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Multi-dimensional Feasibility of Bangladesh's Solar Power Target

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Abstract

The declining cost of solar technology and declaration of Japan, China, and Korea to not invest in new coal power plants has opened up new possibilities for the expansion of solar deployment worldwide. Bangladesh has also scrapped the plan to build new coal power plant like many other lower middle-income countries in Asia. However, the lower middle-income countries were not able to take the opportunity of the declining solar cost in last one decade and the growth of solar remained in the formative phase for most of the developing countries. Bangladesh has already missed the target to generate 10% from renewable by the year 2020. The increasing emphasis on solar globally and locally has pushed the government to set ambitious targets without considering the techno-economic, socio-technical, and political feasibility of solar. This research has used process tracing based on policy documents and interviews to explore the mechanisms through which solar deployment grew slowly in Bangladesh. Then, this paper found out the feasible, moderately feasible, ambitious, and highly ambitious solar targets of Bangladesh and identified the factors that can increase the multi-dimensional feasibility of solar targets. It shows that market mechanism alone cannot increase feasibility of the target and argues that socio-technical and political feasibility must also be considered in setting realistic target.

Key words: Solar growth, Solar in Bangladesh, Multidimensional feasibility of solar, Solar electricity Market, Technology diffusion

1. Introduction

Initially, the renewable energy policy 2008 had a target to produce 5% of the total electricity by 2015 and 10% by 2020 from renewable. Bangladesh missed the first target. Although the costs of different types of solar technology were higher than the current level at the time of setting those targets, later the cost came down gradually. Later, in 2016, the Power System Master Plan of Bangladesh[1] set a target to produce 10% of Bangladesh's electricity from renewable sources by 2041. To achieve this target, the renewable electricity needs to expand more than 10 times, from 648.7 MW

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[1] GoB, Government of the People's Republic of Bangladesh, 2018. *Revisiting Power System Masterplan-2016,* Power Division, Ministry of Power, Energy and Mineral Resources, Government of Bangladesh.

in 2020 to 7900 MW in low case scenario and 9,400 MW in high case scenario. None of these plans had explicitly set separate targets for expansion of solar, wind, hydro, biogas.

In 2020, Sustainable Renewable Energy Development Authority (SREDA), a coordination body for the development of the renewable energy in the country, working under Power Division of the Ministry of Power, Energy and Mineral Resources (MPEMR), prepared a draft National Solar Energy Roadmap, 2021–2041. This draft has proposed 6,000 MW solar PV capacity by 2041 under business as usual scenario. It is approximately 10% of the total generation capacity. Under medium case scenario, the roadmap proposed 20,000 MW by 2041, approximately 33% of total power capacity from solar energy. In high case scenario, the Roadmap[2] proposed 50% of total power capacity from solar energy, approximately 30,000 MW by 2041. However, this draft roadmap has not been officially declared as the national target yet.

In the meantime, in June 2021 the State Minister for Power, Energy and Mineral Resources informed that the government has decided to produce 40%[3] of the electricity from renewable energy by 2041. Besides, although the Minister mentioned solar as the most important potential energy resources, the declared target did not clarify the share of solar by 2041. Recently, in 2021 JICA has been assigned to make an Integrated Energy and Power Master Plan, which is targeted to be finished by the end of 2023. According to the project description, "The project aims to promote a low or zero carbon transformation of the total energy supply and demand system, by formulating a masterplan."[4]

The various existing and future renewable and solar targets in plans and oral declarations create an ambiguity in common understanding of the knowledge of actual solar target of Bangladesh. Therefore, in the absence of a clear and consistent national solar target, this research takes the base case, medium case, and high case scenario target of National Solar Energy Roadmap, 2021–2041, as the intended target

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2 SREDA, 2020. Draft National Solar Energy Roadmap, Sustainable Renewable Energy Development Authority.

3 Tribune Report, 2023. Nasrul: Bangladesh targeting 40% of power generation from clean energy by 2041, Dhaka Tribune, February 23, 2023.

4 JICA, 2021. Signing of Record of Discussions on Technical Cooperation for Development Planning with Bangladesh: Contributing to a transformation to low or zero carbon energy system through formulating a comprehensive, long-term energy plan. *Japan International Cooperation Agency Website*, Available at https://www.jica.go.jp/english/news/press/2020/20210315_30.html [accessed on November 20, 2021]

up to 2041.The research will explore the multidimensional feasibility of base case scenario (10%) target, medium case scenario (33%) target, and high case scenario (50%) target by 2041 mentioned in the draft solar road map to identify the factors that can increase the feasibility of solar target of Bangladesh.

This research aims to analyze whether the base, medium, and high case scenario solar targets in Bangladesh are feasible in light of the worldwide experience of expanding solar electricity and detailed understanding of economic, technological and socio-political context of the country.

The specific objectives are:

(i) To identify the economic, socio-technical and political mechanisms that shape the growth rate of solar power in Bangladesh;

(ii) Based on the factors and experience of other countries, to identify the factors that can increase the feasibility of solar power in Bangladesh;

(iii) Using the knowledge from (i) and (ii), examine whether the current solar targets are sufficiently ambitious and feasible under realistic assumptions about policies, economic conditions, and technology development.

Bangladesh is currently a lower middle-income country aspiring to become an upper middle-income country by 2030 and high-income country by 2041. According to the master plan[5] Bangladesh needs to generate 70,500 MW of electricity by 2041. Installed capacity in 2022 was 22,482 MW.[6] To keep pace with the growth the estimated required electricity growth is approximately 10%. To meet the growing demand Bangladesh has a plan to increase its dependency on imported LNG, coal, and nuclear. However, because of increasing difficulty in getting new investment in coal, Bangladesh has very recently scrapped the plan to build ten coal power plants. The techno-economic advantages of solar is growing with the world wide falling cost of solar equipment and local cost of deployment. However, the feasibility depends not only on the techno-economic feasibility but also on the institutional capacities of the country. Bangladesh has long history of adopting solar home system but its growth has been comparatively slow compared to other countries where solar technology was relatively new. Therefore, it is important to look at whether the

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5 GoB, Power Systems Master Plan-2016, Japan International Cooperation Agency (JICA) Power Division, Ministry of Power, Energy and Mineral Resources, Government of of the People's Republic of Bangladesh

6 BPDB, 2022. Bangladesh Power Development Board Website, Available at https://www.bpdb.gov.bd/ [Accessed on October 10, 2022]

experience of building solar home system has substantially contributed to developing institutional capacity of the country and whether there is a contribution of learning by doing. Lastly, there are other policies that facilitate cost reduction, profitability, and incentives to invest. And these policies are not market driven, but state has a role to decide what interest groups it wants to serve through what policies. Thus, it is important to also look at the political feasibility of achieving the target.

2. Literature Review

Feasibility of energy transitions

Assessing the feasibility of energy transitions requires analysis from different angles. For example, in climate change mitigation scenarios feasibility of energy transition is assessed with respect to the availability of low carbon technologies and the historically observed rates of their growth[7] But this does not ensure economic feasibility without answering the question about profitability, affordability, and availability of finance. Similarly, what may seem technically and economically feasible does not ensure that the solution is politically feasible if there is no supporting policies, regulations, and institutions. Therefore, to understand feasibility of energy transition there is a need for a multidisciplinary approach.

The cutting-edge framework for assessing feasibility of energy transitions[8] is structured along three questions (i) feasibility of what, (ii) feasibility for whom? and (iii) feasibility of when and where?,[9] This framework considers an energy transition as feasible if there is an agent or a group of agents who are capable of pursuing a given set of actions in a given context. Jewell and Cherp (2020) mention:

> "[…] feasibility is not a question of the political will to undertake a single action but rather a matter of our ability to intervene in the economy in a myriad of interdependent ways. Some of these interventions and their combinations are more politically feasible than others."[10]

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[7] N. Bento and C. Wilson, Measuring the duration of formative phases for energy technologies. Environmental Innovation and Societal Transitions, 21, 2016. pp. 95-112; *M. Sluisveld et al.,* Comparing future patterns of energy system change in 2°C scenarios with historically observed rates of change Global Environmental Change, 35 (Energy Econ. 31, 2009), 2015, pp. 436-449. https://dx.doi.org/10.1016/j.gloenvcha.2015.09.019

[8] V. Vinichenko *et al.,* Delayed introduction of wind and solar power on technology periphery is not compensated by faster growth. Presented at *International Sustainability Transitions Conference-2020*, August 2020.

[9] P. Gilabert and H. Lawford-Smith, Political feasibility: A conceptual exploration. *Political Studies*, Vol. 60(4), 2012. pp. 809– 825. https://doi.org/10.1111/j.1467-9248.2011.00936.x

[10] V. Vinichenko *et al*., Delayed introduction of wind and solar power on technology periphery is not compensated by faster growth. Presented at *International Sustainability Transitions Conference 2020*, August 2020.

In order to operationalize this definition, scholars use a metatheoretical framework which brings together economic, technological and political insights as well as a '*feasibility space'* tool to bring these insights together for assessing multi-dimensional feasibility.

"The three-perspective framework"

Energy transitions, such as expansion of renewable electricity, are co-evolution of techno-economic, socio-technical and political action systems,[11] which each encompass causal mechanisms that constrain or enable rapid deployment of renewable power. In the *three-perspective framework* proposed by Cherp *et al.* (2018), renewable electricity expansion will depend upon:

- Profitability as well as availability of capital and finance (techno-economic feasibility)
- Presence and interaction of relevant actors e.g. project developers, investors, suppliers, land-owners etc. (socio-technical feasibility)
- Presence of adequate policy support which in turn depends on supporting political forces such as state goals, relevant lobbies etc. (political feasibility)

The techno-economic perspective is associated with the market (cost, price, demand, supply, investment). In the formative stage a more expensive new energy technology should be subsidized by the government in order not to put upward pressure on energy prices that may provoke strong opposition.[12] On the other hand, the scope and intensity of government intervention in setting the price is influenced by economic capacities of the government. Bashmakov (2007) explains how the market mechanism keep the energy cost stable over time and introduced the first law of energy transition, according to which "stability of energy costs to income ratio results from the existence of energy affordability thresholds and behavioral constants".[13] If energy cost to income ratio exceeds the threshold, economic activities slow down. On the other hand, if price is low, suppliers are demotivated to invest. If government provide subsidies to keep the price affordable to consumers this may not be sustainable either because government cannot indefinitely fund the difference between the price and cost. When share of new energy (i.e. renewables) will

[11] A. Cherp *et al.,* Integrating Techno-Economic, Socio-Technical and Political Perspectives on National Energy Transitions: A Meta-Theoretical Framework. *Energy Research & Social Science,* Vol. 37, 2018, pp. 175–90. doi: 10.1016/j.erss.2017.09.015.

[12] Hourcade Grubb and Neuhoff. *Planetary Economics*: Energy, climate change and the three domains of sustainable development. Routledge, 2014.

[13] I. Bashmakov, Three Laws of Energy Transitions. *Energy Policy,* Vol. 35(7), 2007, pp. 3583–94. https://doi.org/10.1016/j.enpol.2006.12.023

increases overtime in developing countries, it might be costly for the government to keep the price affordable for indefinite period of time. In this situation, the states often intervene in the market by increasing or decreasing subsidies or reforming power or energy sector to rearrange distributive efficiency according to its political need.

From the socio-technical perspective, technology diffusion occurs as a new technology is innovated and adopted in a place. It may depend on the technology receiving countries' institutional, economic, and other socio-technical capacity to learn a new technology. As a result of enhanced performance costs may also decline. Gradual cost decline explains adoption is not instantaneous. There are reasons why it takes longer time in one country and shorter in other countries. For, example renewable energy cost declined faster in India than in Bangladesh. Mechanisms of learning, as explained by Grubler *et al.* (1999)[14] through learning by doing, organizational improvements, or economies of scale may explain the pace of cost decline. Technological expertise in renewable electricity is diffused through specific actors such as project developers and equipment suppliers. Steffen *et al.* (2018) argued "international private developers are a key first mover in many developing countries"[15] and explored that home country policies of international developers and transfer of tacit knowledge from home country for market opening abroad is one of the key drivers for internationalization trend of RE technology.

"Feasibility Space" – The Space that Maps Feasibility

Feasibility space is a methodological tool first proposed by Cherp and Jewell (2020) in their article "On the political feasibility of climate change mitigation pathways: Is it too late to keep warming below 1.5C?" The political feasibility space illustrates how costs of decarbonization actions and capacity of actors involved in these actions can be used to map a feasibility frontier based on empirically observed phenomena. The feasibility frontier is dynamic because it evolves over time with the change in technologies, infrastructures and institutions.

This framework helps to integrate various components of feasibility into a dynamic multi-dimensional 'feasibility space' which helps to determine whether the proposed plans and targets are within reach. For example, feasibility space was created for coal phase-out in Jewell et al. 2019 and for the global expansion of renewables in Vinichenko *et al.* (2020).

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[14] A. Grubler *et al.*, Dynamics of energy technologies and global change. Energy Policy, Vol. 27, 1999, pp. 247-280.

[15] B. Steffen *et al.,* Opening new markets for clean energy: The role of project developers in the global diffusion of renewable energy technologies. *Bus Politics,* Vol. 20, 2018, pp. 553–587.

Vinichenko *et al.* (2020) argued that the feasibility of rapid global expansion of a new low-carbon technology implies its timely introduction at the rim and periphery, subsequent fast growth, and high level of final market penetration.[16] They also developed a Feasibility Space for take-off of renewable electricity (i.e. the time when it reaches 1% of national electricity supply) based on national characteristics (such as GDP per capita and the size of economy) and the proximity of countries to the core region (such as membership in OECD or the EU). They emphasized that the scientific understanding of these challenges should be further developed based on the recognition of different causal mechanisms behind different phases of renewables deployment. Empirically, this understanding can be advanced through comparative studies of national conditions in the core, rim and periphery.

Technology Lifecycle: Formative and Growth Stage

Technology lifecycle is described as a sequence of different set of mechanism driven stages.[17] According to Grübler (1991), in case of energy infrastructures and other pervasive systems a regular S-shaped pattern does not have a single underlying mechanism, but is an aggregate of a variety of adoption processes. Therefore, diffusion of such systems is best described as a sequence of stages in a *technology lifecycle*, with each stage driven by a different set of mechanisms. Technology adoption processes go through different stages: formative stage and growth stage.[18]

In the **formative phase**, diffusion is slow and level of uncertainty and volatility is high. This stage usually ends with the formation of a technological style evolving from best technological practices, and emergence of a social and institutional framework suitable for expansion. Formative phase is driven by learning, innovation, experimentation and technology diffusion. Formative phase ends with the formation of a viable regime that starts self-sustaining growth.[19]

The **growth phase** begins with accelerated expansion of the technology which results in cost reduction from economies of scale.[20] Growth rates depend on economic

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16 V. Vinichenko *et al.,* Delayed introduction of wind and solar power on technology periphery is not compensated by faster growth. Presented at *International Sustainability Transitions Conference-2020*, August 2020.

17 A. Grubler *et al.,* Dynamics of energy technologies and global change. *Energy Policy,* Vol. 27, 199, pp.247–280.

18 J. Markard, The next phase of the energy transition and its implications for research and policy, *Nature Energy,* Vol. 3(8), 2018. pp. 628-633. https://dx.doi.org/10.1038/s41560-018-0171-7

19 J. Markard, The next phase of the energy transition and its implications for research and policy, *Nature Energy,* 3(8), 2018, 628-633. https://dx.doi.org/10.1038/s41560-018-0171-7

20 V. Vinichenko, *Mechanisms of energy transitions: National cases and the worldwide uptake of wind and solar power*. Budapest, Hungary: Central European University, 2018; A. Grubler,

characteristics of the projects, namely their profitability.[21] Schmidt *et al.* (2014) found quantitative evidence that the largest potential for cost reduction lies in local learning. The conditions that enable local learning, include skilled workforce, sustainable business models, a stable regulatory framework. The impact of local learning is more significant than the global technology learning on the cost of renewable energy in developing. Other scholars,[22] showed that the probability of a country introducing renewables increases over time.

3. Method

This research used quantitative data and interview for quantitative and qualitative analysis. In order to identify which economic, socio-technical and political factors have previously slowed down or accelerated the growth rate of solar power in Bangladesh, this paper used *process tracing* to explain the causal mechanisms of solar power uptake by reviewing the policy documents, planning documents, news reports, brochures, and interviews. The initial review of the documents helped to identify the main technological, economic and socio-political actors involved in solar power development. The review of secondary literature also identified the gaps in information, insights, codified knowledge, and developments required to explain the recent developments. Then I identified the relevant actors who could potentially fill the gapin information and codified knowledge that can help explain the mechanisms. The objectives of doing the interview was to find the causal mechanisms of slow growth of solar electricity in Bangladesh. The interviews particularly focused on exploring the techno-economic, socio-technical, and political factors shaping the solar electricity outcome so far.

I conducted 14 open-ended interviews. Although there were some common questions for all, I had to ask different questions to different interviewees because of their diverse backgrounds and professional engagements. Not all interviewees had similar access to information required and the ones who had greater understanding of rooftop

Diffusion: Long-term patterns and discontinuities. In: N. Nakicenovic and A. Grubler (eds.), "Diffusion of technologies and social behavior", Berlin Heidelberg: Springer, 1991. pp. 451-482.

21 P. Lund, Energy policy planning near grid parity using a price-driven technology penetration model Technological Forecasting and Social Change, Vol. 90, 2015, pp. 389-399. https://dx.doi.org/10.1016/j.techfore.2014.05.004

22 T. S. Schmidt, Low-carbon investment risks and de-risking. *Nature Climate Change*, Vol. 4(4), 2014, pp. 237- 239. https://doi.org/10.1038/nclimate2112; C. Binz and B. Truffer, Global Innovation Systems- A conceptual framework for innovation dynamics in transnational contexts, *Research Policy,* Vol. 46, 2017, pp. 1284-1298

technology did not have similar expertise or understanding of utility scale solar projects. Besides, the actors also work at different capacities at different types of organizations. The interviewees include representatives from SREDA, BPDB, IDCOL, The World Bank, energy specialist in UNHCR and UNDP, an academician from the Energy Institute based in University of Dhaka, a solar power consultant, three project developers and supplier, engineers and project managers of solar power plants, and a young renewable energy entrepreneur to fill the existing gap in explaining the causal mechanisms. Since this research heavily relies on the evolving information and events, it is important to have access to the latest information and knowledge that are yet to be published. For example, there is no single number available for profitability and levelized cost of electricity for solar projects. These are project specific and needed to be collected after interviews and having access to unpublished codified knowledge.

To establish whether the solar power targets in Bangladesh are sufficiently ambitious and feasible this research has compared the historical growth scenario of early deployer with future target of late deployer. I have located the growth rates implied in Bangladesh's solar power targets to see whether they are beyond or within the two historical targets of a developed and a developing country having similar characteristics. The targets within the feasibility frontier can be thought of as feasible, the targets beyond the feasibility frontier – as ambitious and highly ambitious.

4. Mechanisms of Transition to Solar

There are multiple mechanisms through which an energy outcome is realized. To explain the mechanisms of transition to solar I try to find the causal relationship between techno-economic, socio-technical, and political factors and the low growth of solar. Identifying the mechanisms will reveal why solar did not grow in Bangladesh at high rate and why it is not growing fast even after some of the previous conditions have changed in recent past. To explain the mechanisms, I used interviews of 14 respondents to define the mechanisms and then compare some of the mechanisms with other countries where similar mechanisms worked differently or similarly and generated similar or deviating outcome.

4.1 Techno-economic Mechanisms

Global Declining Cost of Solar and Local Risk

The cost of solar decreased in last ten years predominantly due to decrease in the price of PV modules, PV panels, and PV inverters. According to the latest IRENA report *Renewable Power Generation Costs in 2020,* at a global level, cost reductions for modules and inverters accounted for 61% of the global weighted-average total installed cost decline between 2010 and 2020. This means that BoS costs are also an important contributor to declining global weighted-average total installed costs. Between 2010 and 2020, 13% of the global reduction came from lower installation costs, 7% from racking, 3% from other BoS hardware (*e.g.,* cables, junction boxes, etc.) and 16% from a range of smaller categories. The reasons for BoS cost reductions relate to competitive pressures and increased installer experience, which has led to improved installation processes and soft development costs. BoS costs that decline proportionally with the area of the plant have also declined as module efficiencies have increased.[23]

According to the latest IRENA report *Renewable Power Generation Costs in 2020, globally the* costs for electricity from utility-scale solar photovoltaics (PV) fell 85% between 2010 and 2020., this reduction has been primarily driven by declines in module prices – which have fallen by 93% since 2010, as module efficiency has improved and manufacturing has increasingly scaled-up and been optimised – and reductions in balance of system costs. In case of Bangladesh the available data shows that although the recent LOIs offered progressively lower tariffs, the price of utility scale solar PV fell by 58% in last five years. The lowest price offered is $0.0749 per unit (Taka 6.3). This is just half of $ 0.18 (Taka 15) offered in 2015. Until June, 2020, the Government of Bangladesh issued an LOI for a total of 27 large-scale solar IPP projects with total capacity of 1695.77 MW. PPA has been signed for 9 projects while 8 projects are at different stages of scrutiny by the proposal processing committee.[24]

Net Metering Pricing Policy

Recently, Bangladesh introduced a net metering guideline, according to which the rooftop solar producers can produce electricity at low cost and sell their excess

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23 IRENA, Renewable Power Generation Costs in 2020, Available at https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jun/IRENA_Power_Generation_Costs_2020.pdf [Accessed on August 20, 2020]

24 SREDA, Draft National Solar Energy Roadmap, Sustainable Renewable Energy Development Authority, 2020.

electricity at market price which is higher than the LCOE of rooftop solar. Despite seemingly lucrative, solar rooftop with net metering system did not receive significant response from producers in Bangladesh, whereas feed-in-tariff in Vietnam got significant response from the producers. Vietnam developed nearly 10 GW new solar rooftops in just two years since the feed in tariff was offered. In 2019 when feed in tariff was offered, the average LCOE was around 8 cent/kwh and the feed-in-tariff was 9.35 cents/kwh. Total installed rooftop solar panel capacity increased to 925.8 megawatts (MW) from 377.9 MW by the end of 2019. In 2020, when the cost decreased further and the feed in tariff was 8.38 cents, in just one year the total capacity addition was nearly 10 GW. The response in Vietnam was huge. On the other hand, Bangladesh started net metering in 2018 but the response was not significant. According to the SREDA national database, up to October 6, 2021 total 1452 net metering systems were developed with a capacity of 33.963 MW. According to the government published brochure the LCOE for the rooftop is Taka 3.10 (3.6 cents) whereas the retail tariff for commercial on-grid is Taka 10.82 (12 cents), for industrial on-grid it is Taka 8.98 (10.5 cents). When asked about the difference in response despite having higher incentive in net metering, the interviewees shared some insights.

First, the net metering policy shifts the risks to producers in case the actual LCOE realized after installation is higher than the standard level due to weather condition, higher maintenance cost, expenditure on replacing older technology for more efficient ones, and the quality of PV equipment. The interviews revealed that SREDA authority published an LCOE value of Taka 3.10 for a 60-kw rooftop project with 20-year lifetime. However, there is a debate about the way the LCOE has been calculated. The interviewees from IDCOL, BPDB, and the solar equipment suppliers, solar developers pointed out that the standard LCOE value published by SREDA is low because it has not used standard procedure of LCOE calculation and did not take into account some variable costs in electricity procurement and construction and various risk associated with it. Some of the interviewees pointed out that the cost differs depending on the LCOE calculation procedure followed, the lifetime assumed, necessity to replace inefficient technologies, and other variable costs arising from difficulties in installing solar in certain buildings, and unplanned developments in the neighborhood. If all these costs were taken into account the LCOE would have been at least Taka 6 (7 cents). So, there is a difference between the published LCOE (3.6 cents) and the actual LCOE (7 cents).

Even if the LCOE is 7 cents, it is still lower compared to the market price. First, the potential deployer often cannot visibly identify the benefits of installing solar rooftop as the producers mostly consume and pay less for lesser consumption of grid electricity, but do not receive any credit in the form of cash from the power development board. This is an ongoing process and the impact of introducing net metering has not been realized yet. Net metering system is not an economic incentive and it does not require any subsidy from the government. Besides, the cost of production fluctuates with the price of PV modules, panels, and inverters, and the associated cost of importing.

Second, a supplier pointed out that the opportunity cost of investing in solar is high because the payback period is longer (6-7 years) than other alternative investments. If the lifetime of the installed rooftop solar is 20 years, the investor starts to get the benefit after cost recovers in 6-7 years. When an investor compares the other investments on variable inputs in production with the investment on rooftop solar, the immediate benefits from investing in other inputs are more attractive to the investors. For example, a garment owner can quickly recover cost from his investment in fabric and employed labour than from his investment in solar. Although the IRR can be high in case of solar rooftop project, the benefit takes longer time to be realized. Therefore, investors are not very enthusiastic to invest in solar.

Third, a solar irrigation pump developer commented that the risk of solar deployment is higher in Bangladesh compared to other regions because of frequent disaster like cyclone in the South and seasonal floods in all over the country. This requires special features in the designs and construction. This increases the cost. Besides, there always remains possibility of damages in times of flooding, especially for some technologies like solar pump. Solar irrigation pumps are used three to four months in a year and the pump remains idle throughout the rest of the seasons making it more costly. In the absence of transmission and distribution facilities, in most of the cases the irrigation pumps are not often connected to the grid. If the developer needs to connect to the grid, the developer needs to invest on the transmission line as the government does not provide the infrastructural support. These are some of the reasons why cost increases in case of solar irrigation.

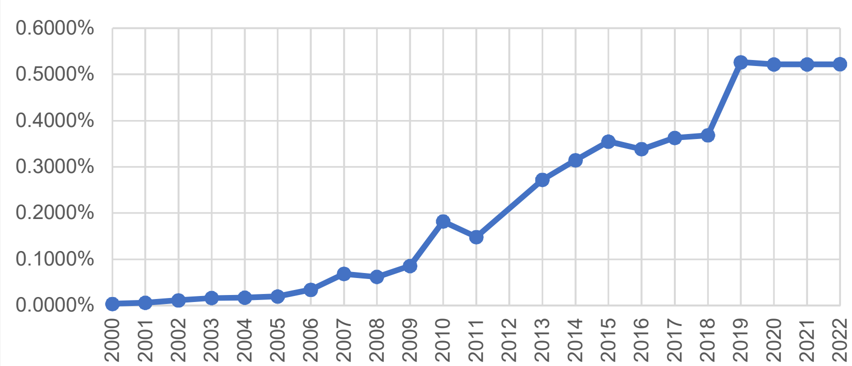
4.2 Socio-technical Mechanisms

Learning by Doing

History of solar power in Bangladesh dates back to the early 1990s with the beginning of installation of off-grid solar home systems (SHSs) mostly in rural areas.

By 2023, Bangladesh has one of the highest numbers of off-grid SHSs in the world: 6,038 million with the total capacity of 263 MW located predominantly in areas outside grid coverage. Currently the total installed capacity of solar is 966 MW, and total installed capacity including captive and renewable sources is 26,700 MW[25]. The current contribution of solar is 3.6% of total capacity. In total installed capacity, off-grid solar electricity generation capacity (365 MW) is 1.36% and on-grid capacity is 2.24% of the nationwide electricity generation capacity. [26]Although slow in development, in 32 years (1990–2022) the off-grid solar technology has been able to reach remote off-grid areas, now there is a challenge to incorporate electricity into the grid.

Figure 4.1: Share of Solar in Electricity Supply (2000-2022)



Source: EMBER Electricity Data (2023)[27]

Although Bangladesh has been developing solar home system from 1990, the contribution of SHS in first ten years was negligible. After 2000 the share of solar has started to gradually increase but the share was less than 0.10% till 2010. After 2010, there has been a rise in electricity supply from solar and it continued throughout the decade till 2020. Figure 4.1 shows the actual share of solar in total

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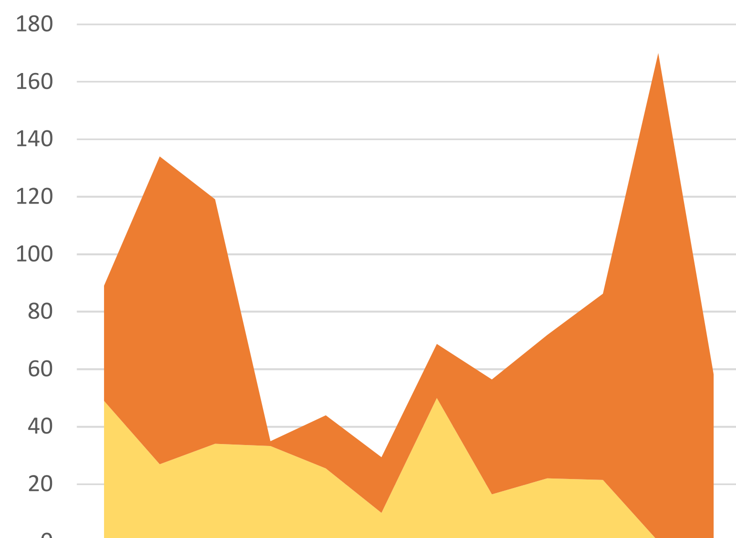
25 Power Division, Power Division Website, Government of Bangladesh, 2023. Available at http://powerdivision.gov.bd [Accessed on April 10, 2023]

26 SREDA, National database of Renewable Energy, Sustainable Renewable Energy Development Authority, 2023. Available at https://ndre.sreda.gov.bd/ [Accessed on April 9, 2023]

27 EMBER, Yearly Electricity Data, 2023. Available at, https://ember-climate.org/data-catalogue/yearly-electricity-data/ [Accessed on April 9, 2023]

electricity supply. The figure shows that since the introduction of on-grid solar the solar share started to increase rapidly.

Figure 4.2: Solar Capacity Addition MWp (2011-2022)



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Large projects	40.03	107.1	85.14	1.64	18.41	19.36	18.79	39.99	49.87	64.77	170	57.52
Small projects	49	26.88	34	33.31	25.56	10.03	50	16.51	22.07	21.48	0	0.71

Source: SREDA, (2023)[28]

By the time solar home system reached 5.5 million, grid connected supply from conventional sources became cheaper and more accessible to the consumers than solar home system. This has made investment in solar home system less attractive. The same happened to mini-grid where large storage requirement made the mini-grid electricity more expensive than grid electricity. Recently, rooftop solar in commercial and industrial buildings and utility projects are more attractive investments than off grid mini-grid and SHS. The interviewees pointed out that rapid change in technology, falling prices, rising efficiency, and rapidly changing transmission and

[28] SREDA, National database of Renewable Energy, Sustainable Renewable Energy Development Authority, 2023. Available at https://ndre.sreda.gov.bd/ [Accessed on April 10, 2023]

distribution system are makingsome technologies more profitable and attractive than the others. Therefore, learning from experience has little impact on the two decades of total growth of solar. As solar home system started to grow in 2000, solar rooftop and irrigation pump started to grow in 2012, and solar park from 2015, there is no linear learning process based on which learning and capacity building could be assessed for all types of solar technologies.

Research and Human Capacity Development

Since the first renewable energy policy was developed in 2008 there has been a number of institutional changes observed in the government and Universities to promote research, human resource development, and capacity building to facilitate development of renewable energy. In 1981, first renewable energy research center was established in University of Dhaka. However, it worked with a limited capacity till 2010. In 2011, Renewable Energy Institute was established to train human resources required for development of renewable. However, in 2013, the institute was renamed to Institute of Energy to increase its scope of work on other energy as well. This change of name indicates the lack of potential of an institute to sustain only with renewable focus. Later, other private universities including United International University, BRAC University, MIST started to offer courses specifically designed to develop human resources in renewable energy. Among these Center for Energy Research based in United International University, established in 2010, made a significant contribution to human resource development. When interviewees were asked about the percentage of graduates working with renewable focus in both University of Dhaka (public) and United International University (private), the responses revealed that when a private university has a record of 80% of their graduates working in the field of renewable energy, only 5% of the graduates from public University has a record of working in the renewable field. This shows that there is an uneven development of capacity across educational institutions and private sector has been playing greater role in the human capacity development in Bangladesh.

4.3 Political Mechanisms

Policies represent the indicators of contested political interests of various interest groups. Although the State Minister of Power and Energy expressed the government's intention to increase the share of solar to 40%, in reality the policies in places do not demonstrate either the desirability or the feasibility of achieving growth of solar in the near future. Rather, in some situations the policies appear to be conflicting to each other and in some situations, they explain the existing dilemma between national capacity development objective and free market objective. The following policies are analyzed by identifying the actors and their contested interests and benefits from the policies in place.

4.3.1 Import Duty

All IPPs (Independent Power Producers), including solar and conventional fuel-based ones, receive import tax or duty waiver on the import of power plant equipment and the spare parts. Thus, solar IPPs enjoy the same benefits as the other IPPs. However, engineering, procurement, construction (EPC) contractors and net metering solar rooftop OPEX operators do not get the same import duty exemption. The interviewees expressed discontent about the discriminatory incentives prevailing over different technologies of solar. While the larger projects get more indirect subsidies, the smaller projects having larger potential to grow do not get similar benefits.

The policy of import duty raises question about the effectiveness of import duty waiver in promoting solar. So far, from 2015 to 2021, 130 MW capacity utility scale solar projects have been deployed in Bangladesh and more are in the pipeline. If this duty waiver were sufficient incentive, we could have observed higher growth of IPPs. The bottleneck does not exist in trade barriers, rather there are other policy choices for which solar did not grow to meet the target in the past. Investors do not clearly make choices based on the import duty waiver alone, there has to be other implementable policies that facilitate growth of solar.

Recently in July 2021, the re-imposition of higher import duty and taxes on inverters has appeared as a burden to Bangladesh's slowly expanding solar sector. Before 2021-22 a special regulatory order had applied a reduced, 11% import duty and tax cost on inverters. The 2021-22 budget which took effect in July, revoked the order and restored the combined levy on the ‘important capital machinery' items to 37%. Contrary to Bangladesh’s ambitious solar target declared by the State Minister of Power and Energy, the imposition of the duty will likely to increase the cost of solar. In India, on the other hand, there is reduced or no import duties on imported plant equipment, tax holidays and other similar favorable policy incentives and regulation have a positive influence on reducing the LCOE.

4.3.2 Income Tax Waiver

The IPPs (Independent Power Producers) selling electricity to the national grid gets tax waiver on their earnings from selling power for the first 15 years of the date of commercial operation. This is an indirect form of subsidy which is equally effective for all kinds of private power generation companies, and not only the solar IPPs[29]. Therefore, this incentive cannot be seen as a preferential treatment to the solar developer. When fossil fuel-based power generation companies get other additional benefits like capacity charge, higher tariff in purchasing power agreement, energy at low price, and infrastructural support like roads, transmission, and distribution facilities, the solar based power generation does not get that benefit. Therefore, the income tax waiver is not a lucrative benefit to the solar IPP developers.

4.3.3 Infrastructural support

"In Bangladesh, the IPPs are burdened with the cost of grid impact study, line root survey, construction of transmission line and evacuation sub-station, and the cost of acquiring right of way for transmission network. These costs are eventually reflected in the higher cost of electricity production."[30]There is a very sharp difference between India and Bangladesh in the government support. While in India the government construct not only the required roads and transportation systems, but also the transmission line and substation for solar projects, in Bangladesh the developer needs to build certain infrastructure on its own expense. These are obviously significant cost components for a large-scale solar plant. In Bangladesh, when the project developers have to build such infrastructure and needs to get the necessary approval from different quarters for building such infrastructure the cost goes up. If we compare other technologies like nuclear, LNG, gas, and oil-based power plants with solar power plants, the absence of this kind of infrastructural support is a clear indicator of government support biased towards the fossil fuel-based electricity generation.

4.3.4 Introduction of net metering system

Net metering system is not an economic incentive for producers. It is rather a risk shifting process from the government to the prosumers who produce for their own consumption. If we compare the current level of officially offered net metering benefit in Bangladesh with that of the feed in tariff benefit offered in Vietnam in 2019 and 2020, the actual economic benefit is actually higher for producers in Bangladesh than for producers in Vietnam.It can be expected that Bangladesh's

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29 Bangladesh Bank, Investment Facilities, *Bangladesh Bank Website*, 2021, Available at https://www.bb.org.bd/investfacility/invesfac.php [Accessed on September 5, 2021]

30 S. A. Chowdhury, Indicative Tariff for Utility-Scale Solar IPP in Bangladesh, *United Nations Development Programme (UNDP),* 2018.

response to the economic benefit of net metering could at least reach closer to Vietnam. However, so far, we have not seen any such growth that could prove that response to net metering is coming along as a positive outcome.

If we compare the feed-in-tariff policy with net-metering system the gap in outcome of these two systems in two countries can be explained by the responses of the interviewees. In techno-economic mechanisms I explained why despite having high potential benefit from net metering system, the responses of investors have not been significant. Here, another factor pointed out by an interviewee has provided another equally important explanation. In the context of rapidly changing technological globalization every year, new innovations in technologies are making older technologies less competitive either by introducing more efficient technologies, or by marketing cheaper technology, or by both. The rapid change in technology over the last one decade has created new expectations among the investors about using more efficient technologies. This has created a ground for speculation. The need for upgrading older projects to improve efficiency has in some circumstances made the older projects less competitive and costly. In this competition for using upgraded technology at lower cost, some investors delay their investment timing. In this context, feed-in-tariff offer for a limited timeframe makes the investment more lucrative as it offers immediate return in exchange of solar electricity and reduces uncertainty associated with future cost recovery as a result of declining cost and compensates against the need for replacing older technology for more efficient ones. Althoughnet metering system in Bangladesh theoretically offers higher long-term benefit, the response to time-bounded feed-in-tariff offer made the investors rush to get the advantage of higher tariff for a longer period of time. While feed-in-tariff reduces the risk of investors, net metering system shifts the burden of risk to the prosumers, making it less attractive investment for investors having multiple investment opportunities to choose from. Bangladesh's policy to introduce net metering is a market approach that does not provide any subsidy and transfers the risk to the prosumers.

4.3.5 Unsolicited proposal

According to the Quick Enhancement of Electricity and Energy Supply (Special Provisions) Act 2010[i], "The Government and all enterprises owned or controlled by the Government may undertake any plan under this Act for quick enhancement of the generation, transmission, transportation and marketing of electricity or energy, or may accept any proposal for undertaking any plan regarding import of electricity or energy from abroad and transmission, transportation and marketing thereof and quick implementation of the same."[31]

This Act may not ensure low cost production when quick implementation of project is given the highest priority. Therefore, unlike competitive bidding this Act opens up opportunities for private actors to make their intended profit. It creates opportunities for selective bidding in which rent seeking transfers public resources to private entities. For solar projects to grow faster the higher tariff offered in purchasing power agreement (PPA) could have potential to incentivize solar industries. However, in case of Bangladesh this has not been the case. Even after getting approval there has been delay is project implementation largely due to other barriers like delay in getting land, preparing land, getting connected to transmission and distribution network etc. The provision of submitting unsolicited proposal sidelining competitive bidding process and getting approval neither speeded up electricity supply, nor did it open up sufficient scope for faster growth of solar in the absence of other necessary incentives. On the other hand, this Act has been used to justify the highly expensive fossil fuel based private generation companies, nuclear, and dependency on imported LNG. Therefore, instead of providing preferential benefit to the solar developer, this policy served the interest of the fossil fuel-based power producers. Besides, when nuclear and fossil fuel-based projects were prioritized and fast-tracked, the development of solar industry got a baffled non-market signal for its potential growth.

5. Feasibility of Solar

The historical growth of solar share in Germany is the first example of a developed country's achievement over the last two decades (2000-2020). Although developed and developing countries have many differences in techno-economic, socio-technical, and political mechanisms, in feasibility analysis the growth of Germany can be taken as an upper limit below which any target can be surely feasible and above which any target can be less feasible and ambitious under certain assumptions.

I take Vietnam's target as an example of a feasible target as this is an example of lower middle-income country in Asia achieving highest growth recently after the cost of solar has gone down. Given some similarities in techno-economic, socio-technical, and political mechanisms between Bangladesh and Vietnam, Vietnam's future target

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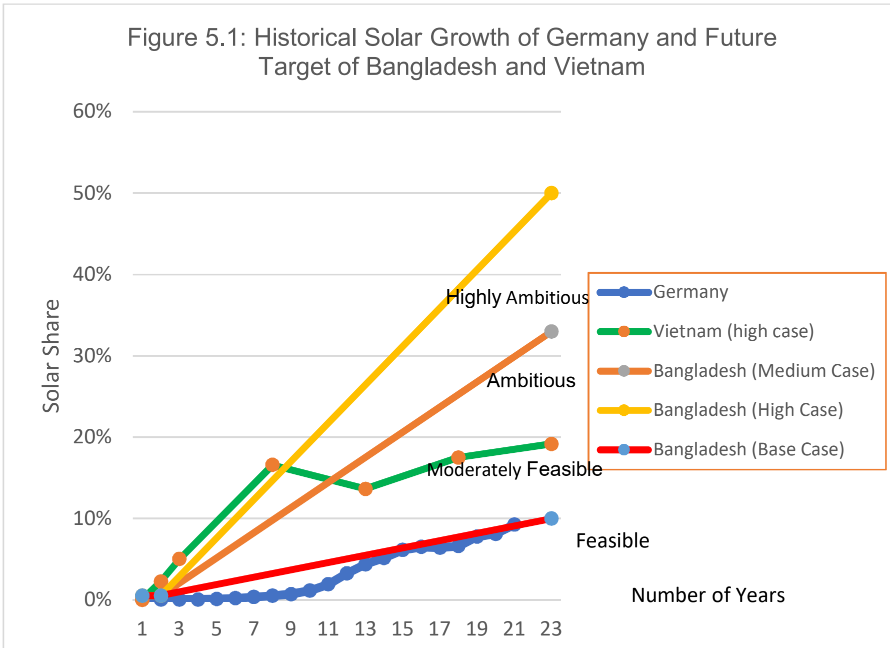
31 GoB, "Quick Enhancement of Electricity and Energy Supply (Special Provisions) Act, 2010", Ministry of Power, Energy & Mineral Resources, 2010.

has been taken as an example of a relatively less feasible target above which any target is ambitious.



Source: Ember (2023)[32], SREDA (2023)[33], GoV (2022)[34]

Note: The X-axis shows the number of years of solar deployment for Bangladesh and Vietnam starting from 2019 and Germany from 2001. The objective is to compare Germany's *achievement in last 20 (2001-2020) years with the intended targets of Vietnam (2040) and Bangladesh (2041) in the future.*

By plotting Germany's share of solar for 21 years (2000-2020) I show the historical growth trend of Germany for 21 years. Vietnam and Bangladesh in 2019 is comparable to Germany in 2001 when Germany was also in the formative phase like

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32 Ember, Global Electricity Review, 2023, *Ember Website*, Available at https://ember-climate.org/data/global-electricity/ [Accessed on April 9, 2023]

33 SREDA, National database of Renewable Energy, Sustainable Renewable Energy Development Authority, 2023. Available at, https://ndre.sreda.gov.bd/ [Accessed on April 9, 2023]

34 Government of Vietnam, Power Development Plan (VIII), Ministry of Industry and Trade, Government of Vietnam, 2022.

2019's Vietnam and Bangladesh. From 2019, every year how the growth can be compared to Germany has been shown for Vietnam's high case and Bangladesh's base, medium, and high case target till 2041. Figure 6.1 depicts the already achieved solar share of Germany and future target for Vietnam and Bangladesh. It shows that Bangladesh's base case target is comparable to Germany's achievement. Germany had to make technological innovations to make solar more efficient and affordable. Germany also had to highly subsidize the initial growth by using feed-in-tariff policy and manufacture its own solar equipment. Germany also had to spend on R&D to take the advantage of early comer in solar market. However, countries like Bangladesh and Vietnam did not provide such huge subsidies or spend on the research and development. As periphery countries both of these lower middle-income countries benefitted from the technology developed in the core (Germany) and semi periphery (China). Therefore, it is not sufficient to compare Bangladesh with Germany and conclude that only Bangladesh's base case target is feasible and all other targets are infeasible.

To be able to find out a feasible target the example of Vietnam can be compared with Bangladesh. The time bound feed-in-tariff in Vietnam has made the investors rush to first build utility scale solar and then emphasize on the rooftop solar. Vietnam is an example of how subsidy through feed-in-tariff has encouraged the investors to rush to take the opportunity. However, in 2021 Vietnam's experience shows that its transmission and distribution facilities are not well equipped to supply the newly connected solar rooftop and solar parks. Electricity of Vietnam (EVN) has urged to reduce production of solar electricity by 70%. Besides, Vietnam is no longer giving feed-in-tariff permission to new producers who entered the market after December 2020. Vietnam's achievement of high growth is now facing new problem of system integration. When the power development plan 8 of Vietnam was drafted and published in early 2020 Vietnam did not did not take into account its unexpected growth in just two years (2019-2020) and kept the future target low while giving more emphasis on coal and LNG. Vietnam has proved that it can reach its target 5 years earlier if right economic incentives are provided to targeted potential investors. Therefore, Vietnam's target of 19.17% can be assumed as a moderately feasible target compared to Germany's target.

Bangladesh's medium case (33%) target is ambitious and high case (50%) target is highly ambitious because the targets are above Vietnam's high case target and much higher than what Germany's solar deployment has achieved in last 20 years. Therefore, based on historical analysis this finding show that the base case target of

Bangladesh is feasible, medium case target is ambitious, high case target is highly ambitious. The 19.17% target of Vietnam can be moderately feasible target if certain conditions are met. Here, I mention some factors that caused Vietnam reach a target faster than any other countries.

1) Both direct and indirect subsidy at the initial stage to keep the price low.
2) Emphasis on rooftop solar in commercial, administrative, and industrial buildings.
3) Increasing coordination among city planning, water resource planning, land reclaiming in making non-agricultural lands available.
4) Insurance against natural disaster.
5) Capacity development of power development board.
6) Government investment in large utility scale solar power plants.
7) Developing capacity of solar manufacturing like Vietnam.
8) Providing other infrastructure support to solar deployment.

The medium target and high target require additional political support of the government. It also depends on the innovation of cheaper and more efficient technologies. Since there are uncertainties about those potential developments the feasibility of these targets can only be assessed based on certain assumptions. The draft national solar road map has already identified those conditionalities that can make those targets feasible. Along with those conditions, here I include other factors that can increase the feasibility of solar target in Bangladesh.

1) Policy to provide more resources for upgradation of grid infrastructure.
2) Using government resources to make available efficient and low-cost storage facilities in the future.
3) Making more lands available through land reform or using reclaimed land.
4) Cancelling coal-based power plant projects that may cause over capacity in the future.

6. Conclusion

The global cost of solar has decreased in last one decade, but the socio-technical and political conditions in Bangladesh were not favorable to make use of the declining cost advantage to grow solar. The expansion of grid to remote areas made the existing solar home system less attractive to consumers because of its intermittency, expense, and limited capacity. In some places the mini-grid technology is exorbitantly costly compared to the grid connected electricity and the government needed to buy the mini-grid electricity at high cost to deliver to the users at low cost. The utility scale solar projects have started to come to operation since 2015 but there are only nine projects that could start operation till 2023. Although the cost of utility scale solar has come down recently, the cost of solar electricity from private IPPs were higher than the public power plant. One of the reasons is that the government did not have to pay for the land whereas the private producers had to pay for the land. The cost of per unit of electricity in IPPs were in the range of Taka 10.36 (12 cents) to Taka 16.11 (19 cents) in the 2020-21. Although according to the latest power purchase agreement the price was set at 10.25 cents, the cost went up because of the load factor, and capacity payment. This shows that the cost is still high for Bangladeshi utility scale solar. However, this higher cost does not reflect the global trend of cost decline, rather it explains the political and socio-technical mechanisms for which the market signal was unfavorable for solar to develop slowly.

In case of rooftop solar, the introduction of net metering system since 2018 could not also produce any significant outcome. Although the government published cost were estimated to be Taka 3.1 (3.6 cents), in reality there is a debate over the cost of rooftop solar. According to the government estimated cost, the profitability is very high if the existing tariff ranges between Taka 7.7 (9 cents) to Taka 10.3 (12 cents). However, this market-based system without any subsidy could not generate any significant outcome either. This shows that profitability does not itself signals demand for investment. It shows that socio-technical capacity of the institutions, human resource capacity, rent seeking through irregularity, and weak regulatory enforcement could not generate positive outcome.

By comparing with international cases this research found that the base case scenario of 10% solar share by 2041 is a certainly a feasible target and 19.17% is a moderately feasible target for Bangladesh. The medium case 33% target is an ambitious target and 50% is a highly ambitious target. The 10% target is feasible if the socio-technical and political conditions remains constant and the policies remain market-based and without much state patronization. The existing policies are neither favorable and nor unsupportive, rather ineffective in promoting solar. The pace of global technological advancement, cost decline, and increase in efficiency will create a market condition to drive solar to its politically and socio-technically feasible level of 10% by 2041.

Beside cost decline and technology advancement, the moderately feasible target of 19.17% will require state subsidy, phase out of existing fossil fuel-based power plants, human capacity development, institutional capacity development, certain measures to ensure land availability, and policies to remove trade barriers, and coordinated infrastructural planning to facilitate solar deployment.

To achieve the ambitious target of 33% and very ambitious target 50%, Bangladesh needs to give the highest priority to the solar development by scrapping all the coal and nuclear power plants, developing grid capacity, fast-tracking system integration, developing necessary infrastructure for storage, transmission, distribution and all other additional required initiative mentioned above for achieving moderately feasible target.

List of Interviewees:

1. Shahriar Ahmed Chowdhury, Chairman, Centre for Renewable Energy Services Ltd. (CRESL), and Director, Centre for Energy Research, United International University, Bangladesh Researcher, policy maker (Drafted National Solar PV Action Plan, 2021–2041).
2. Farzana Rahman, Executive Vice President and Unit Head (investment), Renewable Energy, Infrastructure Development Company Limited (IDCOL).
3. Tauhidul Islam, Project Director, Infraco Asia (providing leadership and capital to develop early stage infrastructure projects into viable investment opportunities).
4. Md. Nurul Aktar, CEO & Director, Energypac Electronics Ltd.
5. Taher Sherpa, Director, Sherpa Power Engineering Ltd.
6. Tanuja Bhattacharjee, Energy Specialist, World Bank.
7. Arif Mohammad Faisal, Programme Specialist, Environment and Energy, UNDP.
8. Saiful Huque, Director and Professor, Institute of Energy, University of Dhaka.
9. Ahmed Jahir Khan, Director, Renewable Energy and Environment, Bangladesh Power Development Board.
10. Mowdud Rahman, Energy Associate, UNHCR.
11. Ismail Ali, Energy Reporter, Share BIZ.
12. Niloy Das, Electric Engineer and a young entrepreneur.
13. A.K.M Kamrul Huda, Project Director, Spectra Solar Park Limited.
14. Jahangir Alam, Engineer and Project Coordinator, Kaptai Solar Power Project.