auctions for the Support of Renewable Energy in Spain: Results and Lesson Learnt*. Auctions for Renewable Energy Support II, Karlsruhe.

Bartek-Lesi, M., Dezsi, B., Diallo, A., Szabo, L., and Mezosi, A. (2020). *Auctions for the support of the renewable energy in Hungary: Main results and lessons learnt*. AURES II project report no. D2.2-HU.

Bayer, B., Bertholt, L., and Freitas, B. (2018). The Brazilian experience with auctions for wind power: an assessment of project delays and potential mitigation measures. *Energy Policy*, 122, 97-117.

Beg, N., Morlot, J.C., Davidson, O., Afrane-Okesse, Y., Tyani, L., Deston, F., Sokona, Y., Thomas, J.P., la Rovere, E.L., Parikh, J.K., Parikh, K., and Rahman, A.A. (2002). Linkages between climate change and sustainable development. *Climate Policy*, 2, 129-144.

Bichler, M., Grimm, V., Kretschmer, S., and Suttener, P. (2020). Market design for energy auctions: An analysis of alternative auction formats. *Energy Economics*, 92, 1-14.

Blazquez, J., Bollino, C.A., Fuertes, R., and Nezamuddin, N. (2016). The renewable energy policy paradox. *King Abdullah Petroleum Studies and Research Center,* KS-1650-DP045A, 1-14.

Botta, E. (2019). An experimental approach to climate finance: the impact of auction design and policy uncertainty on renewable energy equity cost in Europe. *Energy Policy,* 133, 1-13.

Burke, P. J. (2013). The national-level energy ladder and its carbon implications. *Environment and Development Economics,* 18 (4), 484–503.

Canova, F., and Ciccarelli, M. (2013). *Panel Vector Autoregression Model A Survey*. European Central Bank Working Paper Series no. 1507, Frankfurt.

Cassidy, R. Jr. (1967). *Auction and Auctioneering.* Second Edition (May 2021). University of California Press, Oakland.

Cooper, H. (1998). *Synthesizing Research: A Guide for Literature Reviews.* Sage, Washington DC.

Csereklyei, Zs., Thurner, P.W., Langer, J., and Küchenhoff, H. (2017). Energy paths in the European Union: A model-based clustering approach. *Energy Economics*, 65, 442-457.

Dinh, D. V. (2019). Analyzed money supply and inflation: evidence from Vietnam economy. *Advances and Applications in Statistics*, 56(2), 125-142.

Fleck, A. K., and Anatolitis, V. (2023). Achieving the objectives of renewable energy policy-Insights from renewable energy auction design in Europe. *Energy Policy*, 173, 1-13.

Goffetti, G., Montini, M., Volpe, F., Gigliotti, M., Pulselli, F. M., Sannino, G., and Marchettini, N. (2018). Disaggregating the SWOT Analysis of Marine Renewable Energies. *Frontiers in Energy Research*, 134(5), 1-11.

Haelg, L. (2020). Promoting technological diversity: How renewable energy auction designs influence policy outcomes. *Energy Research & Social Science*, 69, 1-21.

Hansen, U.E., Nygaard, I., Morris, M., and Robbins, B. (2020). The effects of local content requirements in auction schemes for renewable energy in developing countries: A literature review. *Renewable and Sustainable Energy Reviews*, 127, 1-12.

Held, A., Ragwitz, M., Gephart, M., de Visser, E., and Klessmann, C. (2014). *Design features of support schemes for renewable electricity*. Technical Report Ecofys Utrecht, Netherlands.

Hochsteller, K., and Kostka, G. (2015). Wind and solar power in Brazil and China: interests, state business relations and policy outcomes. *Global Environment Politics*, 15, 74-94.

IEA (2019). *Atlas of Energy.* International Energy Agency, Paris.

IRENA (2013). *Renewable Energy Auctions in Developing Countries.* International Renewable Energy Agency, Abu Dhabi.

IRENA (2017). *Renewable Energy Auctions: Analyzing 2016.* International Renewable Energy Agency, Abu Dhabi.

IRENA (2019). *Renewable Energy Auctions-Status and Trends: Beyond Price.* International Renewable Energy Agency, Abu Dhabi.

IRENA—GCGET (2019). *A New World: The Geopolitics of the Energy Transformation.* International Renewable Energy Agency – Global Commission on the Geopolitics of Energy Transformation.

Kitzing, L., Anatolitis, V., Fitch-Roy, O., Klessmann, C., Kreiss, J., Rio, P.D., Wigand, F., and Woodman, B. (2019). Auctions for Renewable Energy Support: Lessons Learned in the AURES Project. The International Association of Energy Economics, 3rd Quarter, 11-14.

Kreiss, J., Ehnhart, K.M., and Haufe, M.C. (2017). Appropriate design of auctions for renewable energy support—prequalifications and penalties. *Energy Policy,* 101, 512-520.

Kumar, K., and Paramanik, R. N. (2020). Nexus between Indian economic growth and financial development: A non-liner ARDL approach. *Journal of Asian Finance, Economics and Business,* 7(5), 454-464.

Lucking-Reiley, D. (2000). Vickrey Auctions in Practice: from nineteenth-century to twenty-first century E-commerce. *Journal of Economic Perspectives,* 14(3), 183-192.

Martin, H., Coronas, S., Alonso, A., de la Hoz, J., and Matas, J. (2020). Renewable energy auction prices: near subsidy free? *Energies,* 13, 1-21.

Matthaus, D. (2020). Designing effective auctions for renewable energy support. *Energy Policy,* 142, 1-9.

Maurer, L.T.A., and Barroso, L.A. (2011). *Electricity Auctions- An Overview of Efficient Practices.* The World Bank Study, Washington D.C.

Moldovanu, B., and Tietzel, M. (1998). Goethe's Second-price Auction. *The Journal of Political Economy,* 106(4), 854-859.

Mora, D., Kitzing, L., Rosenlund Soysal, E., Steinhilber, S., del Rio, P., Wigard, F., Klessmann, C., Tiedemann, S., Amazo, A., Welisch, M., Kreiβ, M., Fitch-Roy, O., and Woodman, B. (2017). *Auctions for Renewable Energy Support: Taming the beast of competitive bidding*. Technical Report AURES Final Report, Karlsruhe.

NREL (2019). *Champion Photovoltaic Module Efficiency Chart.* National Renewable Energy Laboratory, Colorado.

Pitticrew, M., and Roberts, H. (2006). *Systematic Reviews of Social Sciences: A Practical Guide.* Blackwell. DOI: 10.1002/978047075 4887.

Pollitt, M.G. (2010). *UK renewable energy policy since privatization*. University Energy Research Group Discussion Paper No. 40, Cambridge.

Power Cell, Government of the People's Republic of Bangladesh. Electricity Generation related information. Accessed 5 March 2021. http://www.powercell.gov.bd/

Reichelstein, S., and Sahoo, A. (2015). Time of day pricing and the levelized cost of intermittent power generation. *Energy Economics*, 48, 97-108.

Rennkamp, B., Haunss, S., Wongsa, K., Ortega, A., and Casamadrid, E. (2017). Competing Coalitions: The politics of renewable energy and fossil fuels in Maxico, South Africa and Thailand. *Energy Research and Social Science*, 34, 214-223.

del Rio, P. (2017). Designing auctions for renewable electricity support-Best practices from around the world. *Energy for Sustainable Development*, 41, 1-13.

del Rio, P. (2019). *Auctions for the support of renewable energy in Mexico: Main results and lessons learnt*. AURES II project report no. D2.1-MX.

del Rio, L., and Linares, P. (2014). Back to future? Rethinking auctions for renewable electricity support. *Renewable Sustainable Energy Review*, 35, 42-56.

del Rio, P., Lucas, H., Dezsi, B., and Diallo, A. (2019). *Auctions for the support of renewable energy in Portugal: Main results and lessons learnt*. AURES II project report no. D2.1-PT.

del Rio, P., and Menzies, C. J. (2021). *Auctions for the support of renewable energy in Spain*. AURES II project report no. D2.1-ES.

Shrimali, G., Konda, C., and Farooquee, A.A. (2016). Designing renewable auctions for India: Managing risks to maximize deployment and cost-effectiveness. *Renewable Energy*, 97, 656-670.

Simelyte, A., and Dudzeviciute, G. (2017). Consumption of renewable energy and economic growth. In: 5th International Scientific Conference on Contemporary Issues in Business, Management and Education' 2017. Vilnius Gediminas Technical University, Vilnius, 232-241. Available at: http://cibmee.vgtu.lt/index.php/verslas/2017/paper/viewFile/48/90 [12 December 2021].

Sovacool, B.K., Axsen, J., and Sorrell, S. (2018). Promoting novelty, rigor, and style in energy social science: towards codes of practice for appropriate methods and research design. *Energy Research and Social Science*, 45, 12-42.

Szabó, L., Bartek-Lesi, M., Dézsi, B., Diallo, A., and Mezősi, A. (2020). *Auction for the support of renewable energy: Lessons learnt from international experiences*. Auctions for Renewable Energy Support II (AURES II), Karlsruhe.

Tiedemann, S., Forster, S., and Wigard, F. (2016). *Auctions for renewable support in Italy: instruments and lessons learnt.* AURES Report, D4.1-IT.

USAID (2019). *Designing Renewable Energy Auctions: A Policymaker's Guide.* United State Agency for International Development, Washington DC.

USAID (2020). Renewable Energy Auctions Toolkit: Stages of Auction Design. United State Agency for International Development, Washington DC.

Vickrey, W. (1961). Counter speculation, Auctions, and Competitive Sealed Tenders. *The Journal of Finance*, 16(1), 8-37.

de Vos, R., and Klessmann, C. (2014). How to design a successful auction for renewable energy projects. *Energypost.eu*.

WBG (2014). *Performance of Renewable Energy Auctions: Experience in Brazil, China, and India.* World Bank Group, Washington DC.

Yalili, M., Tiryakis, R., and Gozen, M. (2020). Evolution of auction schemes for renewable energy in Turkey: An assessment of the results of different designs. *Energy Policy*, 145, 1-11.

Publications based on the dissertation

In the peer-reviewed journals (Scimago Q1, Q2, Q3 ranked) and Scopus indexed book chapter

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

II. Tanvir Alam, S. M., and Somosi, S. (2023). Increasing Renewable Energy Auctions for the Accessibility of Low-cost Clean Energy and its local socio-economic impacts. In: Ozudogru, H., Kaya, M.V., Kaya, U. (eds): *Social & Economic Studies within the Framework of Emerging Global Developments (vol.4)*, Peter Lang, Berlin, 205-217.

III. Tanvir Alam, S. M., and Somosi, S. (2023). The Feasibility and Impacts of Renewable Energy Auctions in Bangladesh: Lessons Based on Best Practices. *International Journal of Energy Sector Management*. https://doi.org/10.1108/IJESM-08-2023-0027 [the paper ahead of print]

IV. 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

V. Tanvir Alam, S. M. (2021). Sustainable Energy Security for Economic Development: Trends and Challenges for Bangladesh. *The Journal of Energy and Development*, 46(2), 219-237. https://www.jstor.org/stable/27107174

Conference Presentations

I. Tanvir Alam, S. M. (2024). 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. DOI: https://doi.org/10.19275/RSEPCONFERENCES241

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.