Contribution of Rooftop Solar Panels in Energy Security of Dhaka City

By

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MPPG 11th Batch

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South Asian Institute of Policy, and Governance (SIPG)

North South University, Dhaka, Bangladesh

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Dedicated

to

my father, Late Mahbub Karim Khondker,
to my beloved daughter, Ayesha Khondker Nuha, and
to my family, and friends,
whose unwavering support, and encouragement have been with me every step of the way.

Declaration

I declare that the dissertation entitled "Contribution of Rooftop Solar Panels in Energy Security of Dhaka City," submitted to the MPPG Program of North South University, Bangladesh, for the Degree of Master in Public Policy, and Governance (MPPG), is an original work of mine. No part of it, in any form, has been copied from other sources without acknowledgment or submitted to any other university or institute for any degree or diploma. Views, and expressions of the thesis bear my responsibility, with the exclusion of MPPG for any errors, and omissions.

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Zahidul Karim Khondker

Abstract

This study investigates the role of rooftop solar panels in enhancing energy security in Dhaka City, Bangladesh. As one of the fastest-growing cities in the world, Dhaka faces significant energy challenges due to rapid urbanization, increasing electricity demand, and heavy reliance on fossil fuels. These factors have led to frequent power shortages, affecting residential, and commercial sectors, and hindering economic activities. To address these issues, rooftop solar panels have emerged as a promising solution for sustainable energy production. Comparative analysis with India, and China demonstrates the potential for growth in Bangladesh's rooftop solar sector. The study explores rooftop solar panels' current penetration, and impact across Dhaka City, analyzing installation trends, energy generation capacity, and contributions to energy security. It examines how these systems can reduce dependence on the national grid, mitigate power shortages, and provide a more stable energy supply. The research also evaluates existing policies governing rooftop solar adoption, identifying strengths, and weaknesses in their design, and implementation. Key findings reveal that while rooftop solar adoption has shown promising growth, several barriers hinder widespread implementation, such as high initial costs, limited public awareness, regulatory hurdles, and insufficient financial incentives. The study highlights successful initiatives by Dhaka Power Distribution Company Limited (DPDC), and Dhaka Electric Supply Company Limited (DESCO), including net metering programs, and innovative projects like electric vehicle charging stations. The research emphasizes the need for improved policy frameworks, increased financial support, and enhanced public awareness campaigns to accelerate adoption rates. Case studies of BRAC University, and Bangladesh University of Engineering, and Technology (BUET) showcase successful implementations, and offer valuable insights into best practices. The study concludes by remarks for policymakers, implementers, and end-users to optimize rooftop solar integration. These include streamlining regulatory processes, enhancing financial incentives, improving technical capacity, and fostering stakeholder collaboration. The findings aim to inform policy decisions, and strategic planning to promote

rooftop solar adoption, ultimately supporting Dhaka's transition to a more sustainable, and secure energy future.

Contents

List of figures, and charts

List of abbreviation

NDCs – Nationally Determined Contributions

MW – Megawatts

DPDC – Dhaka Power Distribution Company Limited

DESCO – Dhaka Electric Supply Company Limited

EV – Electric Vehicle

OPEX – Operational Expenditure

NSM – National Solar Mission (specifically, Jawaharlal Nehru National Solar Mission in India)

SUPRABHA – Sustainable Partnership for RTS Acceleration in Bharat

SRISTI – Sustainable Rooftop Implementation for Solar Transfiguration of India

GW – Gigawatt

PV – Photovoltaic

ISA – International Solar Alliance

SEPAP – Solar Energy for Poverty Alleviation Programme (in China)

R &D – Research, and Development

IEA – International Energy Agency

KWp – Kilowatt-peak (a measure of solar power capacity)

EPC – Engineering, Procurement, and Construction

BDT – Bangladeshi Taka (currency)

DC – Direct Current

AC – Alternating Current

RESCO – Renewable Energy Service Company

PPA – Power Purchase Agreement

IDCOL – Infrastructure Development Company Limited

BRSP – BUET Rooftop Solar Project

JPL – Joules Power Ltd

RMG – Ready-Made Garments

BUET – Bangladesh University of Engineering, and Technology

ACF – Advocacy Coalition Framework (Sabatier’s framework)

Chapter 1 Introduction

1.1 Introduction

Dhaka City faces serious energy challenges due to rapid growth. The demand for electricity is rising quickly because of the increasing number of people, more industries, and more urban areas. However, the energy supply is not keeping up, causing frequent power shortages that disrupt daily life, and businesses. Dhaka relies heavily on fossil fuels like natural gas for electricity, which is risky because these resources are running out, and their prices can change suddenly. To tackle these problems, and ensure a stable energy future, Dhaka is exploring renewable energy options, especially rooftop solar panels. Solar energy is clean, and sustainable, and uses the city's abundant sunlight. Installing solar panels on rooftops of homes, businesses, and factories can produce energy locally, reducing the strain on the national power grid, and lowering dependence on fossil fuels. Despite the benefits, there are challenges to the widespread use of rooftop solar in Dhaka. Many people, and businesses do not know enough about solar power or how to install it. Costs are high initially, and it is hard to get financial help. Government rules, and paperwork also slow down installing solar systems. Better cooperation among the government, energy companies, and residents is crucial to overcoming these challenges. It also reviews current policies, and suggests to help more people use solar energy effectively. By understanding these issues, the research aims to support Dhaka in becoming more sustainable, and secure in its energy supply.

1.2 Background of the Study

Like many rapidly growing urban centers, Dhaka City faces significant energy security challenges. The city's electricity demand has risen sharply due to its expanding population, industrial growth, and increasing urbanization. However, the energy supply has struggled to keep pace, leading to frequent power shortages and load-shedding. This energy deficit affects residential and commercial sectors, disrupting daily life and hindering economic activities. Moreover, Bangladesh's heavy reliance on fossil fuels, particularly natural gas, for electricity generation adds to the vulnerability, as fossil fuel reserves are depleting, and prices are volatile in global markets. These issues highlight the urgent need for sustainable and reliable energy solutions to ensure long-term energy security in Dhaka. One of the most promising solutions to these challenges is adopting renewable energy sources, with rooftop solar panels being a key option. Renewable energy, particularly solar power, offers a clean, sustainable, locally available alternative to fossil fuels. Rooftop solar systems, in particular, have gained attention as they use Dhaka's abundant sunlight throughout the year. These systems are easy to install on residential, commercial, and industrial buildings, allowing for decentralized energy production. Solar energy can reduce the pressure on the national grid, lower the dependency on fossil fuels, and provide a more stable, and sustainable energy supply for the city. Rooftop solar systems play a crucial role in mitigating energy insecurity in Dhaka. By generating electricity on-site, households and businesses can reduce their reliance on the grid and lessen the impact of power shortages. Additionally, solar power reduces the city's carbon footprint, aligning with global sustainability goals. With appropriate policy support, financial incentives, and public awareness, rooftop solar can be vital to Dhaka's strategy to achieve greater energy security and transition towards a more sustainable energy future.

1.3 Statement of the Problem

Dhaka City urgently needs alternative energy sources to address its growing energy crisis. The city's demand for electricity is increasing, but the supply is insufficient. Frequent power outages disrupt daily life and hinder economic activities. The heavy reliance on fossil fuels, particularly natural gas, poses significant risks as these resources are limited and subject to price fluctuations. Exploring renewable energy options, such as solar power, is essential to ensure a stable, sustainable energy future. Rooftop solar systems offer a viable solution to enhance energy security in Dhaka. However, there are several challenges and complexities involved in implementing these systems. Many residents and businesses lack awareness of the benefits of rooftop solar panels and how to install them. Additionally, financial barriers deter many potential adopters, such as the high initial costs and limited access to financing options. Regulatory hurdles and bureaucratic processes can slow down the installation of solar systems. Furthermore, there is often a lack of coordination among stakeholders, including government agencies, energy providers, and consumers. These challenges must be addressed to promote the widespread adoption of rooftop solar energy in Dhaka.

1.4 Objectives of the Research

The main objectives of this research are :

1. Exploring the Current Penetration and Impact of Rooftop Solar Panels in Dhaka City's Energy Landscape: This objective aims to assess how widely rooftop solar panels have been adopted across Dhaka City. It will collect data on the number of installations and the overall solar energy capacity generated. By analyzing this data, we can gain insights into how rooftop solar panels contribute to energy security, reduce reliance on fossil fuels, and support sustainable development in Dhaka.

2. Investigating Policy Implications for Optimizing the Integration of Rooftop Solar Panels to Strengthen Energy Security in Dhaka City: This objective focuses on understanding the policies that govern the adoption and implementation of rooftop solar systems in Dhaka. Based on this analysis, the research will provide insights for optimizing policies to encourage greater adoption of rooftop solar technology.

1.5 Research Questions

This research is guided by two main questions focusing on the impact of solar power panels in Dhaka City.

1. **What are the effects of establishing solar power panels in buildings in Dhaka?** This question seeks to understand the various impacts of installing solar power panels on Dhaka buildings. It aims to explore the installed capacity, generation, and usage of a house building's rooftop solar panels.

2. **To what extent do solar panels add to energy security in Dhaka City?** This question focuses on assessing the role of solar panels in enhancing energy security in Dhaka.

1.6 The Promising Role of Rooftop Solar Systems in Bangladesh: Challenges and Opportunities

Rooftop solar systems have emerged as a significant solution to address energy challenges in Bangladesh. As the country grapples with increasing energy demands and environmental concerns, the potential of rooftop solar systems becomes increasingly apparent. Alam (2022) emphasizes that rapidly installing 2,000 megawatts (MW) of rooftop solar capacity could substantially reduce 15 million tons of CO_2 emissions between 2023 and 2030. This reduction is crucial for Bangladesh to meet its Nationally Determined Contributions (NDCs) under the Paris Agreement. Adopting rooftop solar is not just an environmental necessity but also a strategic approach to bolster energy security in the country.

1.6.1 Energy Demands in Dhaka City

Hossain and Rahman (2021) highlight the pressing energy demands in Dhaka, the capital city of Bangladesh. The city's rapid urbanization and population growth have put significant pressure on the existing energy infrastructure. Traditional energy sources often cannot meet the growing demand, leading to frequent power outages. In this context, decentralized energy solutions like rooftop solar systems can play a vital role. By harnessing solar energy at the individual or community level, Dhaka can alleviate some of the strain on the national grid and provide residents with a more reliable energy supply.

1.6.2 Economic Benefits of Rooftop Solar

Beyond addressing energy shortages, rooftop solar systems offer a range of economic benefits. Begum (2019) points out that these systems can provide a buffer against rising energy costs for households and businesses. With energy prices continuously fluctuating, having a reliable renewable energy source can protect consumers from sudden price hikes. Moreover, deploying rooftop solar can stimulate job creation in the energy services sector. As more households and businesses invest in solar technology, there will be an increased demand for installation, maintenance, and technical support services. This not only generates employment opportunities but also contributes to the country's overall economic growth.

1.6.3 Environmental Benefits

The environmental advantages of rooftop solar systems are also significant. By reducing reliance on fossil fuels, these systems contribute to lower greenhouse gas emissions. This aligns with Bangladesh's commitment to mitigating climate change and adhering to international climate agreements. The transition to renewable energy sources is critical for a country like Bangladesh, which is particularly vulnerable to the impacts of climate change, such as flooding and extreme weather events. Therefore, rooftop solar can be seen as a proactive measure to enhance climate resilience while reducing environmental degradation.

1.6.4 Challenges in Integration

Despite the clear benefits, there are significant challenges in integrating rooftop solar panels into Bangladesh's national grid. Jamal et al. (2015) identify inadequate infrastructure as one of the significant barriers to successful integration. Additionally, regulatory hurdles pose a significant challenge to the growth of rooftop solar. The existing regulatory framework may not support solar energy initiatives sufficiently, discouraging potential investors and stakeholders from participating in the market.

1.6.5 Regulatory Reforms for Growth

Amin et al. (2021) stress the importance of adequate regulations in attracting foreign investment into renewable energy projects in Bangladesh. The lack of clear, supportive policies can create uncertainty for investors, making them hesitant to commit to solar projects. For rooftop solar to thrive, regulatory reforms are essential. Policymakers must work to create a more favorable investment climate by establishing clear guidelines, providing incentives for solar adoption, and simplifying the approval processes for new installations. By addressing these regulatory challenges, Bangladesh can unlock the full potential of its rooftop solar resources.

1.6.6 Public Awareness and Education

Another critical aspect to consider is public awareness and education regarding rooftop solar systems. Many potential users may lack information about solar technology's benefits and availability. Educational campaigns are necessary to inform the public about how rooftop solar works, its financial benefits, and its environmental impact. Increasing awareness will encourage more individuals and businesses to invest in solar systems, leading to higher adoption rates. This educational effort should also include training programs to build local solar installation and maintenance capacity, ensuring the workforce has the necessary skills to support the growing solar market.

1.6.7 Collaboration Among Stakeholders

Collaboration among various stakeholders is crucial for successfully implementing rooftop solar initiatives. This includes partnerships between government agencies, private companies, non-governmental organizations, and local communities. Each stakeholder plays a unique role in promoting and facilitating solar adoption. For instance, government bodies can provide the regulatory framework and financial incentives, while private companies can offer innovative technologies and services. Local communities can contribute by advocating for solar projects and participating in decision-making. By fostering collaboration, stakeholders can create a more conducive environment for rooftop solar deployment.

1.7 Significance of the Study

This research is essential for several reasons, particularly in the context of sustainable development in Dhaka City. As one of the fastest-growing cities in the world, Dhaka faces significant energy challenges. The city's rapid population growth and urbanization have led to increased demand for energy, resulting in frequent power outages and a heavy reliance on fossil fuels. This study aims to contribute to a more sustainable energy future for Dhaka by exploring the potential of rooftop solar panels. Renewable energy sources, especially solar energy, can play a vital role in addressing energy shortages and reducing environmental impact. The findings of this research will be particularly relevant for policymakers. As they develop strategies to enhance energy security and promote sustainable practices, this study will provide valuable insights into the effectiveness of rooftop solar policies. Understanding the challenges and benefits of solar energy adoption can help policymakers design better regulations and incentives. This, in turn, can lead to increased investments in renewable energy and improved access to clean energy for residents. Furthermore, this study will benefit stakeholders, including local businesses, community organizations, and residents. By highlighting the advantages of adopting solar energy, the research can encourage businesses to invest in solar panels and contribute to a more sustainable economy. For community organizations, the research will provide a foundation for advocacy efforts to promote renewable energy adoption among residents. Finally, researchers will find this study relevant as it adds to the growing knowledge of renewable energy implementation. By examining the specific context of Dhaka, this research can serve as a case study for other cities facing similar energy challenges. It will provide valuable lessons and best practices that can be applied in other urban settings. The study aims to impact energy policy, community engagement, and sustainable development in Dhaka City.

1.8 Scope and Limitations of the Study

This study focuses on understanding how rooftop solar panels are used in Dhaka City to address its energy challenges and improve energy security. It tried to find the current status of rooftop solar installations across different areas of Dhaka, aiming to gather data on the number of systems installed and their total energy generation capacity. Furthermore, the research aims to explore rooftop solar panels' impact on energy consumption patterns in Dhaka. It aims to determine whether these installations help reduce reliance on the national power grid, mitigate power shortages, and contribute to a more stable energy supply. Understanding these effects is crucial for evaluating the overall effectiveness of solar energy in enhancing the city's energy security. In addition to assessing the adoption and impact of rooftop solar panels, the study will analyze existing policies and regulations governing their installation and operation in Dhaka. This aspect of the research aims to enhance policy frameworks to facilitate greater adoption of solar technology and address barriers hindering its widespread implementation. However, the study faced several limitations that need to be considered. Firstly, data availability and reliability posed challenges, as comprehensive information on rooftop solar installations in Dhaka has not been found. This has affected the thoroughness of the analysis and the generalizability of the findings. Time constraints represent another limitation, potentially restricting the depth of analysis or the scope of fieldwork conducted. Despite these limitations, this study tried to contribute valuable insights into the role of rooftop solar panels in promoting sustainable energy practices and enhancing energy security in Dhaka City. Addressing these scope and limitations, the research informs policymakers, stakeholders, and future research efforts in renewable energy adoption in urban environments.

1.9 Organization of the Study

(1) This research work consists of seven separate chapters.

1. **Chapter One:** It includes the Introduction, Background of the Study, Statement of the Problem, Objectives of the Research, Research Questions, The Promising Role of Rooftop Solar Systems in Bangladesh: Challenges and Opportunities, Energy Demands in Dhaka City, Economic Benefits of Rooftop Solar, Environmental Benefits, Challenges in Integration, Regulatory Reforms for Growth, Public Awareness, and Education, Collaboration Among Stakeholders, The Way Forward, Significance of the Study, Scope, and Limitations of the Study, Organization of the Study, and Conclusion.

2. **Chapter Two:** Chapter two covers Solar Adoption Globally, Rooftop Solar Energy Adoption in India, Rooftop Solar Energy Adoption in China, Key Variables Influencing Successful Policy Implementation in Rooftop Solar Energy Initiatives, Policy Standards and Objectives, Resources, Inter-organizational Communication, and Enforcement Activities, Characteristics of Implementing Agencies, Economic, Social, and Political Conditions, Disposition of Implementers, Challenges, and Opportunities in Policy Implementation for Rooftop Solar Energy in Developing Countries, Comparative Analysis, Comparative Analysis of Rooftop Solar Energy in India, China, and Bangladesh, Regulatory Framework, Financial Support, Grid Connectivity, Energy Security Impact, Capacity Building, and Current Rooftop Solar Capacity.

3. **Chapter Three:** This chapter discusses Theories of Policy Implementation. Detailed ways and means of research methodology are discussed in chapter three, which includes research design, the unit of analysis, an overview of the research area, sampling, data collection, and analysis method.

4. **Chapter Four:** This includes Research Methodology, Introduction, Research Plan, Research Design, Approach of Inquiry, Unit of Analysis, Analytical Framework Based on Winter's Integrated Implementation Model, Implementation Theory in Practice, Research Area: An Overview, Sampling Method, Data Collection Method, Data Collection Tools, and Techniques, Data Analysis Method, Ethical Considerations, and Conclusion.

5. **Chapter Five:** It covers DESCO & DPDC findings, Dhaka Power Distribution Company Limited (DPDC), Net Meter Installation Information, Rooftop Solar System in DPDC, Net-

Meter Installation Data (Up to Dec), Net-Meter in Government & Private Sector (Up to Dec), Completed Projects, DESCO, Net Meter Data of DESCO, Solar Installed Capacity by Desco, Solar Energy Adoption, and Infrastructure Developments in DESCO Area, Solar Installed on Consumer's Rooftops, Rooftop Solar Installed by DESCO at Own Establishment, Net Metering Information, Net Metering (OPEX Model), Solar Battery Charging Stations Installed by DESCO, Electric Vehicle (EV) Charging Station, Comparison of Solar Energy Initiatives by DPDC, and DESCO, Rooftop Solar Systems, and Total Capacity, Net-Meter Installations, Solar Projects by the Companies, Solar Battery Charging Stations, and Overall Contribution to the Renewable Energy Sector.

6. **Chapter Six:** It includes Policy Findings, Gaps in Bangladesh's Rooftop Solar Regulation, Capacity Limitations, and Net Metering Policy, High Import Duties on Solar Equipment, Lack of Clear Guidelines, and Complex Approval Processes, Inadequate Financial Incentives, and Support, Insufficient Awareness, and Technical Capacity, Political Will, and Policy Support, and Regulatory Constraints on System Capacity.
7. **Chapter Seven:** This chapter comprises Case Studies of BRAC University and BUET, Brac University's Rooftop Solar Panel System, BUET's Rooftop Solar Panel System, OPEX Model, and OPEX Model in Bangladesh.
8. **Chapter Eight:** This section covers the Rationale for Choosing Winter's Integrated Implementation Model, Comprehensive and Holistic Approach, Emphasis on Feedback Mechanisms, Contextual Adaptability, Focus on Multi-Level Dynamics, Practical Application, Comparison with Other Theories, and Alignment with Study Objectives.
9. **Chapter Nine:** It includes Policy Design and Objectives (Top-Down Perspective), Local-Level Dynamics, Stakeholder Engagement (Bottom-Up Perspective), Interplay Between Policy and Practice (Hybrid Perspective), and Contextual Factors.
10. **Chapter Ten:** This chapter summarizes Findings, Recommendations, and Final Thoughts.

1.10 Conclusion

Dhaka City faces significant energy challenges due to rapid urbanization, increasing electricity demand, and reliance on fossil fuels, leading to frequent power shortages. To address these issues, rooftop solar panels are being explored as a sustainable energy solution. Solar energy offers an environmentally friendly and decentralized alternative, reducing dependence on the national grid and enhancing energy security. However, adoption faces several challenges, including high initial costs, limited awareness, regulatory hurdles, and lack of coordination among stakeholders. This study focuses on the current penetration and impact of rooftop solar panels in Dhaka, analyzing installation trends, energy generation, and contributions to energy security. It also evaluates existing policies and provides recommendations to improve financial incentives, streamline regulations, and promote stakeholder collaboration. Despite the benefits, challenges such as inadequate infrastructure, unclear regulations, and limited public awareness hinder widespread adoption. Addressing these barriers through policy reforms, financial support, and education can accelerate the transition to renewable energy. This research aims to guide policymakers, businesses, and communities in fostering a more sustainable and secure energy future for Dhaka City.

Chapter 2 Solar Adoption Global

2.1 Introduction

The global transition toward renewable energy has positioned rooftop solar (RTS) systems as a cornerstone of sustainable development, offering decentralized energy solutions that enhance energy security, reduce carbon footprints, and empower communities. As leading Asian economies, India and China have emerged as pivotal players in advancing rooftop solar adoption, driven by ambitious policy frameworks, technological innovation, and socio-economic imperatives. Meanwhile, although smaller in scale, Bangladesh reflects the challenges and opportunities developing nations face in scaling RTS adoption. This chapter examines the trajectories of rooftop solar energy in India, China, and Bangladesh, analyzing their policy landscapes, implementation strategies, and socio-economic impacts. The chapter begins with a detailed exploration of India's RTS sector, highlighting its record growth in 2024, state-led successes in Gujarat and Maharashtra, and flagship initiatives like the Pradhan Mantri Surya Ghar Yojana. It then delves into China's rapid ascent as a global RTS leader, underpinned by programs such as the Golden Sun Programme and the Whole County PV Initiative, which have integrated solar energy into poverty alleviation and urban resilience strategies. Bangladesh's evolving RTS landscape is analyzed to contrast the progress and hurdles in smaller economies.

2.2 Growth and Policy Framework of Rooftop Solar in India

India's rooftop solar (RTS) sector has continued its impressive growth in 2024, reaffirming its commitment to renewable energy. The RTS sector has seen significant achievements this year, including an installed capacity increase of 2.99 GW from 2023 to 2024, reaching a total installed RTS capacity of 11.87 GW as of March 31, 2024 (Roy, 2024). This increase marks the highest growth in RTS installations reported in a single year, reflecting the effectiveness of government policies and the dedication of stakeholders. Despite these achievements, much work remains to unlock the full RTS potential, which is estimated at approximately 796 GW across India. The government's ambitious energy targets, aiming for 500 GW of renewable energy capacity by 2030 with a solar target of 280 GW, position rooftop solar as a central component of India’s transition toward clean energy.

Figure 1 Solar panels installed atop an apartment building in J.P. Nagar, Bengaluru (Roy, 2024)

The RTS program in India began with the Jawaharlal Nehru National Solar Mission (NSM) in 2010, an initiative focused on building a strong solar infrastructure to reach an initial goal of 20 GW. By 2015, the target was revised to 100 GW by 2022, emphasizing achieving 40 GW, specifically from rooftop solar installations (Roy, 2024). While the timeline for reaching this target has been extended to 2026, RTS capacity growth has been fueled by supportive policies, financial incentives, and technological advances. Programs like the Sustainable Partnership for RTS Acceleration in Bharat (SUPRABHA) and the Sustainable Rooftop Implementation for Solar Transfiguration of India (SRISTI) have provided financial support, technical assistance, and training programs that empower local stakeholders and improve adoption rates. Nevertheless, the RTS sector must increase to contribute around 100 GW by 2030 to meet India's larger renewable energy goals and net-zero emissions by 2070.

2.3 State-Level Progress and Challenges in RTS Adoption

State-level efforts are crucial to India’s RTS success, and Gujarat, Maharashtra, and Rajasthan have made substantial progress. With its installed RTS capacity of 3,456 MW, Gujarat leads the country due to favorable policies, quick approval processes, and high consumer awareness. The state's pioneering achievements include establishing Modhera as India's first solar-powered village, with 1,300 rooftop solar systems installed, showcasing the potential of community-level solar initiatives. Maharashtra and Rajasthan follow with 2,072 MW and 1,154 MW, respectively, demonstrating the positive impact of proactive policies, high solar irradiance, and streamlined approval processes. Other states, such as Kerala, Tamil Nadu, and Karnataka, have also made steady progress. However, Uttar Pradesh, Bihar, and Jharkhand still face challenges in fully realizing their RTS potential due to bureaucratic inefficiencies and limited awareness (Roy, 2024).

Figure 2 Rooftop in India (Nagrika, 2024)

In 2024, a landmark initiative, the Pradhan Mantri Surya Ghar: Muft Bijli Yojana, aimed at equipping one crore (10 million) households with rooftop solar systems, has further accelerated adoption rates (Manas Pimpalkhare, 2024). This scheme enhances energy security and affordability by providing households up to 300 units of free electricity each month, especially in rural and low-income areas. The initiative, supported by a financial outlay of Rs 75,021 crore, covers central financial assistance, distribution companies' incentives, local bodies' funding, and model solar villages. Acknowledging the limited number of trained professionals, the scheme allocates Rs 657 crore for capacity building, fostering a skilled workforce for RTS installation, maintenance, and management. This trained workforce will be essential as India continues to scale up rooftop solar installations, especially under ambitious targets set by the government.

Public awareness and education initiatives have also been prioritized to ensure the widespread adoption of RTS. Grassroots campaigns led by distribution companies and local authorities aim to increase household awareness of RTS's economic and environmental benefits. Such campaigns emphasize the ease of obtaining loans, simplified installation procedures, and the long-term financial savings of solar energy. Moreover, enhancing access to affordable financing options has encouraged RTS adoption. Several banks and non-banking financial companies now offer low-interest loans for solar installations, making RTS more accessible to residential and commercial customers.

2.4 Financing, Public Awareness, and Future Prospects

Ensuring that RTS financing is as readily available as traditional loans for vehicles or property can help motivate more households to invest in rooftop solar (Roy, 2024). India's solar photovoltaic (PV) capacity growth has become a global point of reference, with rooftop solar representing a key component. This year alone, India added 17 GW of solar capacity, resulting in solar energy constituting 20% of the country's total energy mix (Manas Pimpalkhare, 2024). The global implications of this achievement were emphasized by Minister Pralhad Joshi, who announced that India had reached the milestone of 400,000 rooftop solar units installed under the Muft Bijli Yojana. These installations reduce reliance on fossil fuels, provide energy security to underserved regions, and reduce the burden on the central power grid. The government's recent efforts to streamline regulatory approvals and provide policy clarity signal a commitment to resolving these issues, and ongoing international partnerships with organizations like the International Solar Alliance (ISA) can offer additional support for India's solar energy initiatives (Manas Pimpalkhare, 2024). The Indian government's renewed focus on RTS and aggressive targets are setting the stage for substantial growth in the coming years. With over 400,000 new rooftop units installed under the Muft Bijli Yojana, India has demonstrated its capability to accelerate solar adoption through well-structured programs and financial incentives.

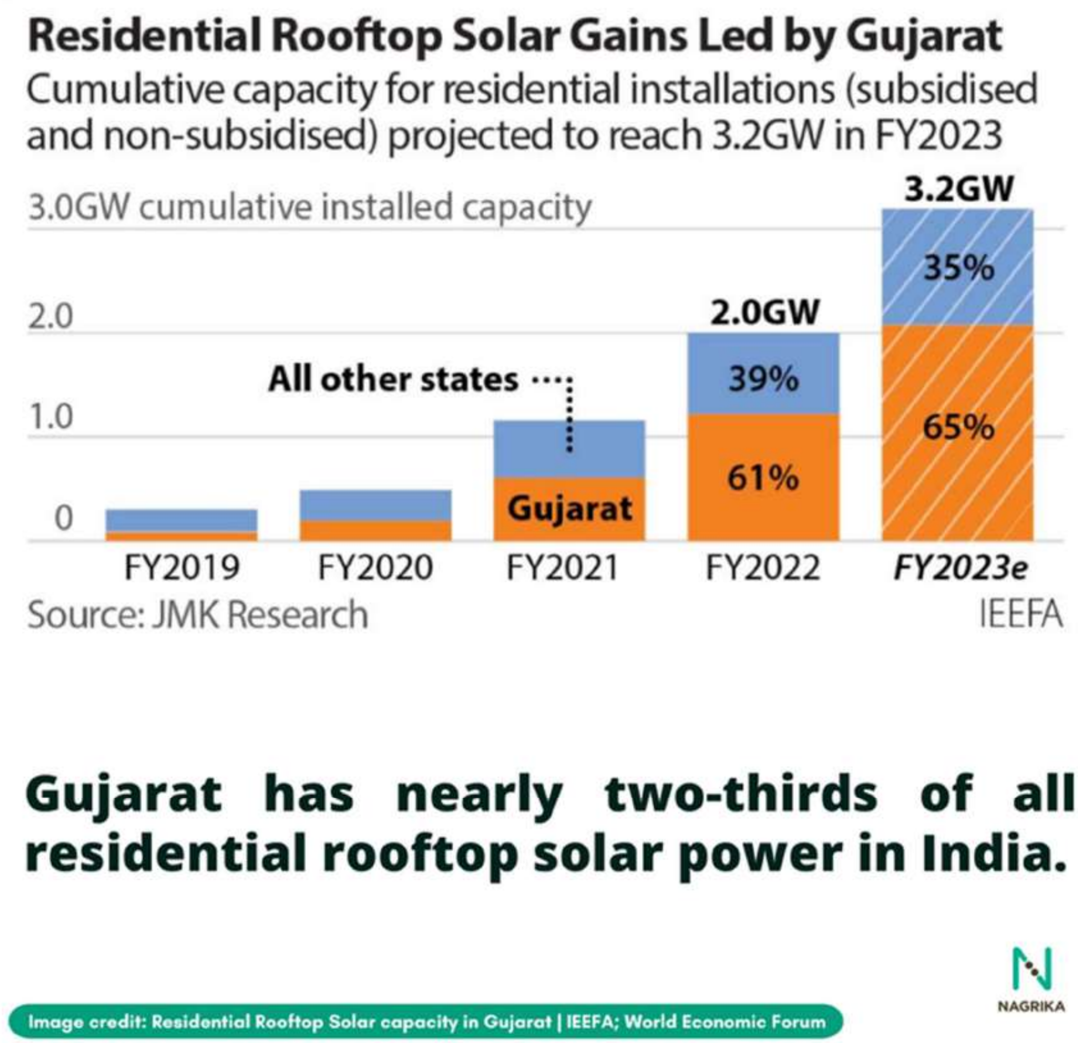


Figure 3 Gujrat Rooftop Gains (Nagrika, 2024)

Gujarat has made impressive strides in residential rooftop solar adoption, leading India's rooftop solar gains with policies encouraging household installations and streamlining regulatory processes. The state's success is mainly due to its proactive approach, including financial incentives, streamlined approvals, and the promotion of innovative programs like "Rent a Roof." This program lets residents lease their rooftops to third parties for solar energy generation, providing financial returns without upfront investment. Gujarat's Renewable Energy Policy has also provided attractive subsidies, making solar installations more affordable for homeowners. As of early 2023, Gujarat achieved an 85% increase in residential solar installations, with a significant portion of its 3,456 MW capacity from residential rooftops alone. The state's efforts have positioned it as a model for other Indian states aiming to expand residential rooftop solar use (Nagrika, 2024).

2.5 Growth and Policy Framework of Rooftop Solar in China

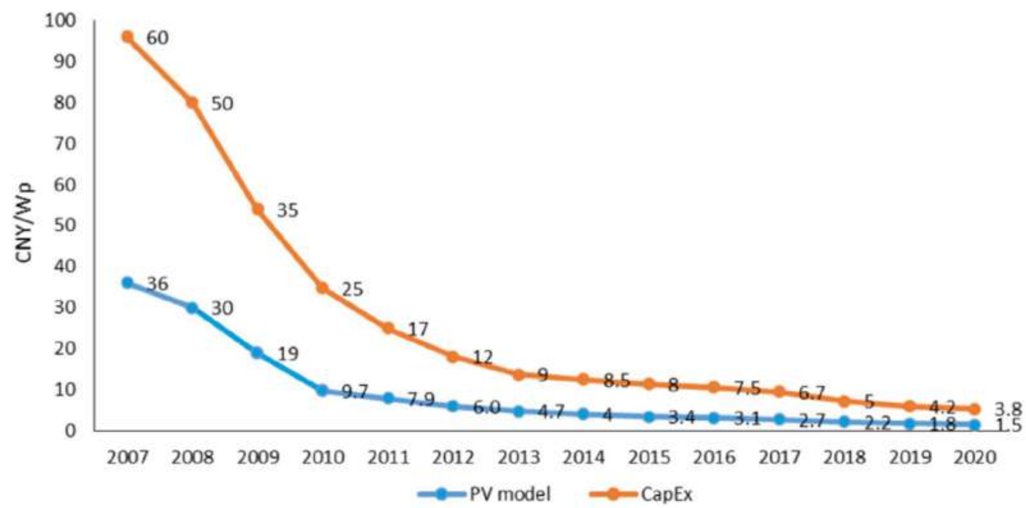
China has rapidly advanced its rooftop solar (RTS) sector, positioning itself as a leader in distributed solar adoption. With an immense technical solar potential of 2,070 GW, China had installed 609 GW of cumulative solar capacity by the end of 2023, driven by government-led initiatives targeting residential, rural, and commercial installations (Goyal, 2024). The country expects to reach 1 TW of solar PV capacity by 2026, with distributed solar projected to make up nearly half of the total capacity. China's RTS journey began with the Golden Sun Programme (2009-2011), which aimed to create domestic solar demand, especially in rural areas with limited or no grid connectivity. This initiative supported less than 6 MW distributed solar systems with capital subsidies of up to 70% for rural installations and 50% for grid-connected projects. By targeting both grid-connected and off-grid areas, the program provided electricity access and helped China build a strong, industrialized solar market from the ground up.

National targets	• China aims to achieve 1,200 GW solar and wind capacity by 2030. • It also aims to achieve net-zero emissions by 2060.
Current deployments	• Approximately 37 per cent of the total solar PV installation is contributed by distributed solar (225 GW). • Residential sector deployment has increased from 20 GW in 2020 to 105 GW in 2023.

Figure 4 Solar Targets of China (Goyal, 2024).

China implemented the Solar Energy for Poverty Alleviation Programme (SEPAP) from 2014 to 2020 to further expand solar benefits to impoverished regions. SEPAP aimed to improve income for 2 million people across 35,000 rural villages by installing 10 GW of distributed solar. Through SEPAP, low-income families received 100% subsidized rooftop solar installations, and financing options allowed beneficiaries to pay off loans by selling excess power back to the grid. This program exceeded its target, adding around 26 GW and benefiting over 4.18 million impoverished households. The program provided reliable energy access and a steady annual income of CNY 3,000–3,500 per household, highlighting the socio-economic potential of RTS systems (Goyal, 2024). Building on these achievements, China launched the Whole County PV Programme in 2021 to scale distributed solar deployment while addressing challenges from earlier programs. This initiative sets installation targets for government, public, and commercial buildings and for rural homes in selected counties. The program minimizes soft costs and logistical challenges by appointing a single investment company for each county to construct, operate, and manage RTS systems. By 2022, this approach resulted in a 50% growth in rural installations, adding 87.4 GW of distributed solar capacity across 676 counties.

Figure 4 Significant reduction in solar PV module and CapEx costs in China



Source: Authors' adaptation from WRI 2020

Figure 5 Solar Adoption in China (Goyal, 2024).

2.6 Technological Innovation, Financial Incentives, and Regional Growth

Looking ahead, China plans to invest approximately USD 70 billion to bolster grid infrastructure, improve energy storage, and extend green certificates to distributed solar generators, ensuring grid stability as RTS adoption continues to surge. These investments support China's RTS sector's steady growth, pushing the nation toward its 1 TW solar capacity target and enabling widespread RTS adoption across residential and commercial sectors (Goyal, 2024).

China has emerged as a global leader in solar energy production, particularly emphasizing the expansion of rooftop solar photovoltaic (PV) systems. Chen and Chen (2021) explore how distributed solar PV has significantly contributed to the total solar power generation in the country. The growth of the household solar PV (HSPV) market has been remarkable, with millions of households adopting solar technology to meet their energy needs. This trend demonstrates the potential of solar energy in urban areas and indicates a shift toward more sustainable energy consumption patterns across China. One of the key drivers of rooftop solar energy growth in China is the regulatory framework established by the government. Zhu et al. (2020) emphasize how well-designed regulations have facilitated rapid expansion while ensuring high-quality installations and safety standards. The Chinese government has implemented various policies, such as feed-in tariffs and subsidies, which incentivize homeowners and businesses to invest in solar energy. These regulations have made it easier for consumers to access the benefits of solar technology, thus promoting widespread adoption. Research and development (R&D) investment is crucial for building a robust rooftop solar energy infrastructure in China. Wang et al. (2023) highlight the significance of R&D funding, which has led to technological innovations and cost reductions in solar panel manufacturing.

Figure 6 A house in Qingdao, in China's eastern Shandong province ((Ye, 2023))

The government and private sector have collaborated to enhance the efficiency of solar panels, making them more accessible to consumers. This emphasis on R&D has positioned China as a global leader in solar technology, enabling the country to produce high-quality solar products at competitive prices. Additionally, financial incentives and grants have played a significant role in encouraging the adoption of rooftop solar systems. The government has introduced various programs aimed at reducing the upfront costs of installation, making it easier for households to invest in solar energy. These financial incentives have proven to be effective in driving the growth of the rooftop solar market, allowing more individuals and businesses to benefit from clean energy solutions. China's success in establishing a robust solar infrastructure is evident in the number of installations and the increasing public acceptance of solar technology. Schunder et al. (2020) discuss how the country's strong solar infrastructure has led to higher adoption rates among the populace. As awareness of environmental issues and the benefits of renewable energy grows, more individuals are inclined to invest in rooftop solar systems. This cultural shift towards embracing clean energy is vital for the long-term sustainability of solar energy in China. The environmental benefits of integrating rooftop solar into the energy mix cannot be overstated. Zhang and He (2016) examine how combining renewable energy sources, including rooftop solar, reduces pollution and enhances urban resilience. The shift toward solar energy presents a viable solution for mitigating environmental damage in a country where air pollution has long been a significant concern.

Xu et al. (2023) analyze residential rooftop solar (RRS) growth in China, highlighting the roles of air pollution, population density, GDP, and other factors in driving this expansion across regions. Using the Geographic Detector Model with city-level data, they find that RRS growth is highly variable by region, with distinct differences between northern and southern areas. For instance, the RRS growth rate responds more strongly to population density and GDP in the northern region, where factors like population density have a 0.243 coefficient impact on RRS growth. At the same time, in the south, this effect is much lower.

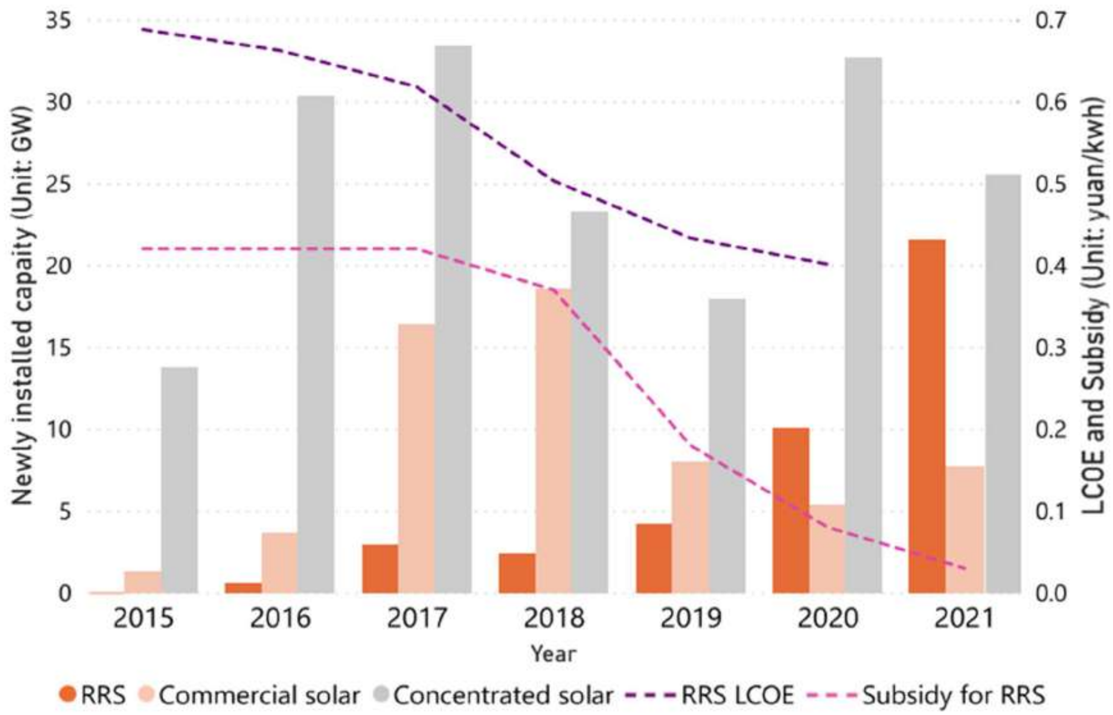


Figure 7 Growth, cost, and subsidy for residential rooftops (Xu et al., 2023)

Key findings include the minimal impact of fiscal subsidies, which, contrary to Western trends, show limited influence on China's RRS development (e.g., a coefficient of -0.009 in some models), suggesting that RRS growth is mainly independent of subsidies. Instead, pollution levels (with a coefficient of 0.154 for PM2.5 concentration) and existing renewable energy infrastructure show a more substantial, more direct impact. Population density demonstrates a complex, inverted U-shaped relationship with RRS growth, indicating that medium levels of density correlate with the highest growth rates. In policy terms, Xu et al. recommend focusing RRS incentives in high-density, high-pollution regions to maximize efficacy. They suggest that regional, rather than national, subsidy frameworks could better support balanced RRS development across China.

2.7 Challenges, Future Prospects, and Policy Recommendations

China aims to address pressing environmental challenges while fostering sustainable development by decreasing reliance on fossil fuels and utilizing cleaner energy sources. Despite these successes, challenges remain in China's rooftop solar landscape. One notable issue is the uneven distribution of solar installations across different regions. While urban areas often see high adoption rates due to better access to resources and information, rural areas may lag due to economic constraints and lack of awareness. Addressing this disparity is essential for ensuring that the benefits of rooftop solar energy are accessible to all, regardless of geographical location. Moreover, the rapid growth of the solar market has raised concerns about the quality of installations. With so many new players entering the market, maintaining standards becomes crucial. The government must continue enforcing regulations prioritizing safety and quality to avoid potential issues that could undermine public confidence in solar technology. Another challenge is the integration of solar energy into the existing energy grid. As more households install rooftop solar systems, managing the influx of distributed energy resources becomes increasingly complex. Effective grid management and storage solutions are necessary to balance supply and demand. The government and utility companies must collaborate to develop strategies for integrating rooftop solar into the energy grid while maintaining reliability.

The Chinese government has launched initiatives to promote energy storage technologies in response to these challenges. By investing in battery storage systems, households can store excess energy generated during sunny days for use during peak demand times or cloudy days. This approach enhances rooftop solar systems' reliability, making them more appealing to consumers. China's commitment to renewable energy is also evident in its international collaborations. The country has partnered with other nations to share technology and best practices in solar energy deployment. By learning from successful global case studies, China can refine its policies and approaches to accelerate rooftop solar adoption. Public awareness campaigns are essential for fostering a sustainability culture and encouraging more individuals to consider solar energy. The government and non-governmental organizations can play a crucial role in educating the public about the benefits of rooftop solar systems.

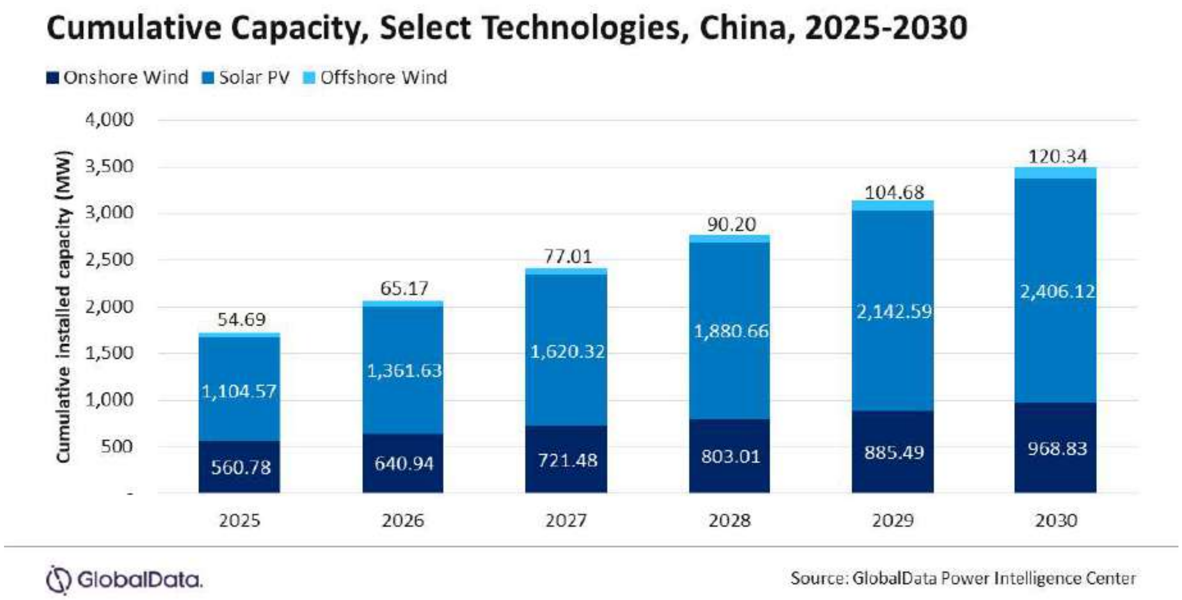


Figure 8 China's Aim for Solar Power Capacity (ep-bd, 2024)

Providing information on financial incentives, installation processes, and environmental advantages can help demystify solar technology and empower consumers to make informed decisions. As China moves forward in its renewable energy journey, the importance of rooftop solar energy will only grow. The country has set ambitious targets to significantly increase its renewable energy capacity, focusing on solar energy. By 2030, China aims to have over 1,200 GW of solar power capacity, with a substantial portion coming from rooftop installations. Achieving these targets will require continued investment, regulatory support, and public engagement.

2.8 Key Variables Influencing Successful Policy Implementation in Rooftop Solar Energy Initiatives

The successful implementation of policies in the context of rooftop solar energy initiatives is influenced by various critical variables. Van Meter and Van Horn (1975) identify six key factors determining whether a policy achieves its goals. Understanding these variables is essential for policymakers and stakeholders who aim to promote the adoption of renewable energy sources and enhance energy security.

Figure 9 Van Meter and Van Horn's six key factors for policy implementation

2.8.1 Policy Standards and Objectives

Clear and specific policy goals are essential for successful implementation. Regarding rooftop solar, policies must set measurable standards, such as target installation capacities or specific emissions reductions (Van Meter & Van Horn, 1975). Clear objectives help stakeholders align their efforts toward common goals and provide benchmarks for assessing progress and success.

2.8.2 Resources

Adequate resources, including financial, human, and technological resources, are necessary for effective policy execution. This includes government funding or subsidies to reduce initial costs, technical expertise to support installation, and access to solar technology for rooftop solar. Even well-designed policies may struggle to achieve significant adoption rates without sufficient resources.

2.8.3 Inter-organizational Communication and Enforcement Activities

Effective communication and coordination among the involved agencies are crucial. Rooftop solar policies often require collaboration between government departments, local utilities, and private companies. Good inter-organizational communication ensures that regulations are consistently applied and that incentives, permits, and other aspects of the policy are implemented smoothly.

2.8.4 Characteristics of Implementing Agencies

The capabilities and commitment of the agencies responsible for implementing rooftop solar policies directly impact success. Agencies with skilled staff, a precise mission alignment with renewable energy goals, and a strong organizational structure are more likely to achieve positive outcomes (Van Meter & Van Horn, 1975). These agencies must also be responsive and adaptable to address any issues during implementation.

2.8.5 Economic, Social, and Political Conditions

External conditions can influence how policies are received and implemented. For example, consumers may be more receptive to rooftop solar in regions with high electricity costs, increasing policy success. Similarly, strong public support for renewable energy and favorable political backing can drive policy momentum, while economic downturns or competing political priorities may hinder implementation efforts.

2.8.6 Disposition of Implementers

The attitudes and motivations of the individuals executing the policy are crucial. In rooftop solar initiatives, the willingness of agency staff, contractors, and utility workers to support and promote solar adoption can make a significant difference (Van Meter & Van Horn, 1975). Implementers who believe in the value of rooftop solar and are motivated to achieve the policy’s objectives are more likely to go beyond minimum requirements, troubleshoot issues, and advocate for continuous improvement.

2.9 Challenges and Opportunities in Policy Implementation for Rooftop Solar Energy in Developing Countries

Adopting rooftop solar energy systems has become increasingly important for addressing energy security, promoting sustainability, and mitigating climate change, particularly in developing countries. However, implementing effective policies to support rooftop solar adoption is challenging. Narendra Raj Paudel (2010) emphasizes that developing nations face significant obstacles in translating policies into practice. These challenges can hinder the effectiveness of renewable energy initiatives, such as rooftop solar energy programs. One of the primary challenges in implementing rooftop solar policies in developing countries is widespread poverty. Many individuals and communities lack the financial resources to invest in solar technology. The initial costs of purchasing and installing rooftop solar systems can be prohibitive for low-income households. This economic barrier limits access to renewable energy and perpetuates dependence on traditional energy sources, which are often less reliable and more polluting. Without addressing these financial constraints, achieving meaningful progress in expanding rooftop solar energy adoption becomes difficult. In addition to economic challenges, active public participation is critical for successfully implementing rooftop solar policies. Public involvement ensures that policies are well-designed and aligned with the needs and preferences of the communities they serve. However, many developing countries face political instability, undermining public trust in government initiatives. Political unrest can hinder effective communication between policymakers and the public, making engaging citizens in discussions about renewable energy options challenging. As a result, the lack of public participation can lead to poorly targeted policies that do not resonate with the intended beneficiaries.

Parichat Pongloe et al. (2015) treat policy implementation as an ongoing process influenced by various factors. Their study highlights the importance of effective communication, resource availability, and bureaucratic structure in shaping the outcomes of policy initiatives. In developing countries, weak institutional frameworks and limited resources can significantly hinder the implementation of rooftop solar energy policies. For instance, if the bureaucratic structure is inefficient or poorly organized, it can delay project approval and execution. Additionally, a lack of skilled personnel can impede the effective management of renewable energy programs, further complicating the implementation process. The attitudes and dispositions of those responsible for policy implementation also play a crucial role in determining success or failure. Anisur Rahman Khan (2016) notes that the effectiveness of policy implementation is dependent on two key elements: well-designed policies and effective management. Policymakers must recognize the importance of fostering a positive attitude among stakeholders, including government officials, private sector players, and community members. If there is resistance or indifference from those involved in the implementation process, it can undermine the overall effectiveness of the policy. This emphasizes the need for training and capacity-building initiatives that empower stakeholders to take ownership of solar energy projects. Khan (2016) identifies several common factors that can lead to policy implementation failures, including ambiguous goals and objectives, a lack of coordinated planning, and inadequate standardization. In the context of rooftop solar energy, policymakers must establish clear and measurable goals to guide implementation efforts. Ambiguity in objectives can confuse stakeholders and result in misalignment between policy intentions and actual outcomes. Moreover, effective coordination among different government agencies, NGOs, and private sector actors is essential for seamless project execution. If stakeholders do not collaborate effectively, it can lead to duplication of efforts or gaps in service delivery, hindering progress in rooftop solar adoption. The complexity of joint actions among various stakeholders can also pose significant challenges. Rooftop solar energy initiatives often involve multiple actors, including government agencies, local communities, private companies, and financial institutions. Coordinating efforts among these diverse stakeholders can be complicated, mainly when competing interests or differing priorities exist.

A lack of communication and collaboration can create barriers to effective policy implementation and slow the progress toward achieving renewable energy goals. Despite these challenges, there are several opportunities for advancing rooftop solar energy adoption in developing countries. One promising avenue is the development of innovative financing mechanisms that make solar technology more accessible. For instance, pay-as-you-go models and microfinance options can help reduce the upfront costs associated with rooftop solar systems. These approaches enable low-income households to invest in solar energy without the burden of significant financial risk. Policymakers can empower communities to embrace renewable energy by leveraging technology and creative financing solutions. Additionally, raising public awareness about the benefits of rooftop solar energy is essential for driving adoption. Educational campaigns informing citizens about solar energy's environmental advantages and potential cost savings can increase interest and demand for solar installations. Engaging community leaders and local organizations in these outreach efforts can enhance credibility and ensure messages resonate with target audiences. Another opportunity lies in fostering international collaboration and knowledge sharing. Developing countries can benefit from the experiences of nations that have successfully implemented rooftop solar policies. Learning from best practices and lessons learned can help policymakers avoid common pitfalls and design more effective programs. International partnerships can also facilitate access to funding and technical assistance, enabling developing countries to build the necessary infrastructure for solar energy adoption.

Moreover, integrating rooftop solar energy into existing energy policies can create synergies that enhance overall energy security. Policymakers should consider how solar energy can complement other renewable sources, such as wind or biomass, to create a diverse and resilient energy mix. By adopting a holistic approach to energy policy, governments can maximize the benefits of renewable energy technologies and improve energy access for all citizens. Finally, ongoing monitoring and evaluation of rooftop solar policies are crucial for assessing their effectiveness and making necessary adjustments. Policymakers should establish clear metrics to measure progress and identify areas for improvement. Regular feedback from stakeholders can inform decision-making processes and help fine-tune implementation strategies to meet the needs of communities better.

2.10 Comparative Analysis

Aspect	India	China	Bangladesh
Regulatory Framework	- Announced robust policies. - The Indian National Solar Mission promotes rooftop solar adoption through targets and incentives (Shankar , 2024).	- Excellent regulations leading towards rapid expansion and ensuring quality and safety standards. (Zhang, 2024)	- Simplified approval process for rooftop installations; still, policies need to be improved for faster expansion. (Alam, 2022)
Financial Support	- Financing schemes for residential and commercial sectors. - Central, and state	- Tax incentives for solar projects. - Grants and subsidies for installations, huge budget for	- Announced low-interest loans for solar installations but allotted a small budget for R&D.

	government subsidies (Shankar, 2024).	R&D. (Zhang, 2024)	
Grid Connectivity	- Net metering to enable surplus energy sale - Smart metering for efficient management. (Auroville, 2020)	- Advanced grid infrastructure to support renewables. (Zhang, 2024)	- I initially faced difficulty while integrating into the national grid. (Alam, 2022)
Energy Security Impact	- Mitigates power shortages in urban areas - Lessons strain on centralized power grids	- Diversifies energy mix, reduces pollution - Contributes to urban resilience (IEA, 2021)	- Reduces dependency on fossil fuels. - Reliability during grid outages. (Zahid, 2023)
Capacity Building	- Skill development initiatives in solar energy. - Training centers for solar workforce. (Auroville, 2020)	- Educational programs promoting solar adoption. - Research institutions for solar technology advancement. (IEA, 2021)	- Training programs for technicians, and engineers. - Awareness campaigns for public education.
Current Rooftop Solar Capacity	- 10.6 GW (as of 2022) (energy.gov, 2023)	- 58.2 GW (as of 2022) (Scully, 2022)	- 1.7 GW (as of 2022) (Zahid, 2023)

2.11 Comparative Analysis of Rooftop Solar Energy in India, China, and Bangladesh

Rooftop solar energy has significantly addressed energy challenges and promoted sustainable development across various countries. This analysis compares the regulatory frameworks, financial support, grid connectivity, impact on energy security, capacity building, and current rooftop solar capacity in India, China, and

Bangladesh.

2.11.1 Regulatory Framework

India has made notable progress in establishing a robust regulatory framework for rooftop solar adoption. The Indian National Solar Mission has set ambitious targets and offers various incentives to promote solar energy. According to Shankar (2024), these policies encourage solar technology investments and ensure widespread adoption. However, the regulatory landscape still needs continuous improvement to enhance the speed of adoption. In contrast, China has developed an excellent regulatory framework supporting rapid rooftop solar sector expansion. As noted by Zhang (2024), China's regulations promote growth and maintain high quality and safety standards in solar installations. The government's proactive stance has led to significant investments in solar technologies, making it a leader in the global solar market. Bangladesh's regulatory framework for rooftop solar is evolving. The government has implemented a simplified approval process for solar installations. However, as Alam (2022) points out, there is still a need for more comprehensive policies to facilitate faster expansion and integration of rooftop solar technologies into the national energy system. Strengthening the regulatory framework is crucial for attracting investments and ensuring the successful deployment of rooftop solar systems.

2.11.2 Financial Support

Financial support is a critical aspect of promoting rooftop solar adoption. In India, various financing schemes are available for residential and commercial sectors. The central and state governments offer subsidies to encourage investments in solar technologies (Shankar, 2024). These financial incentives are vital in reducing the initial costs associated with solar installations, making them more accessible to a broader audience. China stands out for its extensive financial support mechanisms. The country offers tax incentives for solar projects, grants, and installation subsidies. Additionally, China has allocated a substantial budget for research and development in solar technology, ensuring continued advancements and innovations in the sector (Zhang, 2024). This comprehensive financial support framework has been instrumental in driving the growth of rooftop solar across the nation. In Bangladesh, while the government has announced low-interest loans for solar installations, the allocated budget for research and development remains small compared to the sector's needs. As Alam (2022) emphasizes, increasing financial support and resources for solar projects is essential for fostering growth in the rooftop solar market.

2.11.3 Grid Connectivity

Effective grid connectivity is crucial for integrating rooftop solar systems into the national energy infrastructure. In India, net metering has allowed users to sell surplus energy generated by their solar systems back to the grid. This initiative encourages the adoption of rooftop solar and helps manage energy consumption more efficiently (Auroville, 2020). Innovative metering technology further enhances solar energy management, providing real-time data and better control over energy usage. China has significantly improved its grid infrastructure, enabling better support for renewable energy sources. The country's advanced grid systems facilitate the integration of distributed solar energy, ensuring a stable, reliable energy supply (Zhang, 2024). This robust infrastructure is essential for accommodating the growing demand for solar energy and optimizing its use in urban areas. Bangladesh initially faced difficulties in integrating rooftop solar systems into its national grid. As Alam (2022) noted, the existing grid infrastructure struggled to manage the influx of distributed energy. However, improvements are being made to enhance grid connectivity and support the integration of renewable energy sources.

2.11.4 Energy Security Impact

Rooftop solar systems have a significant impact on energy security in each country. In India, these systems help mitigate power shortages in urban areas, easing the burden on centralized power grids. By diversifying energy sources, rooftop solar contributes to a more reliable energy supply, especially in regions that experience frequent outages (Shankar, 2024).

China's approach to rooftop solar diversifies its energy mix and reduces pollution levels. The deployment of solar technologies has contributed to urban resilience, enabling cities to cope better with energy demands and environmental challenges (IEA, 2021). This not only enhances energy security but also addresses broader sustainability goals. In Bangladesh, rooftop solar panels reduce dependency on fossil fuels and provide reliability during grid outages. Zahid (2023) emphasizes that solar systems can serve as backup power sources, ensuring that households and businesses can access energy even during challenging circumstances. This is particularly important for a country like Bangladesh, which faces significant energy challenges.

2.11.5 Capacity Building

Capacity building is essential for the sustainable development of the solar energy sector. Various skill development initiatives in India focus on creating a workforce skilled in solar energy technologies. Training centers have been established to provide education and practical experience to individuals interested in solar installation and maintenance (Auroville, 2020). This investment in human capital is crucial for supporting the growing solar market. China also prioritizes capacity building through educational programs that promote solar adoption. Research institutions are actively engaged in advancing solar technology and fostering innovation (IEA, 2021). By focusing on education and research, China ensures a steady supply of skilled professionals who can contribute to the growth of the solar sector. Bangladesh recognizes the importance of training programs for technicians and engineers involved in solar installations. Awareness campaigns are also being conducted to educate the public about the benefits and feasibility of rooftop solar systems. These efforts aim to increase acceptance and participation in the solar market.

2.11.6 Current Rooftop Solar Capacity

As of 2022, India boasts a rooftop solar capacity of approximately 10.6 gigawatts (GW) (Energy.gov, 2023). This significant capacity reflects the country’s ongoing commitment to expanding its solar energy infrastructure. Continuous policy support and financial incentives have contributed to this growth. China leads the world in rooftop solar capacity, with an impressive 58.2 GW installed as of 2022 (Scully, 2022). This achievement results from years of investment in solar technology and a strong regulatory framework that encourages adoption. China’s success is a model for other countries looking to expand their solar capabilities. In comparison, Bangladesh has a rooftop solar capacity of 1.7 GW as of 2022 (Zahid, 2023). While this figure indicates progress, there is still considerable room for growth. Increasing investments, improving regulatory frameworks, and enhancing public awareness will be essential for scaling up rooftop solar capacity in the country.

2.12 Conclusion

Rooftop solar energy has significantly addressed energy challenges and promoted sustainable development across various countries. This analysis compares the regulatory frameworks, financial support, grid connectivity, impact on energy security, capacity building, and current rooftop solar capacity in India, China, and Bangladesh.

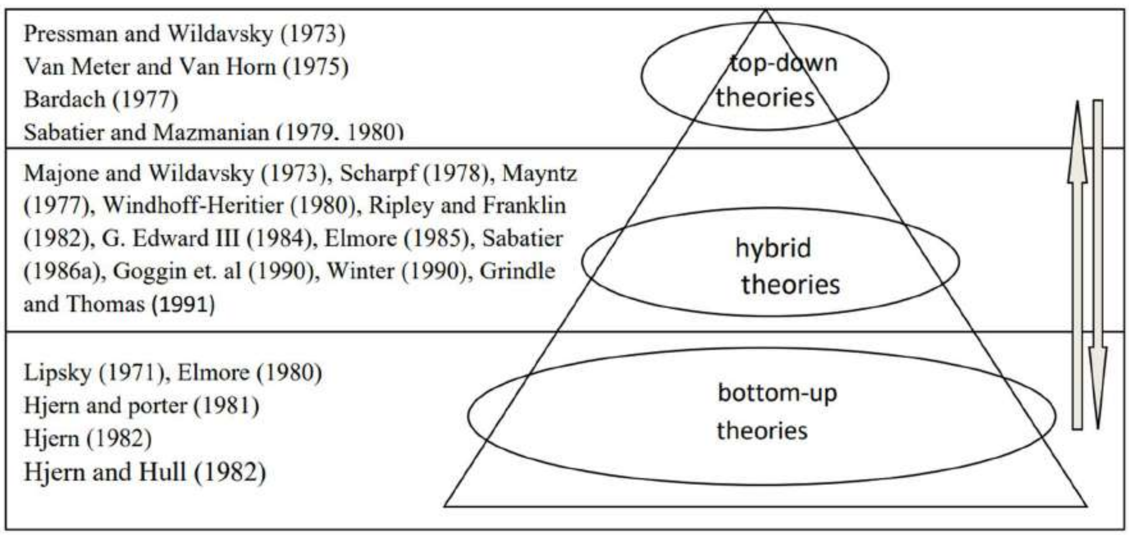
Chapter 3 Conceptual Ideas about Policy Implementation

3.1 Introduction

Policy implementation theories offer critical frameworks for understanding policies transitioning from legislative intent to tangible outcomes, particularly in complex sectors like renewable energy adoption. This chapter explores foundational policy implementation theories, tracing their evolution from top-down and bottom-up approaches to more integrated models that account for multi-level governance, stakeholder dynamics, and contextual adaptability. In the context of rooftop solar energy adoption in Dhaka City, these theories illuminate the challenges of aligning national renewable energy goals with urban realities marked by dense populations, economic constraints, and institutional gaps. The chapter begins with an overview of key implementation theories, including Pressman and Wildavsky's emphasis on decision-point complexities, Van Meter and Van Horn's six-variable framework, and Bardach's strategic "gamesmanship" perspective. It contrasts top-down models (e.g., Sabatier and Mazmanian) with bottom-up approaches (e.g., Lipsky's Street-Level Bureaucracy) and hybrid models (e.g., Sabatier's Advocacy Coalition Framework). These theories collectively reveal the importance of resource allocation, stakeholder coordination, and adaptive learning in policy execution. However, the limitations of purely hierarchical or grassroots models become evident in dynamic urban contexts like Dhaka, where fragmented governance, infrastructural challenges, and socio-economic disparities demand a more flexible approach. Winter's Integrated Implementation Model emerges as the chosen analytical framework for this study. Unlike rigid top-down or bottom-up paradigms, Winter's model synthesizes national policy directives with local-level realities, emphasizing iterative feedback loops, multi-stakeholder collaboration, and contextual adaptation. This hybrid approach is uniquely suited to Dhaka's rooftop solar adoption, where successful implementation hinges on reconciling centralized energy targets with decentralized urban challenges, from navigating bureaucratic inefficiencies to addressing financial barriers and climate vulnerabilities. By bridging the gap between policy design and practical execution, Winter's model provides a robust lens to analyze how rooftop solar initiatives can overcome systemic bottlenecks and achieve scalable impact.

3.2 Theories of Policy Implementation

Implementation theories provide a framework for understanding how policies, projects, and innovations are put into practice, and how their success or failure is influenced by various factors. In the context of rooftop solar energy adoption in Dhaka City, these theories help to evaluate how well solar energy policies are being translated from legislation into real-world outcomes, such as increased energy security, reduced reliance on fossil fuels, and enhanced sustainability. By leveraging the insights of implementation theories, this research aims to explore the challenges, and opportunities in the rollout of rooftop solar systems, identify key stakeholders, and recommend strategies to improve policy execution.



(Source: As modified from Parichat Pongloe *et al article,* 2015)

Figure 10 Three models of policy implementation at a glance

Implementation theories can be broadly divided into two categories: top-down, and bottom-up approaches:

- Top-down theories focus on how central authorities, and policy designers ensure that policies are executed as intended by following hierarchical structures. In this context, the role of governmental bodies, regulators, and policymakers in promoting rooftop solar energy will be scrutinized.
- Bottom-up theories, on the other hand, consider the roles of local actors such as businesses, households, and solar energy service providers. This approach

emphasizes the importance of ground-level implementation, community engagement, and the adaptability of policies to local conditions. Both approaches are relevant for assessing rooftop solar adoption in Dhaka, as the success of policies depends on both national directives, and the active participation of local entities.

3.2.1 Pressman, and Wildavsky's Implementation Theory (1973)

Pressman, and Wildavsky's Implementation Theory, introduced in their book *Implementation* (1973), explores the complexities, and challenges involved in putting public policies into action. They argue that policy implementation is often a difficult, and fragmented process involving numerous actors, and institutions. These actors may include government agencies, private contractors, and various stakeholders who must work together to achieve the policy's goals. A key insight from Pressman, and Wildavsky is that implementation is not a straightforward process. It involves multiple decision points, each of which can introduce delays or deviations from the policy's original intent. This series of decision points means that the more steps there are between policy formulation, and implementation, the greater the chance of failure. They emphasize that even well-designed policies can fail if the implementation process is not managed effectively. Successful implementation, according to Pressman, and Wildavsky, requires coordination among all involved parties, and sufficient resources, such as funding, and trained personnel (Pressman & Wildavsky, 1973).

3.2.2 Van Meter, and Van Horn's Framework for Policy Implementation (1975)

Van Meter, and Van Horn's Framework for Policy Implementation, introduced in 1975, builds on previous work by offering a more structured approach to understanding how policies are put into action. Their framework identifies six key variables that influence policy implementation: policy standards, and objectives, resources, inter-organizational relationships, characteristics of the implementing agencies, the socio-political environment, and the dispositions or attitudes of the implementers. Van Meter, and Van Horn stress the importance of clear policy goals. If the goals are ambiguous or conflicting, it becomes difficult for implementers to know what they are supposed to achieve. Similarly, they argue that resources, such as financial support, and skilled personnel, are essential for effective implementation. The framework also highlights the role of inter-organizational relationships, which can either facilitate or hinder cooperation between different agencies or departments involved in the policy (Van Meter & Van Horn, 1975). Additionally, the socio-political environment, such as public opinion, and political support, plays a critical role in shaping the success of policy implementation. The attitudes of those responsible for implementing the policy whether they are motivated, and aligned with the policy's objectives can also significantly affect the outcome. Van Meter, and Van Horn’s framework thus provides a comprehensive view of the many factors that need to align for successful policy implementation.

3.2.3 Bardach's Implementation Game (1977)

Eugene Bardach’s *Implementation Game* (1977) takes a more strategic view of policy implementation by framing it as a game in which various actors maneuver to advance their interests. Bardach views the implementation process as a dynamic interaction between different players, including government officials, interest groups, and private sector stakeholders. These actors have their own goals, and interests, which can lead to competition, and conflict during the implementation process. Bardach's key contribution is his emphasis on the "gamesmanship" of policy implementation. He argues that actors often engage in strategic behavior to secure resources, influence decisions, or shift responsibilities. For example, an agency tasked with implementing a policy might attempt to delay or modify the policy if it perceives that doing so will protect its interests. Bardach also points out that resource constraints, bureaucratic inertia, and misaligned incentives can create opportunities for actors to "game" the system, leading to inefficiencies or policy failure (Bardach, 1977). In *The Implementation Game*, Bardach suggests that one way to improve policy implementation is to anticipate the potential strategies, and behaviors of the actors involved. By designing policies, and implementation plans that account for these behaviors, policymakers can minimize delays, and conflicts. This approach is particularly useful in complex policy environments, where multiple stakeholders with different interests must work together to achieve policy goals.

3.2.4 Sabatier, and Mazmanian's Top-Down, and Bottom-Up Approach (1979, 1980)

Sabatier, and Mazmanian (1979, 1980) developed a theory that integrates both *top-down*, and *bottom-up* perspectives to explain policy implementation. The *top-down* approach focuses on the central authority, emphasizing how decisions made by policymakers influence the success of implementation. In this model, policies are designed with clear objectives, and success depends on how well lower-level actors, such as local governments or institutions, carry out the policy as planned. Sabatier, and Mazmanian argue that for top-down implementation to succeed, the policy goals must be clearly stated, and there must be sufficient resources, authority, and accountability at all levels (Sabatier & Mazmanian, 1979). The *bottom-up* approach, in contrast, emphasizes the role of local actors, and the importance of flexibility in policy execution. This perspective argues that local implementers often face specific challenges or circumstances that policymakers cannot predict. Therefore, local governments or agencies need to adapt policies to fit the specific needs of their communities. Sabatier, and Mazmanian suggest that both approaches are necessary. A successful policy implementation must blend top-down guidance with bottom-up flexibility, enabling policies to be adapted while still meeting overall objectives (Sabatier & Mazmanian, 1980).

3.2.5 Majone, and Wildavsky's Policy Implementation as a Learning Process (1973)

Majone, and Wildavsky (1973) introduce the concept of policy implementation as a continuous learning process. They argue that policies should not be seen as rigid plans that are fixed once they are designed, but rather as dynamic processes that evolve over time. Policymakers, and implementers learn from their experiences, and make adjustments as necessary. This theory emphasizes that the implementation process is often unpredictable due to changing conditions, new information, or unforeseen challenges. Therefore, flexibility, and learning are essential for success. According to Majone, and Wildavsky, policies should be viewed as experiments where feedback is gathered from early stages of implementation, and this feedback helps refine the policy. As problems arise during the implementation, actors involved can use that information to adapt their strategies, making improvements along the way. This view encourages an iterative process, where learning, and adaptation are central to achieving the desired outcomes (Majone & Wildavsky, 1973).

3.2.6 Scharpf's Interorganizational Policy Implementation (1978)

Scharpf (1978) focuses on the complexity of policy implementation in systems where multiple organizations are involved. In his *interorganizational policy implementation* theory, Scharpf argues that policies are often carried out by several different agencies, departments, or even private organizations. Coordination between these entities becomes critical for effective implementation. The more organizations that are involved, the more challenging it becomes to ensure smooth cooperation, and to avoid conflicts of interest. Scharpf notes that each organization involved in policy implementation has its own goals, resources, and constraints, which can lead to conflicts or inefficiencies. For instance, a policy designed to improve public health might require collaboration between health departments, local governments, and non-governmental organizations. If these entities are not well-coordinated, the policy may fail to achieve its goals. Scharpf emphasizes the importance of building strong communication channels, and cooperation mechanisms among organizations to ensure they work together efficiently, and are aligned with the policy's objectives (Scharpf, 1978).

3.2.7 Mayntz's Implementation as a Multilevel Process (1977)

Renate Mayntz (1977) introduced the idea of *policy implementation as a multilevel process*, highlighting how different levels of government, and actors are involved in the implementation process. According to Mayntz, policies are typically designed at the national or central level but are implemented at the regional or local levels. This creates challenges, as each level may have different priorities, resources, and capacities. Mayntz argues that successful implementation requires coordination, and cooperation between the different levels of government. National governments may provide the overall framework, resources, and goals, but local governments are responsible for adjusting the policy to their specific context. This theory also highlights the importance of communication, and clear division of roles between national, regional, and local authorities. Inadequate communication or poorly defined responsibilities can lead to implementation gaps, where policies are either poorly executed or not executed at all (Mayntz, 1977).

3.2.8 Windhoff-Heritier's Administrative, and Political Implementation (1980)

Adrienne Windhoff-Heritier (1980) proposed the *administrative, and political implementation* theory, emphasizing the distinction between two major aspects of implementation: administrative, and political. According to this model, administrative implementation focuses on the formal, technical, and bureaucratic aspects of executing a policy. It involves following rules, procedures, and guidelines established by the government or relevant authorities. On the other hand, political implementation refers to the influence of political actors, power dynamics, and interest groups on the implementation process. Windhoff-Heritier argues that policies are not implemented in a vacuum, and political pressures often play a significant role in shaping how policies are carried out. Political actors, such as elected officials or advocacy groups, may attempt to modify or delay policies to align with their interests. Therefore, understanding both the administrative, and political aspects of implementation is essential for ensuring policy success (Windhoff-Heritier, 1980).

3.2.9 Ripley, and Franklin's Political Model of Implementation (1982)

Ripley, and Franklin (1982) developed the *political model of implementation*, which highlights the inherently political nature of policy implementation. They argue that policy implementation is not a neutral, technical process but one that is influenced by political considerations, such as power struggles, conflicts of interest, and negotiation among stakeholders. According to this model, various actors—including government agencies, interest groups, and politicians—seek to influence the outcome of policy implementation to align with their own objectives. Ripley, and Franklin emphasize that policy implementation is often shaped by political bargaining, and compromise. Different groups may have competing interests, and the implementation process becomes a matter of finding a middle ground that satisfies multiple stakeholders. The political model suggests that conflicts, and negotiations are inherent in policy implementation, and that policies are rarely implemented exactly as they were originally designed (Ripley & Franklin, 1982).

3.2.10 G. Edward III's Policy Implementation Framework (1984)

George C. Edwards III (1984) proposed a comprehensive *policy implementation framework* that identifies four key factors influencing the success of policy implementation: communication, resources, disposition, and bureaucratic structure. According to Edwards, these factors must align for successful implementation to occur.

1. **Communication**: Clear, and consistent communication between policymakers, and implementers is crucial for ensuring that the goals of the policy are understood, and properly carried out.

2. **Resources**: Adequate resources, including funding, personnel, and equipment, are necessary to implement policies effectively.

3. **Disposition (or attitudes)**: The attitudes, and motivation of those responsible for implementing the policy significantly affect the process. If implementers are indifferent or opposed to the policy, its success is at risk.

4. **Bureaucratic Structure**: The organization, and efficiency of the bureaucracy also play a critical role. A well-structured bureaucracy with clear lines of authority, and coordination increases the chances of successful policy implementation.

Edwards emphasizes that failure in any one of these factors can hinder the policy implementation process. For example, even if resources are available, poor communication or negative attitudes among implementers can lead to failure (Edwards III, 1984).

3.2.11 Elmore's Forward, and Backward Mapping Approaches (1980, 1985)

Richard Elmore (1980, 1985) introduced two distinct approaches to policy implementation: *forward mapping*, and *backward mapping*. These approaches offer different strategies for designing, and implementing policies.

1. **Forward Mapping**: In this approach, the policy implementation process begins at the top, with policymakers outlining clear objectives, and then passing them down to implementers. Policymakers assume that if clear instructions are given, and sufficient resources are provided, the desired outcomes will be achieved. This

approach resembles a top-down strategy, where policy directives flow from higher authorities to lower levels of government or organizations (Elmore, 1980).

2. **Backward Mapping**: In contrast, the backward mapping approach starts at the bottom, with a focus on the implementers, and the conditions they face. Instead of beginning with policy goals, backward mapping looks at the challenges that frontline implementers encounter, and designs policies that address those challenges. This approach allows for more flexibility, and adaptation to local conditions. Elmore suggests that backward mapping is often more effective because it takes into account the practical realities of implementation, and provides room for adjustments (Elmore, 1985).

3.2.12 Sabatier's Advocacy Coalition Framework (1986a)

Paul Sabatier (1986a) introduced the *advocacy coalition framework* (ACF) to explain how policy implementation, and policy change occur over time. This framework emphasizes the role of advocacy coalitions, which are groups of actors—such as interest groups, government officials, and researchers—who share a common belief system, and work together to influence policy outcomes. These coalitions compete with each other to shape the direction of policy implementation, and change. According to Sabatier, policy implementation is not a static process but one that evolves over time as advocacy coalitions interact with each other. Each coalition seeks to promote its own interpretation of the policy, and to adjust implementation strategies to reflect its goals. The ACF suggests that long-term policy implementation is shaped by shifts in power among competing coalitions, changes in external conditions, and learning that occurs as a result of ongoing interactions between different actors (Sabatier, 1986a).

3.2.13 Goggin et al.'s Communications Model of Policy Implementation (1990)

In 1990, Malcolm Goggin, and his colleagues introduced the *Communications Model of Policy Implementation*, which emphasizes the role of communication between different levels of government in ensuring effective policy implementation. Goggin et al. argue that policy implementation is often hampered by poor communication between the policymakers (typically at higher levels of government), and those responsible for executing the policy (at the lower levels). This model sees policy implementation as a hierarchical process in which instructions, resources, and information flow from top to bottom. The success of the policy depends on how well these messages are communicated, and understood by the implementers. Goggin et al. highlight that policies are more likely to succeed if the communication is clear, consistent, and responsive to the concerns of implementers. Furthermore, they suggest that feedback mechanisms are critical, allowing implementers to provide input to policymakers about any challenges they encounter. The model also stresses the importance of political, and organizational support to facilitate the communication process (Goggin et al., 1990).

3.2.14 Winter's Model of Implementation as Process (1990)

Søren Winter's *Model of Implementation as Process* (1990) views policy implementation as a dynamic, and continuous process rather than a one-time event. Winter focuses on how the different stages of the policy process—from formulation to execution—are interconnected, and influence each other. This model stresses that implementation is influenced by both the content of the policy, and the environment in which it is carried out. Winter argues that the behavior of street-level bureaucrats (those who implement policies directly) is crucial to understanding how policies are implemented. He points out that the personal attitudes, beliefs, and motivations of these individuals can shape the outcomes of implementation. Additionally, external factors such as political pressure, organizational culture, and available resources play a significant role in the process. The model highlights that policy implementation is not just about following instructions; it is about continuously adapting to the realities on the ground, and managing the complex interactions between policy, implementers, and the environment (Winter, 1990).

3.2.15 Grindle, and Thomas's Policy Reform Process Model (1991)

Merilee Grindle, and John Thomas's *Policy Reform Process Model* (1991) focuses on how political, institutional, and social factors influence the success of policy reform efforts. Their model emphasizes that policy implementation is not just a technical process but also a political one, where the interests of various actors need to be managed. Grindle, and Thomas argue that policy reform is often resisted by powerful groups that benefit from the status quo. Therefore, the success of policy reform depends on how well policymakers can navigate the political landscape, build coalitions, and manage conflicts among stakeholders. They highlight the importance of leadership in driving reform, as well as the need for strategic planning to overcome opposition. Their model also recognizes that the context in which a policy is implemented—such as the level of development, institutional capacity, and public support—plays a crucial role in determining whether reforms are successfully adopted (Grindle & Thomas, 1991). This model offers a more holistic view of implementation, considering not only the policy design but also the political, and social dimensions of the reform process. It emphasizes that successful implementation requires more than good policies; it also requires managing the political, and institutional barriers to change.

3.2.16 Lipsky's Street-Level Bureaucracy (1971)

Michael Lipsky's *Street-Level Bureaucracy* (1971) theory focuses on the role of frontline workers—such as teachers, police officers, and social workers—who are responsible for implementing public policies at the local level. Lipsky argues that these street-level bureaucrats have a significant amount of discretion in how they apply policies, which can lead to variations in implementation. According to Lipsky, street-level bureaucrats often work in environments characterized by limited resources, high demand for services, and conflicting policy objectives. As a result, they develop coping mechanisms, such as simplifying rules or rationing services, to deal with these challenges. This discretion means that the implementation of a policy can vary widely depending on the decisions, and actions of individual bureaucrats. Lipsky's theory highlights the gap between policy as written, and policy as implemented. Even though policies may be well-designed, their implementation can be inconsistent because street-level bureaucrats have the power to interpret, and modify them in response to local conditions, and pressures. Lipsky's work underscores the importance of understanding the behavior of frontline workers in the study of policy implementation (Lipsky, 1971).

3.2.17 Hjem, and Porter's Network Analysis Approach (1981)

Hjem, and Porter's *Network Analysis Approach* (1981) focuses on understanding policy implementation through the lens of networks, and relationships among various actors involved in the process. This approach emphasizes that policy implementation is not a linear process controlled solely by a central authority. Instead, it involves a range of actors—including government agencies, private organizations, and local communities—who are interconnected through networks. According to Hjem, and Porter, successful policy implementation depends on how well these actors work together, and coordinate their efforts. They highlight the importance of relationships, and collaboration between different stakeholders. For example, effective communication, and cooperation between local authorities, central government, and private sector entities are crucial for overcoming challenges, and ensuring the smooth implementation of policies. The network analysis approach also recognizes that each actor in the network has its own interests, which can affect how they contribute to or hinder the implementation process (Hjem & Porter, 1981). This model is particularly useful for analyzing complex policy environments where multiple actors have varying degrees of influence, highlighting the need for a decentralized approach to policy implementation.

3.2.18 Hjern's Implementation Structure Analysis (1982)

Hjern (1982) introduced the *Implementation Structure Analysis*, which expands on the network approach by focusing on the structural aspects of policy implementation. Hjern argues that policy implementation occurs within a multi-organizational context, where different organizations are responsible for executing various components of the policy. Rather than viewing policy implementation as a top-down process, Hjern believes that implementation should be understood by looking at the interactions, and interdependencies between these organizations. Hjern's analysis emphasizes the importance of understanding how different agencies, and organizations are structured, and how they interact with one another. He argues that policy success depends on how well these organizations align their goals, and actions to meet the objectives of the policy. This theory also highlights the importance of feedback loops, where organizations involved in implementation continuously communicate with one another to adjust their actions based on evolving circumstances. Hjern's work shows that effective policy implementation requires an understanding of the broader system of organizations, and their interactions (Hjern, 1982).

3.2.19 Hjern, and Hull's Social Structure, and Policy Implementation (1982)

In their collaborative work, Hjern, and Hull (1982) developed the *Social Structure, and Policy Implementation* theory, which builds on the earlier work of Hjern's Implementation Structure Analysis. Their theory emphasizes the role of social structures—specifically, how policies are shaped, and implemented by the broader social context in which they operate. Hjern, and Hull argue that the success of policy implementation depends on the social networks, and institutional structures within which the policy is being executed. Their model highlights that policy implementation is influenced by a range of factors, including the social norms, power dynamics, and relationships between different groups in society. For instance, in a local community where there is strong social cohesion, implementation may be more successful because the community is more likely to work together toward shared goals. Conversely, in areas where there is social conflict or mistrust between groups, implementation can face significant obstacles. Hjern, and Hull's theory also stresses the importance of local actors, and their ability to adapt national or regional policies to local contexts. They argue that policies should be flexible enough to allow for adaptation to specific social, and cultural circumstances, which can increase the likelihood of successful implementation (Hjern & Hull, 1982).

3.3 Analytical Framework Based on Winter's Integrated Implementation Model

The Winter's Integrated Implementation Model is selected as the theoretical framework. This hybrid model combines elements of both top-down, and bottom-up approaches, providing a comprehensive lens to analyze the implementation of rooftop solar systems in Dhaka City. The model emphasizes the interplay between policy design, local-level dynamics, and stakeholder interactions, making it highly relevant for understanding the complexities of renewable energy adoption in an urban context like Dhaka.

3.4 Rationale for Choosing Winter's Integrated Implementation Model

The Winter's Integrated Implementation Model was selected as the theoretical framework for analyzing rooftop solar adoption in Dhaka City due to its hybrid approach, which combines top-down, and bottom-up perspectives. This model is particularly well-suited for addressing the complexities, and multi-level dynamics of renewable energy implementation in an urban context like Dhaka. Below is the rationale for choosing this model over other implementation theories:

3.5 Comprehensive, and Holistic Approach

Winter's model integrates both top-down policy analysis, and bottom-up stakeholder engagement, providing a holistic view of the implementation process. Unlike purely top-down models (e.g., Sabatier & Mazmanian) or bottom-up models (e.g., Lipsky's Street-Level Bureaucracy), Winter's framework acknowledges the interplay between national policies, local dynamics, and contextual factors. This is critical for understanding rooftop solar adoption in Dhaka, where national policies (e.g., 2012 solar mandate, 2023 net metering guidelines) must align with local realities (e.g., high population density, limited rooftop space).

3.6 Emphasis on Feedback Mechanisms

The model emphasizes the importance of feedback loops between policymakers, implementers, and end-users. This is particularly relevant for rooftop solar adoption, where misaligned incentives, inadequate communication, and lack of stakeholder collaboration often hinder effective implementation. By incorporating feedback mechanisms, the model allows for continuous refinement of policies, and practices, addressing gaps in real-time.

3.7 Contextual Adaptability

Winter's model considers contextual factors such as urban challenges, economic barriers, and environmental conditions, which are critical for rooftop solar adoption in Dhaka. For example:

- Urban Challenges: High population density, and limited rooftop space require tailored solutions.
- Economic Barriers: High upfront costs, and lack of financial incentives deter adoption.
- Environmental Factors: Dhaka’s climate (e.g., high humidity, monsoons) affects system performance, and maintenance.

This adaptability makes the model highly relevant for addressing the unique challenges of renewable energy implementation in Dhaka.

3.8 Focus on Multi-Level Dynamics

The model recognizes the multi-level dynamics of implementation, involving national policymakers, local implementers (e.g., DPDC, DESCO), and end-users (e.g., residential, commercial, industrial consumers). This is essential for rooftop solar adoption, where success depends on the alignment of policies, resources, and stakeholder actions. For instance:

- Top-Down: National policies must provide clear guidelines, and adequate resources.
- Bottom-Up: Local implementers, and end-users must have the capacity, and motivation to adopt rooftop solar systems.

3.9 Practical Application

Winter's model is practical, and action-oriented, making it suitable for real-world implementation challenges. It provides a structured framework for:

- Policy Analysis: Assessing the clarity, feasibility, and enforceability of national policies.
- Stakeholder Engagement: Understanding the roles, and challenges of local implementers, and end-users.
- Feedback, and Refinement: Identifying gaps, and refining policies based on local feedback.

  This practical focus aligns with the study's goal of providing actionable recommendations for rooftop solar adoption in Dhaka.

3.10 Comparison with Other Theories

- Top-Down Models (e.g., Sabatier & Mazmanian): These models focus on the role of national policies but often overlook local dynamics, and contextual factors. They are less effective in addressing the ground-level challenges of rooftop solar adoption in Dhaka.
- Bottom-Up Models (e.g., Lipsky's Street-Level Bureaucracy): These models emphasize the role of local implementers but may neglect the importance of national policy frameworks, and resource allocation.
- Hybrid Models (e.g., Elmore's Forward, and Backward Mapping): While hybrid

models also combine top-down, and bottom-up perspectives, Winter's model is more comprehensive, and contextually adaptable, making it better suited for the study's objectives.

3.11 Implementation Theory in Practice

Winter's Integrated Implementation Model provides a structured approach to understanding the multi-level dynamics of rooftop solar adoption in Dhaka. By combining top-down policy analysis with bottom-up stakeholder engagement, the framework ensures a holistic view of the implementation process. It also emphasizes the importance of feedback mechanisms, and contextual adaptability, which are critical for addressing the unique challenges of renewable energy adoption in an urban setting.

3.12 Conclusion

The exploration of policy implementation theories underscores the multifaceted nature of translating renewable energy goals into actionable outcomes, particularly in a complex urban environment like Dhaka. While traditional top-down models prioritize hierarchical control, and bottom-up approaches emphasize grassroots agency, Winter's Integrated Implementation Model stands out for its holistic synthesis of these perspectives. By emphasizing the interplay between policy design, stakeholder engagement, and contextual adaptability, Winter's framework addresses the unique challenges of rooftop solar adoption in Dhaka such as high population density, limited rooftop space, and fragmented institutional coordination. The model's focus on feedback mechanisms ensures that policymakers can iteratively refine strategies based on ground-level insights, while its recognition of multi-level dynamics bridges the gap between national mandates, and local execution. For instance, Dhaka's 2012 solar mandate, and 2023 net metering guidelines must be complemented by localized solutions, such as tailored financial incentives for low-income households or partnerships with NGOs to build technical capacity. Winter's approach also highlights the critical role of street-level bureaucrats from utility officials to solar installers whose discretion, and motivation directly shape policy outcomes. Ultimately, Winter's Integrated Implementation

Model provides a pragmatic roadmap for Dhaka to overcome barriers to rooftop solar adoption. By fostering alignment between policy intent, resource allocation, and community participation, the model supports the city's transition toward energy security, and sustainability. As Bangladesh strives to meet its renewable energy targets, adopting such adaptive, context-sensitive frameworks will be essential to transforming rooftop solar from a niche initiative into a mainstream urban energy solution. This chapter lays the groundwork for applying Winter's model to Dhaka's context, offering actionable insights to bridge the chasm between ambition, and achievement in the renewable energy sector.

Chapter 4 Research Methodology

4.1 Introduction

The adoption of rooftop solar energy policies in urban areas like Dhaka City involves navigating a complex landscape where policy goals need to be effectively translated into practical results. This research focuses on understanding the factors that impact rooftop solar adoption in Dhaka City, Bangladesh. By examining different implementation theories, and models, the study aims to uncover both the challenges, and opportunities associated with implementing these policies. Additionally, the research seeks to identify strategies that can enhance the execution of rooftop solar initiatives in this unique urban context. Dhaka City offers a compelling case due to its rapid urbanization, and pressing energy demands. The city faces significant challenges related to energy security, and environmental sustainability, making rooftop solar adoption a critical component of its future energy strategy. Understanding how policies translate from intentions to outcomes in such a dynamic urban environment is crucial for informing effective policy decisions, and fostering sustainable development. These theories provide frameworks for understanding the roles of different stakeholders, regulatory frameworks, financial incentives, and community engagement in shaping policy outcomes. By examining these factors through qualitative research methods, such as interviews, and document analysis, the research aims to uncover the nuanced dynamics influencing rooftop solar adoption. Furthermore, the research methodology prioritizes ethical considerations, ensuring that participants' confidentiality, and privacy are protected throughout the data collection process. By adhering to ethical guidelines, and rigorous data analysis techniques, the study aims to produce findings that are reliable, valid, and relevant to stakeholders involved in urban energy policy, and planning. This research contributes to the broader discourse on sustainable urban development by examining rooftop solar adoption in Dhaka City. By identifying key factors influencing policy implementation, and recommending strategies for improvement, the study aims to support informed decision-making that promotes renewable energy adoption, and contributes to achieving long-term energy goals in urban areas.

4.2 Research Design, and Approach of Inquiry

The research design for this study adopts an exploratory, and descriptive approach to investigate rooftop solar adoption in Dhaka City, Bangladesh. This approach is chosen to thoroughly explore how policy intentions translate into real-world outcomes within urban settings. By utilizing case studies, and conducting in-depth interviews, the study aims to gather comprehensive, and nuanced data from various stakeholders involved in the rooftop solar sector. The exploratory, and descriptive approach is well-suited for uncovering the multifaceted dynamics of rooftop solar adoption in Dhaka City. This methodological choice allows the research to delve deeply into emerging issues, and complexities surrounding policy implementation. Through the exploration of diverse perspectives, and detailed descriptions, the study seeks to provide a thorough understanding of the factors influencing the uptake of rooftop solar systems. Central to the research methodology are case studies that provide in-depth examinations of specific instances of rooftop solar adoption within Dhaka City. In-depth interviews serve as a primary method for gathering qualitative data directly from key stakeholders involved in rooftop solar adoption.

1. **Data Collection**:
    - **Primary Data**: Conduct interviews, and surveys with policymakers, DPDC/DESCO officials, local installers, and end-users to gather insights on policy implementation, and local dynamics.
    - **Secondary Data**: Analyze policy documents, project reports, and case studies (e.g., Brac University, BUET) to assess alignment between policy objectives, and implementation outcomes.
2. **Data Analysis**:
    - **Qualitative Analysis**: Use thematic analysis to identify key themes from interviews, and policy reviews, focusing on policy design, local dynamics, and feedback mechanisms.
    - **Quantitative Analysis**: Perform statistical analysis of adoption rates, capacity installations, and cost-benefit data to evaluate the effectiveness of implementation strategies.

3. **Case Studies**:
    - Examine successful rooftop solar projects (e.g., Brac University, BUET) to identify best practices, and lessons learned.
    - Analyze failed or underperforming initiatives to understand barriers, and gaps in implementation.

4.3 Data Collection Method

The data collection method chosen for this study on rooftop solar adoption in Dhaka City, Bangladesh, is primarily qualitative, aiming to capture rich, and contextual insights from various stakeholders involved in or affected by rooftop solar policies. Qualitative methods are selected for their ability to delve deeply into the nuances of policy implementation, stakeholder interactions, and the underlying factors influencing adoption decisions. Central to the data collection approach are in-depth interviews with key stakeholders. These interviews will be semi-structured, allowing flexibility to explore participants' perspectives, experiences, and challenges related to rooftop solar adoption. The semi-structured format ensures that key topics are covered while allowing for new themes to emerge organically during the conversation. Interviews will be conducted face-to-face or remotely, depending on participant availability, and preferences, to ensure candid, and detailed responses. Additionally, the study will employ case studies to provide detailed examinations of specific instances of rooftop solar adoption within Dhaka City. Case studies offer a comprehensive way to analyze real-world examples, providing contextual depth, and allowing researchers to explore the complexities, and dynamics of policy implementation in specific settings. Each case study will involve gathering documentary evidence, conducting interviews with relevant stakeholders, and analyzing the outcomes, and challenges faced in implementing rooftop solar initiatives. To complement the qualitative data collection, document analysis will be employed. This involves reviewing policy documents, reports, and other relevant materials related to rooftop solar policies, and their implementation in Dhaka City. Document analysis provides additional context, and background information, helping to triangulate findings from interviews, and case studies. Throughout the data collection phase, rigorous note-taking, and documentation of findings will be maintained to ensure accuracy, and reliability. Audio recordings, and transcripts of interviews will be securely stored, and analyzed using qualitative data analysis software to facilitate systematic coding, and thematic analysis.

4.4 Data Collection Tools, and Techniques

Data collection tools, and techniques are crucial components of any research endeavor, particularly in qualitative studies focused on nuanced topics like rooftop solar adoption in Dhaka City, Bangladesh. The tools, and techniques selected must align with the research objectives, and ensure the robust capture of data from diverse stakeholders involved in or impacted by rooftop solar policies.

In-depth Interviews: The primary data collection tool for this study is in-depth interviews. These interviews will be semi-structured, allowing for flexibility in exploring participants' perspectives, experiences, and insights related to rooftop solar adoption. Semi-structured interviews strike a balance between predefined questions, and the opportunity to delve deeper into emergent themes, and issues that arise during the conversation. This approach ensures that the researcher captures rich, detailed narratives that provide depth, and context to the study.

Case Studies: Another essential data collection technique employed in this research is the use of case studies. Case studies offer a detailed examination of specific instances of rooftop solar adoption within Dhaka City. Each case study involves gathering multiple sources of evidence, including interviews, documents, and observational data if applicable (Sulaiman & Baldry, 2008). By focusing on real-world examples, case studies provide an in-depth understanding of the complexities, challenges, and successes associated with implementing rooftop solar policies in urban settings.

Document Analysis: Document analysis serves as a complementary technique to interviews, and case studies (Bowen, 2019). It involves systematically reviewing, and analyzing policy documents, reports, academic literature, and other relevant materials related to rooftop solar policies, and their implementation in Dhaka City. This method helps researchers contextualize interview, and case study findings within broader policy frameworks, historical contexts, and existing research.

4.5 Ethical Considerations

Ethical considerations are paramount in any research endeavor, particularly when studying sensitive topics such as policy implementation, and stakeholder perspectives on renewable energy adoption like rooftop solar in Dhaka City. This section outlines the ethical principles, and practices that guide the conduct of this research, ensuring integrity, respect for participants, and transparency throughout the study. Obtaining informed consent from participants is a fundamental ethical principle. Prior to any data collection, participants will be fully informed about the research objectives, procedures, potential risks, and benefits (Manti & Licari, 2019). They will have the opportunity to ask questions, and provide voluntary consent to participate. Special attention will be given to ensuring that participants understand the nature of their involvement, and any potential implications. Protecting the confidentiality, and anonymity of participants is crucial to maintaining trust, and respecting their privacy. All data collected, including interviews, survey responses, and documents, have been done with consent. Participants were assured that their identities will not be disclosed in any publications or presentations resulting from the research unless they provide explicit consent or if required by law. Measures will be implemented to ensure the security of data throughout the research process.

4.6 Conclusion

This chapter outlined the research methodology adopted to investigate rooftop solar adoption in Dhaka City, Bangladesh. By employing an exploratory, and descriptive research approach, the study integrates qualitative data collection methods, including in-depth interviews, case studies, and document analysis. These methods provide a comprehensive understanding of the challenges, and opportunities associated with policy implementation in the rooftop solar sector. Ethical considerations, such as informed consent, and data confidentiality, have been prioritized to ensure the integrity, and reliability of the research process. The chosen methodology aims to generate insightful findings that can inform policy improvements, enhance implementation strategies, and contribute to the broader discourse on sustainable urban energy solutions.

Chapter 5 FINDINGS

5.1 Introduction

Dhaka City, a rapidly urbanizing metropolis, faces mounting energy demands driven by population growth, industrialization, and urbanization. In response, rooftop solar energy has emerged as a critical component of Bangladesh's strategy to enhance energy security, reduce carbon emissions, and promote sustainable development. This chapter examines the roles of Dhaka Power Distribution Company Limited (DPDC), and Dhaka Electric Supply Company Limited (DESCO), the two primary electricity distribution utilities in Dhaka, in advancing rooftop solar adoption. Through detailed analysis of their infrastructure, net-metering initiatives, completed projects, and capacity-building efforts, this chapter evaluates how these entities are driving the integration of solar energy into the urban energy mix. The chapter begins by exploring DPDC's contributions, including its 750 KW grid-tied solar project, and net-metering installations, which have collectively added 36.5 MWp of solar capacity. It then shifts focus to DESCO, highlighting its 62.2 MWp of rooftop solar capacity, and innovative ventures like electric vehicle (EV) charging stations. A comparative analysis of both organizations underscores their distinct approaches, challenges, and achievements in scaling solar adoption. By delving into policy frameworks, technological investments, and stakeholder engagement, this chapter provides a comprehensive overview of Dhaka's transition toward a renewable energy future, anchored by the efforts of DPDC, and DESCO.

5.2 Dhaka Power Distribution Company Limited (DPDC)

The Dhaka Power Distribution Company Limited (DPDC) plays a critical role in the energy sector of Bangladesh, serving as one of the major electricity distribution utilities in Dhaka city. Operating across an area of approximately 250 square kilometers, DPDC's jurisdiction spans a wide array of urban landscapes, from densely populated residential neighborhoods to vibrant commercial zones, and essential industrial hubs. These diverse regions present unique challenges in terms of electricity distribution, but DPDC has consistently worked to meet the growing demand for power in these areas, ensuring reliable, and efficient delivery to millions of consumers (dpdc, 2022).

DPDC's infrastructure is a key asset in ensuring that the electricity supply meets the needs of its wide-ranging customer base. The company operates an extensive network of substations, feeders, and distribution transformers that enable it to supply power to residential, commercial, and industrial areas efficiently. This network is designed to handle varying load requirements, from high-demand commercial centers to large residential clusters. The city of Dhaka, being one of the fastest-growing urban centers in South Asia, sees a continuous increase in both population, and industrial activity, necessitating constant upgrades, and expansions to the distribution network to accommodate the city's dynamic energy needs (Staff Reporter, 2023). To enhance operational efficiency, and service reliability, DPDC has undertaken significant modernization initiatives. These efforts include the implementation of smart grid technologies, which enable real-time monitoring, and management of the distribution network. Such advancements are crucial for promptly identifying, and addressing power outages, thereby minimizing downtime, and improving customer satisfaction (afd, 2015).

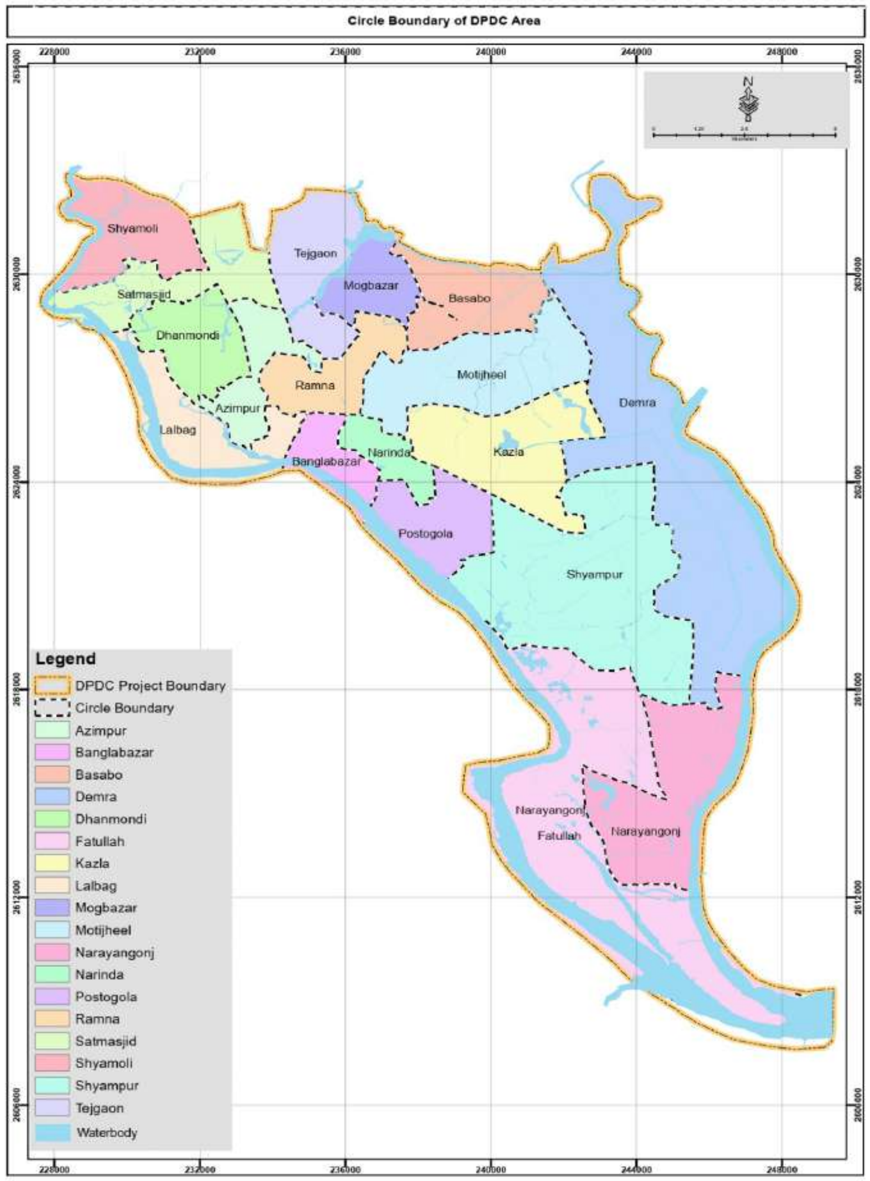


Figure 11 Area map of DPDC (dpdc, 2024)

In recent years, DPDC has made substantial investments in modernizing its infrastructure, with a strong emphasis on technological advancements. The implementation of smart grid systems, for instance, has been a significant step forward in improving operational efficiency, and reliability. These systems allow for real-time monitoring, and management of the distribution network, enabling DPDC to quickly detect, and address any faults or power outages. Such capabilities are vital for minimizing downtime, which is crucial in a city like Dhaka, where electricity demand is high, and interruptions can have far-reaching consequences for both residents, and businesses. Smart grid technologies also facilitate better load management, helping DPDC optimize its resources, and reduce energy losses. As part of its modernization efforts, DPDC has also focused on expanding its capacity, and reach to ensure that underserved areas are not left behind. With the rapid urbanization of Dhaka, new residential, and commercial developments are constantly emerging, which requires an expanding power infrastructure to meet the increasing energy demands. DPDC has responded to this by strategically investing in infrastructure expansion, including building new substations, and upgrading older facilities to handle higher loads. This expansion also aims to provide equitable access to electricity across all areas of the city, ensuring that every resident, and business, regardless of their location, has access to a reliable power supply. Another notable aspect of DPDC's operations is its commitment to sustainability, and renewable energy initiatives. As the global focus on sustainable energy grows, DPDC has been active in integrating renewable energy sources, such as solar power, into its distribution network. Through various projects, including rooftop solar installations, and participation in net-metering programs, the company is helping to reduce the carbon footprint of Dhaka’s energy consumption. These initiatives also enable consumers to generate their own electricity, and reduce reliance on the grid, leading to both economic, and environmental benefits.

5.3 Net Meter Installation Information

Dhaka City has seen a steady increase in the adoption of rooftop solar systems, as evidenced by the data on net-meter installations, completed projects, and the overall distribution of solar systems. These projects are pivotal in supporting Bangladesh's renewable energy goals, and contribute to a more sustainable energy future for the country. The data on rooftop solar systems in Dhaka reveals the scope of efforts being made to harness solar power in urban areas, particularly in residential, commercial, and governmental sectors.

5.3.1 Rooftop Solar System in DPDC

Rooftop solar systems in Dhaka have been steadily growing in number, with a total of 55,478 installations across the city, yielding an impressive 36,516.17 KWp of installed capacity. This expansion is driven by both government incentives, and private sector initiatives that are focused on reducing dependence on conventional energy sources while simultaneously addressing environmental concerns. The number of net-meter installations has also been on the rise, with significant contributions from both the private, and government sectors. For instance, the total number of net-meter installations has reached 388 systems, with a combined capacity of 5,224.22 KWp, demonstrating the increasing penetration of solar technology into the energy mix.

5.3.2 Net-Meter Installation Data (Up to 1st Dec 2024)

The net-meter installation data provided for rooftop solar systems in Dhaka City offers a clear picture of the gradual adoption, and growth of solar energy usage, as well as the increasing integration of solar power into the national grid. Net metering is an important policy tool that allows consumers—both residential, and commercial—to feed surplus energy generated by their rooftop solar systems back into the national grid. In return, they receive credits on their energy bills, making solar energy not only an environmentally friendly option but also a financially beneficial one. The data provided highlights this upward trend in installations, and capacity, indicating the growing shift towards renewable energy.

The following table summarizes the installation data for net meters up to December 2024:

Fiscal Year	Number of Systems	Capacity (KWp)
2024-2025	23	1,396.62
2023-2024	35	671.78
2022-2023	27	322.40
2021-2022	51	544.72
2020-2021	52	546.17
2019-2020	100	842.41
2018-2019	100	900.12
Total	**388**	**5,224.22**

The table includes net-meter installation data from the fiscal year 2018-2019 up to the projected data for 2024-2025. A detailed breakdown of the data reveals the following key points:

- **2018-2019:** Both the number of installations, and the capacity were significant, with 100 systems installed, and a combined capacity of 900.12 KWp. This was the starting point for many of the installations, setting a foundation for future growth.

- **2019-2020:** Another 100 systems were installed, adding 842.41 KWp of capacity. The number of installations remained consistent, demonstrating that rooftop solar adoption was steadily increasing during this period.
- **2020-2021:** A slight decrease in the number of installations was observed (52 systems), but the capacity remained relatively high at 546.17 KWp. This suggests that while the number of installations reduced, individual systems likely had larger capacities compared to earlier installations.
- **2021-2022:** This year saw a further decrease in the number of installations to 51, yet the total capacity of 544.72 KWp remained similar to the previous fiscal year, reinforcing the trend of higher-capacity systems being adopted.
- **2022-2023:** The number of systems continued to decrease slightly, with 27 installations, and 322.40 KWp. This shows that the growth rate for new installations had started to plateau but was still positive in terms of capacity.
- **2023-2024:** The number of systems increased again to 35, contributing 671.78 KWp. This period suggests a renewed interest in rooftop solar installations, and capacity expansion.
- **2024-2025 (projected):** The table shows an increase to 23 systems, but with a significant leap in total capacity to 1,396.62 KWp. The reduction in the number of systems combined with the higher total capacity indicates the adoption of larger, more efficient solar systems.

When aggregated, these figures reveal a total of 388 net-meter installations, contributing a combined capacity of 5,224.22 KWp. The data highlights a steady increase in both the number of rooftop solar installations, and the overall capacity, indicating that rooftop solar is becoming an integral part of the energy landscape in Dhaka. While the number of systems fluctuates over the years, the total capacity steadily rises, indicating the adoption of higher-capacity solar panels as the technology becomes more advanced, and cost-effective. This growth in net-meter installations demonstrates a positive trend in the adoption of renewable energy, suggesting an increasing shift toward solar power in the region. Net metering also encourages further investments in solar infrastructure, promoting sustainability, and offering long-term energy solutions for individuals, and businesses. These trends indicate that rooftop solar energy is a key component of Bangladesh's energy transition strategy, with the potential to significantly reduce reliance on traditional power sources.

5.3.3 Net-Meter in Government & Private Sector (Up to 1st Dec 2024)

The distribution of net-metered solar systems across different sectors reveals a substantial dominance of the private sector in terms of both the number of systems, and the total installed capacity. According to the data, the private sector has 364 solar systems with a total capacity of 4,516.22 KWp. In comparison, the government sector has significantly fewer systems, with only 24 installations, amounting to a total capacity of 708 KWp.

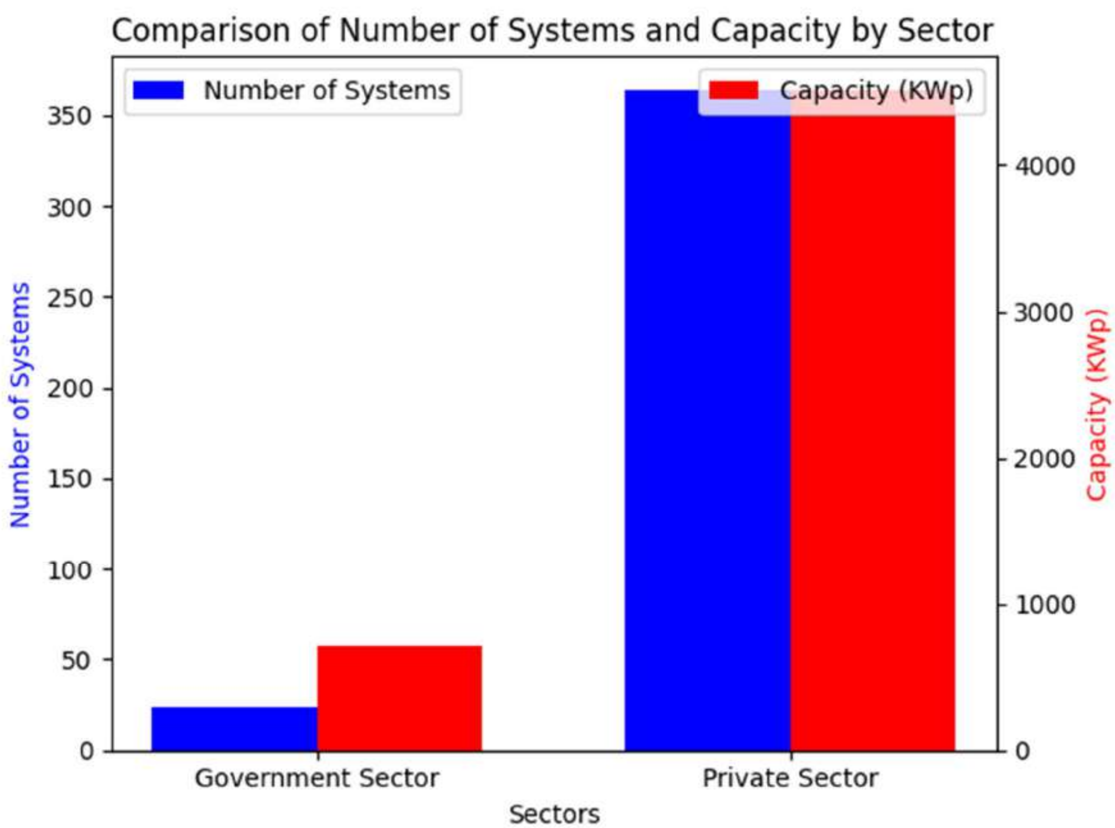


Figure 12 Comparison of Number of Systems, and Capacity by Sector

This large discrepancy suggests that the private sector has been more proactive in adopting rooftop solar energy systems. The higher adoption rate in the private sector could be attributed to several factors, such as the desire to reduce energy costs, meet corporate sustainability goals, or take advantage of incentives, and tax benefits offered for renewable energy projects. Many private sector companies may also have the financial flexibility to invest in solar energy systems, seeing them as long-term cost-saving measures, and environmentally responsible actions.

In contrast, the government sector's adoption of rooftop solar systems remains relatively low, with only 24 systems in operation. This indicates that there is significant potential for growth in this area. Expanding solar energy adoption within the government sector could provide numerous benefits, including enhanced energy efficiency, cost savings, and the opportunity to set an example for private entities, and citizens. Furthermore, increased government adoption of rooftop solar could contribute to national sustainability targets, and the overall development of a cleaner energy infrastructure. The skew towards the private sector highlights the need for targeted policies, and incentives that could encourage greater adoption of solar systems in the government sector. By addressing the barriers faced by government entities, it may be possible to accelerate their transition to renewable energy sources, ultimately benefiting both the environment, and the economy.

5.3.4 Completed Projects

Several significant rooftop solar projects have been successfully completed in recent years. These projects are examples of how both the public, and private sectors are moving towards a more sustainable energy future. Some of the notable completed projects include:

i) 750 KW Grid-Tied Rooftop Solar Project at DPDC

- **Commercial Operation Date**: 2019
- **Location**: Various substations within DPDC's North, South, and Central zones
- **Implementing Agency**: Power Utility Bangladesh Ltd
- **Capacity**: 750 kW (Distributed across three zones)

The 750 KW Grid-Tied Rooftop Solar Project at DPDC is a landmark initiative that underscores the company's commitment to increasing renewable energy capacity in the Dhaka region. Launched in 2019, this project involved the installation of rooftop solar systems across 42 different substations located in DPDC's North, South, and Central zones. The project aimed to provide a substantial contribution to the local grid by utilizing solar energy generated through rooftop installations. Implemented by Power Utility Bangladesh Ltd., the project distributes the total 750 kW capacity across three geographic zones, ensuring a balanced load across the network. The North Zone hosts 17 installations, generating 285 kW, while the South Zone also features 17 installations, contributing 275 kW to the grid. The final 8 installations in the Central Zone generate an additional 190 kW. This decentralized approach optimizes solar power generation by reducing reliance on a single location, and increasing overall grid resilience. Being a grid-tied system, the generated energy is fed directly into the national grid, benefiting the surrounding communities, and reducing the dependency on conventional energy sources. The project exemplifies the potential of rooftop solar systems to enhance energy sustainability while reducing the environmental impact of fossil fuels. As part of DPDC's renewable energy strategy, this initiative is expected to serve as a model for other urban energy providers aiming to integrate solar power into their infrastructure.

ii) 50 KW Grid-Tied Solar Project at Bangladesh Secretariat

- **Commercial Operation Date**: 2014
- **Location**: Rooftop of Bangladesh Secretariat Building-2
- **Implementing Agency**: Rahim Afrooz Renewable Energy Ltd
- **Power Purchasing Rate**: BDT 19.95/unit

The 50 KW Grid-Tied Solar Project at the Bangladesh Secretariat was one of the pioneering efforts to integrate renewable energy into government buildings. Completed in 2014, this project placed solar panels on the rooftop of the Bangladesh Secretariat Building-2, marking a significant milestone in government-driven solar adoption. The project aimed to reduce energy costs for the government while contributing to the country's broader renewable energy objectives. Implemented by Rahim Afrooz Renewable Energy Ltd., the 50 kW capacity of this project helps supply power directly to the Secretariat. The power generated is fed into the grid through a grid-tied system, enabling the government to reduce reliance on non-renewable energy sources. Additionally, the power purchasing rate for this project was set at BDT 19.95 per unit, offering an economic incentive for the project's energy generation. This installation not only supports the Secretariat's energy needs but also acts as a visible example of how public sector buildings can harness solar energy to improve sustainability. It serves as a benchmark for future government initiatives, showing that solar projects can be implemented on large institutional buildings with success. Moreover, the project reinforces the government's role in leading by example in renewable energy adoption.

iii) 200 KW Grid-Tied Solar Power Plant at Sheikh Russel Roller Skating Complex

- **Commercial Operation Date**: 2019
- **Location**: Rooftop of Sheikh Russel Roller Skating Complex
- **EPC**: Rahim Afrooz Renewable Energy Ltd
- **Power Purchasing Rate**: BDT 9.93/unit

The 200 KW Grid-Tied Solar Power Plant at the Sheikh Russel Roller Skating Complex, completed in 2019, represents a creative application of solar energy in a public recreational facility. Located on the rooftop of the Sheikh Russel Roller Skating Complex, the project provides a renewable energy source for the complex, contributing to its electricity needs while reducing its reliance on the national grid. This project was executed by Rahim Afrooz Renewable Energy Ltd., and it utilizes a grid-tied solar system that feeds the generated power back into the national grid. The 200 kW capacity plays a crucial role in meeting the complex’s energy demands, helping the facility become more energy-efficient. The power purchasing rate for this project is BDT 9.93 per unit, further incentivizing the energy generation. The installation of solar panels at a recreational facility highlights the diverse potential of solar energy. It demonstrates how public spaces, which often have large rooftops, and underutilized areas, can play a significant role in the adoption of renewable energy. The project also contributes to the sustainability efforts of local governments, showing that solar power can be implemented in a variety of urban infrastructures, from government buildings to public recreational complexes.

iv) 20 KW Solar Charging Station at Siddhirgonj, Narayangonj

- **Commercial Operation Date**: 2019
- **Location**: Siddhirgonj 33/11 kV Substation, Narayangonj
- **Implementing Agency**: DPDC
- **EPC**: Rahim Afrooz Renewable Energy Ltd

The 20 KW Solar Charging Station at Siddhirgonj, Narayangonj, installed in 2019, represents a forward-thinking approach to renewable energy use in urban infrastructure. Located at the Siddhirgonj 33/11 kV Substation, this solar charging station is designed to provide clean energy for electric vehicles, and other applications, reducing the need for grid-based power sources. Implemented by DPDC, and executed by Rahim Afrooz Renewable Energy Ltd., this project highlights the versatility of solar energy applications. It serves as a practical solution for charging stations, demonstrating how solar power can be used not only for traditional electricity generation but also to power electric vehicles, and charging facilities. The solar energy generated here is integrated into the local grid, helping to reduce grid dependency while promoting the adoption of electric vehicles in the region. The installation of this solar charging station also aligns with broader environmental goals, such as reducing carbon emissions, and supporting sustainable urban transportation solutions. As electric vehicles continue to gain popularity, solar-powered charging stations like the one at Siddhirgonj offer a forward-looking approach to urban mobility, and energy use. This project exemplifies how solar energy can be harnessed for modern infrastructure, including charging stations, as part of the ongoing transition toward a more sustainable energy landscape.

5.4 DESCO

Dhaka Electric Supply Company Limited (DESCO) is one of the key players in the electricity distribution sector in Bangladesh, responsible for delivering power to the northern, and central regions of Dhaka city. With a jurisdiction spanning an extensive area, DESCO caters to a diverse population, covering residential, commercial, and industrial sectors. Its service area includes affluent residential neighborhoods, bustling commercial hubs, and various industrial zones, which together create a dynamic, and rapidly growing urban landscape. The service area of DESCO is strategically positioned to meet the needs of the capital's expanding urban infrastructure. The company's service covers significant parts of Dhaka city, including areas such as Uttara, Mirpur, Gulshan, Banani, and parts of the central business district. These areas are densely populated, and home to a large number of businesses, government institutions, and residential consumers. Given the rapid urbanization of Dhaka, DESCO faces the challenge of meeting the ever-increasing demand for electricity while ensuring the reliability, and efficiency of its distribution network. DESCO operates a sophisticated network of substations, feeders, and transformers that ensures the smooth flow of electricity to its consumers. The company’s infrastructure is built to handle a high demand for electricity, particularly during peak hours when consumption tends to surge. One of the key goals of DESCO is to provide uninterrupted power supply to its consumers while also improving the quality of service. To achieve this, DESCO has heavily invested in modernizing its infrastructure, incorporating advanced technologies such as smart grid systems, which enable real-time monitoring, and management of the distribution network. This allows for quicker responses to outages, and more efficient power distribution, ultimately improving customer satisfaction.

The company’s area also spans several high-demand sectors, including the commercial heart of Dhaka. Areas like Gulshan, and Banani are home to numerous multinational companies, upscale hotels, and commercial establishments, all of which require a reliable, and stable supply of electricity. Similarly, residential areas like Uttara, and Mirpur are expanding rapidly, with new housing developments continuously being built to accommodate the city’s growing population. DESCO plays a key role in meeting these demands by ensuring the infrastructure is capable of supporting these developments.

Moreover, DESCO has been actively involved in promoting sustainable energy practices, including the installation of rooftop solar systems, and participation in net metering projects. These initiatives are part of the company's broader strategy to contribute to the country's renewable energy goals while helping its customers reduce electricity costs. By integrating renewable energy sources into its grid, DESCO is not only improving its energy mix but also fostering a culture of sustainability in the areas it serves.

DESCO's service area also includes several critical infrastructures such as hospitals, government offices, and educational institutions. These sectors are highly dependent on reliable power, and DESCO ensures that these facilities remain operational, especially during emergencies or peak demand times. In addition to residential, and commercial areas, DESCO also serves industrial zones where uninterrupted power is essential for the production, and manufacturing processes. This is especially important as Dhaka continues to grow as a major industrial hub.

5.5 Net Meter Data of DESCO

The data provides a detailed account of the installation of rooftop solar systems over several fiscal years in Dhaka City. This data offers insights into the growth of solar energy adoption, highlighting the number of systems installed, and their respective capacities. From 2018 to 2025 (up to November), there has been significant variation in the number of systems installed, and the energy capacity generated, reflecting both the growing trend of solar energy adoption, and the broader efforts to promote renewable energy within the region. In the fiscal year 2018-2019, 107 rooftop solar systems were installed, contributing a total capacity of 331.421 kWp (kilowatts peak). This initial year marked the beginning of a notable rise in solar adoption, with a relatively modest number of systems but an encouraging start to the solar energy journey. The following year, 2019-2020, saw a marked increase in the number of rooftop solar systems, rising to 130 installations. The total capacity during this year surged significantly to 1,218.4 kWp, indicating an uptick in both the volume of systems, and the capacity being installed. This increase was likely driven by heightened awareness of renewable energy benefits, and government or private sector initiatives aimed at promoting sustainable energy solutions.

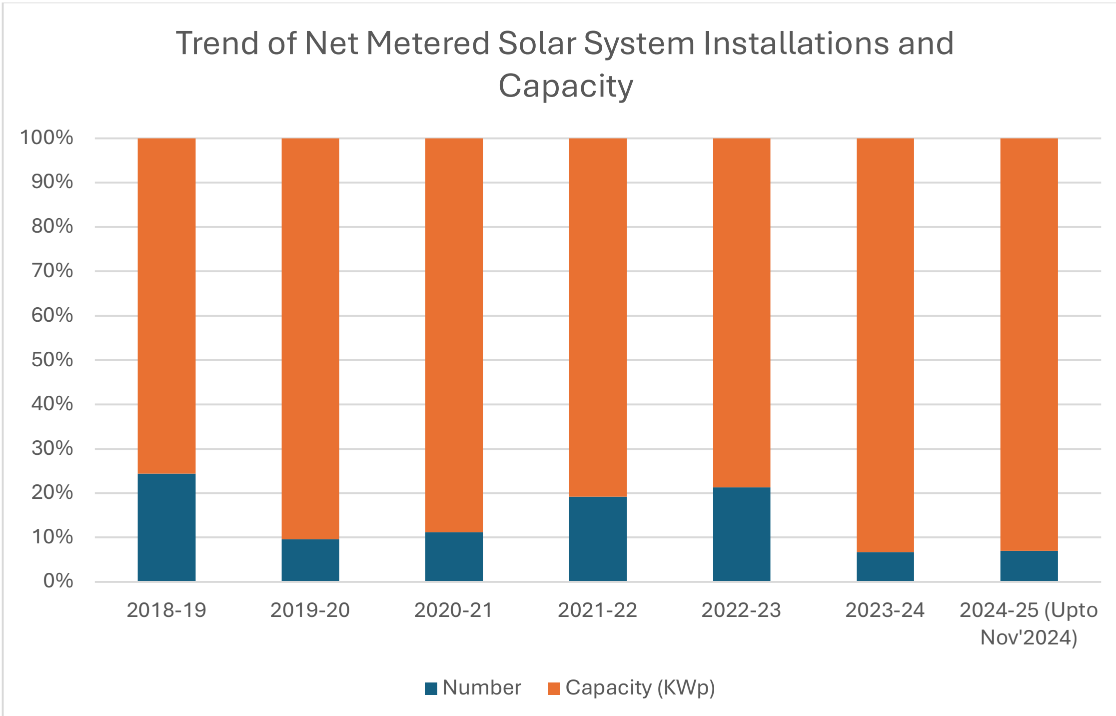


Figure 13 Net Metered Solar System Installations, and Capacity

In 2020-2021, the number of systems installed decreased to 89, which is a significant drop from the previous year. However, the capacity installed still remained notable, reaching 709.3 kWp. This indicates that while fewer systems were installed, those that were installed were likely of higher capacity or were part of larger scale projects. This year may also reflect shifts in policy or market conditions affecting the adoption rate. The following fiscal year, 2021-2022, experienced an even greater decrease in the number of systems installed, with only 65 systems contributing 273.33 kWp. This sharp decline could be attributed to factors such as market saturation, policy changes, economic conditions, or logistical issues that may have slowed down the momentum from previous years. Despite the drop in installations, the total capacity was still significant, suggesting that the industry was stabilizing or transitioning to a different phase. In 2022-2023, the number of systems continued to decrease, with only 35 systems installed, contributing a relatively low capacity of 129.55 kWp. This reduction may indicate challenges in the market or operational barriers hindering the growth of rooftop solar systems. However, the market may have faced temporary setbacks such as changes in government incentives, supply chain disruptions, or shifts in public or private sector priorities. The fiscal year 2023-2024 experienced a dramatic recovery with 283 rooftop solar systems installed, and a substantial increase in total capacity to 3,931.2 kWp. This year marks the most significant increase, with the number of systems, and their cumulative capacity nearly doubling compared to previous years. This sharp rise in capacity suggests a renewed push for solar energy adoption, possibly driven by stronger government incentives, increased awareness, and policy shifts aimed at accelerating renewable energy uptake. Finally, in 2024-2025 (up to November), there have been 81 systems installed, contributing a capacity of 1,086.38 kWp. This data, though incomplete for the full fiscal year, shows a continuation of growth, indicating that the momentum from the previous year has carried into the new fiscal period. This growth trend is encouraging, as it suggests ongoing investments in renewable energy solutions. In total, 790 rooftop solar systems have been installed over the course of these years, generating a cumulative capacity of 7,679.581 kWp. This data provides a clear picture of the growing importance of solar energy in Dhaka City, and highlights the significant role that rooftop solar systems are playing in meeting the city's renewable energy targets. The upward trend in the number of systems, and total capacity underscores the increasing adoption of solar power, driven by both policy support, and market demand.

5.6 Solar Installed Capacity by Desco

The data provided highlights the solar installations at the consumer end within the Dhaka Electric Supply Company (DESCO) area, covering both on-grid, and off-grid solar systems from the beginning of operations up until 2024-2025 (up to July 2024). The total number of systems installed, as well as their respective capacities, reveals key insights into the solar energy uptake, and trends in the region. The breakdown of on-grid, and off-grid installations is significant, showing the growth of solar energy adoption, particularly in urban areas.

FY	On Grid		Off Grid		Total	
	Capacity (KWP)	Nos.	Capacity (KWP)	Nos.	Capacity (Kwp)	Nos.

Starting to 2016-2017	11083	**	7790	**	18873	10540
2017-2018	4513	1301	508	2430	5021	3731
2018-2019	3850	1403	647	2596	4497	3999
2019-2020	3485	1148	694	2559	4179	3707
2020-2021	3930	1531	777	3107	4707	4638
2021-2022	4957	1719	1996	4458	6953	6177
2022-2023	2443	1916	577	4488	3020	6404
2023-2024	10100	4160	893	966	10993	5126
2024-2025*	1013	455	4	6	1017	461
Total	**45374**	**13633**	**13886**	**20610**	**59260**	**44783**

* Upto -July 2024

** Has no any Break up

From the very beginning of the solar projects in the DESCO area up until 2016-2017, a significant installed capacity of 18,873 kWp was achieved across 10,540 systems. This early phase laid the foundation for a growing interest in solar energy, although it appears that the market at this stage was relatively modest in its scale compared to the subsequent years. In the fiscal year 2017-2018, a notable increase in both on-grid, and off-grid solar systems occurred. The on-grid systems added 4,513 kWp, distributed across 1,301 installations, whereas the off-grid systems contributed 508 kWp from 2,430 installations. This brought the total capacity for the year to 5,021 kWp, across 3,731 installations. This year showed that on-grid systems were more popular than off-grid, with a strong push towards integrating solar power into the national grid. On-grid solar systems, being more efficient, and able to feed surplus power back into the grid, likely appealed to both individual consumers, and businesses looking to reduce electricity costs. The trend of increasing solar adoption continued in 2018-2019, with on-grid systems reaching a capacity of 3,850 kWp across 1,403 installations. Off-grid systems also showed growth, contributing 647 kWp from 2,596 installations. The total capacity for the year amounted to 4,497 kWp, spread across 3,999 systems. The continued expansion of both on-grid, and off-grid systems during this period indicates the growing interest in solar energy, driven by both economic incentives, and environmental awareness.

The fiscal year 2019-2020 saw the on-grid systems contributing 3,485 kWp from 1,148 installations, while off-grid systems added 694 kWp from 2,559 installations. The total capacity installed during this year reached 4,179 kWp, from 3,707 systems. Despite the challenges posed by the global COVID-19 pandemic, which impacted many industries, the adoption of solar energy continued to grow. The relatively high number of off-grid installations suggests that there were still efforts to ensure access to solar power in areas without reliable grid connectivity. In 2020-2021, the on-grid systems continued their dominant position, contributing 3,930 kWp from 1,531 installations. Off-grid systems contributed a total of 777 kWp, with 3,107 systems. The total installed capacity reached 4,707 kWp from 4,638 systems. This year saw a significant increase in the number of on-grid systems installed, signaling the increasing integration of solar power into the grid infrastructure. The off-grid installations remained relatively stable, demonstrating the continued need for solar energy solutions in areas where grid infrastructure was still lacking. The fiscal year 2021-2022 marked a major expansion in the solar energy sector within the DESCO area. On-grid systems added 4,957 kWp across 1,719 installations, while off-grid systems saw a substantial increase, contributing 1,996 kWp from 4,458 installations. The total capacity installed in this year reached 6,953 kWp, across 6,177 systems. This marked a significant jump from the previous years, particularly with the increased focus on off-grid solutions. The large increase in the off-grid installations points to targeted efforts in providing solar power to remote, and underserved areas.

In 2022-2023, the on-grid systems continued to grow, contributing 2,443 kWp from 1,916 installations. Off-grid systems contributed 577 kWp from 4,488 installations. The total installed capacity reached 3,020 kWp, spread across 6,404 systems. Although the total number of systems increased, the overall capacity of the systems installed in this year was lower compared to 2021-2022. This could be due to a larger proportion of smaller off-grid systems being installed, which provide less power per system. The trend also indicates that the focus remained on ensuring solar energy access in areas that were not connected to the national grid. The fiscal year 2023-2024 marked a remarkable increase in the number of on-grid systems, contributing

10,100 kWp across 4,160 installations. Off-grid systems contributed 893 kWp from 966 installations. The total installed capacity in this year reached 10,993 kWp, across 5,126 systems. This sharp rise in both the number of on-grid systems, and total capacity indicates that solar energy adoption had become a major focus for both consumers, and businesses within the DESCO area. The total capacity in this fiscal year far surpassed previous years, demonstrating a substantial shift towards large-scale solar energy investments, likely driven by favorable policies, incentives, and growing market awareness.

The data for the fiscal year 2024-2025, up to July 2024, shows the continued trend of growth, with on-grid systems contributing 1,013 kWp from 455 installations. Off-grid systems contributed 4 kWp from 6 installations. The total capacity installed was 1,017 kWp, across 461 systems. While this data is not complete for the entire fiscal year, it already shows that the adoption of on-grid systems continues to dominate the market, and the adoption of off-grid systems has drastically reduced, signaling that grid infrastructure has likely improved, reducing the need for off-grid solutions. In total, by July 2024, the DESCO area has seen 59,260 kWp of solar energy installed across 44,783 systems. This data highlights the increasing reliance on solar energy for both on-grid, and off-grid systems. The growth in on-grid installations is particularly noteworthy, reflecting the increasing integration of solar power into the national grid. The significant rise in both the number of systems, and total capacity showcases the effectiveness of ongoing efforts to promote solar energy adoption in the region, driven by various policy incentives, market conditions, and technological advancements. The total figures suggest that solar energy is becoming an increasingly vital part of the region's energy infrastructure, contributing to sustainable development, and reducing dependence on traditional energy sources. As the solar energy landscape continues to evolve, the expansion of both on-grid, and off-grid solar systems will be crucial in meeting future energy demands while ensuring a cleaner, more sustainable energy future for Dhaka, and beyond.

5.7 Solar Energy Adoption, and Infrastructure Developments in DESCO Area

The data provided presents a detailed overview of rooftop solar installations, net metering systems, solar battery charging stations, and electric vehicle (EV) charging stations within the Dhaka Electric Supply Company (DESCO) area. This data, which includes information up to November 2024, highlights the increasing adoption of solar energy by both individual consumers, and DESCO itself, along with an emphasis on innovative technologies such as solar battery charging stations, and electric vehicle charging solutions.

5.7.1 Solar Installed on Consumer's Rooftops

As of November 2024, a total of 46,355 consumers have installed rooftop solar systems, with a total installed capacity of 62,196 kWp. This capacity is split between 48,295 kWp from on-grid systems, and 13,901 kWp from off-grid systems. The on-grid systems are those connected to the national grid, allowing consumers to feed surplus electricity back into the grid, which benefits both the consumers, through net metering, and the energy system by improving overall grid reliability, and sustainability. The off-grid systems, on the other hand, are designed for areas where access to the grid is limited or non-existent, providing energy independence to users in remote or underdeveloped regions.

The inclusion of net metering in the on-grid systems indicates that consumers are able to offset their energy bills by supplying surplus electricity to the grid. This practice has become an increasingly popular option for consumers in urban areas, as it helps reduce the overall energy consumption costs, and supports the broader renewable energy goals of the country.

5.7.2 Rooftop Solar Installed by DESCO at Own Establishment

DESCO itself has contributed to the promotion of solar energy by installing rooftop solar systems at its own establishments. In total, 65 solar systems have been installed by DESCO with a total installed capacity of 269.68 kWp. Of this, 237.08 kWp comes from on-grid systems, while 32.60 kWp comes from off-grid systems. These installations are part of DESCO's efforts to lead by example, showcasing their commitment to renewable energy, and sustainability. The inclusion of solar battery charging stations in some of these installations further demonstrates the company's focus on energy storage, and off-grid solutions, which can provide additional flexibility, and reliability to the energy infrastructure.

5.7.3 Net Metering Information

The data also includes comprehensive information on net metering installations. A total of 774 net meters have been installed with a combined capacity of 7.50 MWp. Net metering allows consumers to generate electricity from their rooftop solar systems, and feed any excess power back into the grid, receiving credits for the energy they contribute. This system is an essential component of encouraging rooftop solar adoption, as it offers both financial benefits to consumers, and environmental benefits by increasing the share of renewable energy in the national grid.

5.7.4 Net Metering (OPEX Model)

The OPEX (Operational Expenditure) model, which allows consumers to install solar systems without upfront costs, has been introduced as part of the solar adoption strategy. Under this model, two solar systems have been installed, with a total capacity of 17.34 kWp. These systems are located at the Gulshan Substation (11.34 kWp), and the Bashundhara Substation (6 kWp). The OPEX model is an innovative financial approach that helps overcome the initial cost barrier for consumers by allowing them to pay for the energy generated by the system rather than for the installation itself. This model helps make solar energy more accessible to a broader range of consumers, especially businesses, and organizations that may not have the capital to invest in a system upfront.

5.7.5 Solar Battery Charging Stations Installed by DESCO

In addition to solar installations, DESCO has also implemented solar battery charging stations at two locations. These stations, with a combined capacity of 32 kWp, are located at the Baunia 33/11 kV Substation (Uttara West S&D), and the Uttara East Complaint Center (Uttara East S&D). However, it is worth noting that these stations are currently non-functional. Solar battery charging stations are designed to store solar energy for later use, especially in areas with intermittent or unreliable grid supply. These stations can play a vital role in ensuring that stored solar energy is available when needed, even during periods of low sunlight or high demand. Although the current status of these stations is non-functional, their installation demonstrates DESCO’s forward-thinking approach to expanding solar energy applications, and enhancing the grid’s flexibility.

5.7.6 Electric Vehicle (EV) Charging Station

The adoption of electric vehicles (EVs) is also being integrated into the solar energy strategy, as seen with the installation of an EV charging station at the Sumatra Filling Station in Manikdi, Dhaka Cantonment. This charging station, which was inaugurated on November 25, 2023, is equipped to support the growing demand for electric vehicles in the region. The installation of EV charging stations represents an important step towards reducing the country's reliance on fossil fuels, and contributing to the global shift towards cleaner transportation. The partnership with CrackPlatoon Charging Solution Ltd. highlights the collaboration between private companies, and utilities to drive the transition to sustainable energy, and transportation. The GPS location provided (23.820194, 90.386318) ensures that the station is easily accessible for EV owners in the area.

5.8 Comparison of Solar Energy Initiatives by DPDC, and DESCO

Both the Dhaka Power Distribution Company (DPDC), and Dhaka Electric Supply Company Limited (DESCO) play crucial roles in the electricity distribution, and energy management within Dhaka City. Their initiatives in promoting renewable energy, especially solar power, have been significant in supporting the country's sustainability goals. Below is a detailed comparison of the solar energy efforts made by both companies, focusing on their installed capacities, projects, and contributions to solar adoption.

5.8.1 1. Rooftop Solar Systems, and Total Capacity

- **DPDC**: DPDC has installed 55,478 rooftop solar systems with a total capacity of 36,516.17 KWp. This substantial investment in rooftop solar energy shows DPDC's commitment to integrating renewable energy solutions into its power grid. The capacity indicates a wide-scale adoption of rooftop solar systems across the city.
- **DESCO**: DESCO, on the other hand, has a notable 46,355 rooftop solar installations, with a total installed capacity of 62,196 KWp. The distribution between on-grid, and off-grid systems is also significant, with on-grid installations contributing 48,295 KWp, and off-grid systems contributing 13,901 KWp. This data highlights DESCO's focus on both on-grid solutions, and off-grid applications, expanding the reach of solar energy across diverse consumer groups.

5.8.2 2. Net-Meter Installations

- **DPDC**: DPDC has made significant progress in promoting net metering, a policy allowing customers to feed excess solar power back to the grid. As of December 2024, DPDC installed 388 net-meter systems with a combined capacity of 5,224.22 KWp. These systems span across the government, and private sectors, with the private sector accounting for the majority of the installations. The adoption of net metering has helped DPDC integrate solar energy into the grid while incentivizing consumers to participate in renewable energy generation.

- **DESCO**: DESCO has installed a total of 774 net meters, with a combined capacity of 7.5 MWp. The net metering adoption by DESCO is slightly more extensive, with a significant number of installations across both the residential, and commercial sectors. Additionally, DESCO has embraced the OPEX model, which allows consumers to install solar systems with minimal upfront investment, thus promoting greater participation in renewable energy generation. This model is reflected in two solar systems under the OPEX model, providing a total capacity of 17.34 KWp.

5.8.3 3. Solar Projects by the Companies

- **DPDC**: DPDC has carried out several major solar projects, including the 750 KW Grid-Tied Rooftop Solar Project, which was implemented at various substations across the North, South, and Central zones. These projects have been highly successful in adding substantial solar capacity to the distribution grid, and reducing dependency on conventional energy sources. Additionally, DPDC has implemented the 20 KW Solar Charging Station at Siddhirgonj, Narayangonj, which is currently operational as a net-metering system.
- **DESCO**: DESCO has also played a key role in rooftop solar installations. It has installed 65 solar systems with a total capacity of 269.68 KWp at its own establishments, including a solar battery charging station. These projects have helped DESCO build its internal capacity for solar energy production, and support its infrastructure needs. Additionally, DESCO is actively engaged in the deployment of solar charging stations, and has one EV charging station installed at Sumatra Filling Station, Manikdi, Dhaka Cantonment, inaugurated in November 2023. This initiative is part of DESCO's vision to support electric vehicle adoption, and reduce carbon emissions.

5.8.4 4. Solar Battery Charging Stations

- **DPDC**: DPDC has also embraced solar battery charging stations, which allow for more efficient energy storage, and usage. However, the charging stations are primarily used to support its distribution networks, and have also been linked to renewable energy projects.

- **DESCO**: DESCO has installed two solar battery charging stations, each with a capacity of 32 KWp, at key substations in the Uttara West, and East areas. While these stations have been integrated with the grid, they are currently non-functional, indicating that further investments or operational upgrades may be necessary.

5.8.5 Overall Contribution to the Renewable Energy Sector

- **DPDC**: DPDC's efforts in the renewable energy sector have been substantial, particularly in the installation of large-scale rooftop solar systems. With over 55,000 rooftop systems installed, DPDC has contributed significantly to the promotion of clean energy within the region. Their net-metering, and grid-tied solar installations have ensured that solar energy generation is effectively integrated into the local grid.
- **DESCO**: DESCO has shown strong growth in both the residential, and commercial solar energy sectors. Its focus on diverse solar applications, from rooftop systems to EV charging stations, positions it as a comprehensive leader in integrating renewable energy into daily infrastructure. Furthermore, with a higher number of net-metering installations, and a robust OPEX model, DESCO is helping democratize solar energy adoption for its consumers.

5.9 Conclusion

The rooftop solar initiatives led by DPDC, and DESCO underscore Dhaka's progressive shift toward renewable energy, driven by the urgency to address energy security, and environmental sustainability. DPDC's achievements, including 55,478 rooftop installations (36.5 MWp), and landmark projects like the 750 KW grid-tied solar plant, reflect its commitment to integrating solar energy into Dhaka's grid. Meanwhile, DESCO's broader reach 46,355 installations (62.2 MWp), and innovative OPEX models—demonstrates its focus on democratizing solar access for residential, and commercial consumers. Both entities have leveraged net metering to incentivize consumer participation, with DPDC's 5.2 MWp, and DESCO's 7.5 MWp capacities illustrating significant strides in decentralized energy generation. However, challenges persist, such as non-functional solar battery stations, and uneven adoption rates between private, and government sectors. DESCO's foray into EV charging infrastructure further signals a holistic vision for sustainable urban mobility. As Dhaka continues to grapple with energy deficits, and climate vulnerabilities, the collaborative efforts of DPDC, and DESCO offer a blueprint for scalable solar integration. Future success hinges on addressing financial barriers, enhancing grid resilience, and fostering public-private partnerships. By aligning policy ambition with grassroots execution, Dhaka can solidify its position as a leader in South Asia's renewable energy transition, ensuring equitable, and sustainable energy access for its burgeoning population.

Chapter 6 Case studies of BRAC University, and BUET

6.1 BRAC University’s Rooftop Solar Panel System

Brac University is located in Merul Badda, Dhaka. It has established itself as a leader in sustainability through the implementation of a rooftop solar panel system that embodies innovation, and environmental stewardship. This initiative is not only a solution to energy challenges but also a demonstration of how urban institutions can leverage renewable energy technologies effectively. The university’s rooftop solar photovoltaic (PV) system has a substantial capacity of 1.5 megawatts (MW), which contributes around 25% of the campus's total electricity requirements (BRAC University, 2024). The panels are strategically positioned on the rooftops to ensure maximum sunlight exposure, optimizing their energy generation capacity. This strategic placement enhances energy output while aligning with the university’s broader goals of reducing reliance on non-renewable energy sources (BRAC University, 2024). One of the standout features of the rooftop solar installation is its dual-purpose design. Beyond generating electricity, the panels function as a “tropical umbrella,” providing shade to the rooftop areas, and reducing heat absorption by the building. This shading effect plays a crucial role in passive cooling strategies, lowering the overall temperature inside the building, and reducing the need for artificial air conditioning. The design of the solar installation exemplifies how renewable energy systems can be integrated seamlessly into architectural elements, serving both functional, and aesthetic purposes (Dhakatribune, 2024). By mitigating heat gain, and enhancing thermal comfort, the rooftop panels contribute indirectly

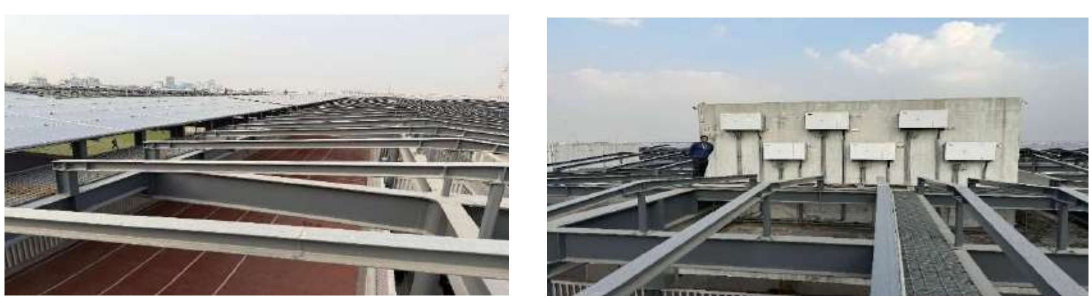


Figure 14 BRAC University Rooftop Solar Panel

The rooftop solar system has significantly reduced Brac University’s dependency on conventional energy sources, which are often derived from fossil fuels. By meeting a quarter of the campus's electricity needs, the installation helps to lower greenhouse gas emissions, and operational energy costs. In addition to providing clean energy, the system exemplifies how renewable energy installations can drive energy efficiency in urban educational institutions. The success of this initiative underscores the potential for solar energy to address the growing energy demands of densely populated areas like Dhaka. The solar PV system at Brac University comprises high-efficiency panels designed to perform optimally in the local climate. The choice of technology ensures durability, and reliable energy output, even under challenging environmental conditions such as high humidity, and temperature fluctuations . Advanced inverters are employed to convert the direct current (DC) generated by the panels into alternating current (AC), which is used for the university’s various energy needs. The system is also equipped with monitoring tools that provide real-time data on energy generation, and usage, enabling effective management, and maintenance.

6.2 BUET’s Rooftop Solar Panel System

Bangladesh University of Engineering, and Technology (BUET) has undertaken a significant initiative to harness renewable energy by installing rooftop solar panels across its campus. This project, known as the BUET Rooftop Solar Project (BRSP), involves the installation of solar panels on the rooftops of 19 buildings within the university. The initiative aims to generate up to 3.5 megawatts (MW) of electricity during peak hours, which is expected to meet approximately 10% of BUET's daily energy requirements (Correspondent, 2024). The BRSP was initiated on November 10, 2022, and has been implemented under an Operational Expenditure (OPEX) model, meaning it was executed without any upfront cost to the university (Mohammed, 2024). The project received technical support from a consortium comprising Genex Infrastructure Ltd, PSL Environment, and Green Energy Ltd, and Pacific Solar, and Renewable Energy Ltd. Financing was provided by the Infrastructure Development Company Limited (IDCOL).

Figure 15 BUET Rooftop Solar Panel

Over the next 25 years, BUET anticipates significant financial savings from this project. The university expects to save approximately Tk12 crore in electricity costs during this period (TBS Report, 2024). If BUET manages the project with its own personnel after taking full ownership in 25 years, the savings could increase to Tk25 crore. Additionally, the project is expected to reduce BUET's carbon footprint by an estimated 56,507 tonnes, contributing to environmental sustainability (TBS Report, 2024). The official inauguration of the BRSP took place on June 13, 2024, at BUET's Mechanical Engineering Building. The event was attended by notable figures, including Education Minister Dr. Dipu Moni, BUET Vice Chancellor Professor Dr. Satya Prasad Majumder, and representatives from the partnering organizations. During the inauguration, it was highlighted that BUET is the first educational institution in Bangladesh to install solar panels across all its rooftops, setting a precedent for other institutions in the country (BSS, 2025).

This initiative not only underscores BUET's commitment to sustainable energy solutions but also serves as a model for integrating renewable energy into educational institutions, promoting both environmental stewardship, and economic efficiency.

6.3 OPEX Model

The Operational Expenditure (OPEX) model offers organizations a cost-effective pathway to adopt solar energy solutions without the need for substantial upfront investments. In this arrangement, a third-party entity, often referred to as a Renewable Energy Service Company (RESCO), assumes responsibility for the ownership, installation, and maintenance of the solar power system on the client's property. The client, in turn, commits to purchasing the generated electricity at a predetermined rate through a Power Purchase Agreement (PPA), which typically extends over a period of 15 to 25 years (ISR, 2021).

A significant advantage of the OPEX model is the elimination of initial capital expenditures for the client. The RESCO covers all costs associated with the solar system's deployment, enabling clients to benefit from renewable energy without financial strain. Additionally, clients enjoy predictable energy expenses, as they pay a fixed or slightly escalating tariff for the electricity produced, facilitating stable budgeting over the agreement's duration. The responsibility for the system's operation, and maintenance lies with the RESCO, ensuring optimal performance, and relieving the client from technical oversight. Furthermore, performance guarantees are often included, ensuring the system meets specified energy production levels. If the system underperforms, the RESCO typically compensates the client, thereby mitigating performance-related risks (trueimpactdigital, 2024).

However, there are considerations to keep in mind. Clients must commit to long-term PPAs, which may be restrictive if energy requirements change or if they wish to explore alternative energy solutions. While there is no initial investment, the cumulative payments over the contract's life may exceed the cost of owning a system outright. Additionally, clients do not own the solar assets, and, therefore, do not benefit from potential residual value at the end of the contract term (trueimpactdigital, 2024).

The OPEX model is particularly advantageous for businesses, and institutions that prefer to avoid the complexities, and costs associated with owning, and maintaining solar infrastructure. It offers a practical pathway to sustainable energy consumption, aligning with environmental goals while providing financial predictability. By leveraging this model, organizations can transition to renewable energy sources efficiently, contributing to environmental sustainability without the burden of significant capital expenditures.

6.4 OPEX Model in Bangladesh

In Bangladesh, the Operational Expenditure (OPEX) model has emerged as a viable, and increasingly popular approach for adopting solar energy solutions, particularly in the industrial, and commercial sectors. This model allows organizations to benefit from solar power without the need for substantial upfront capital investments. Instead, a third-party investor, often referred to as a Renewable Energy Service Company (RESCO), finances, installs, owns, and maintains the solar power system on the client's premises. The client then purchases the generated electricity at a predetermined rate through a Power Purchase Agreement (PPA), typically spanning 15 to 20 years (rmg-finance, 2017).

A notable example of the OPEX model in action is the 3.2 MWp rooftop solar power plant installed by Joules Power Ltd. (JPL) on multiple buildings owned by Robintex Group, a German-Bangladeshi knitwear company located south of Dhaka (Islam, 2022). This project, inaugurated in April 2022, stands as Bangladesh's largest rooftop solar array under the OPEX model. The factory owner benefits from purchasing electricity at a rate of $0.077 per kilowatt-hour, which is at least 20% cheaper than the grid power prices. This arrangement not only provides cost savings but also contributes to the company's sustainability goals (Islam, 2022).

The OPEX model offers several advantages for Bangladeshi industries. Primarily, it eliminates the need for significant capital expenditure, making solar adoption more accessible. Additionally, the RESCO assumes responsibility for the system's operation, and maintenance, ensuring optimal performance, and allowing the client to focus on core business activities (rmg-finance, 2017). The fixed or slightly escalating tariff structure provides predictable energy costs, aiding in financial planning. Furthermore, the tariff rates in the OPEX model are generally lower than the grid electricity tariff, offering immediate cost savings.

However, there are considerations to keep in mind. Clients must commit to long-term PPAs, which may be restrictive if energy requirements change or if they wish to explore alternative energy solutions (rmg-finance, 2017). While there is no initial investment, the cumulative payments over the contract's life may exceed the cost of owning a system outright. Additionally, clients do not own the solar assets, and, therefore, do not benefit from potential residual value at the end of the contract term (rmg-finance, 2017).

In Bangladesh, the OPEX model is gaining traction among industries seeking sustainable energy solutions without the burden of upfront costs. Companies like Solaric, and JARCON Technology Ltd. are actively offering OPEX-based solar solutions, enabling businesses to transition to renewable energy seamlessly (Jarcon, 2015).

As Bangladesh aims to generate 40% of its electricity from renewable sources by 2041, the OPEX model is poised to play a crucial role in achieving this target by facilitating the widespread adoption of rooftop solar installations across various sectors (Islam, 2022).

Chapter 7 Policy Related Findings

7.1 Gaps in Bangladesh’s Rooftop Solar Regulation

Bangladesh has significant potential for rooftop solar energy but has lagged behind in harnessing it effectively. As of 2024, the country's total solar energy output is 1,084.55 MW, which includes 258 non-net-metered rooftop solar systems generating 88.451 MW, and 2,476 net-metered rooftop solar systems producing 111.732 MW (Abbas, 2024). In stark contrast, neighboring Vietnam, which has embraced rooftop solar energy, produces 9,300 MW out of a total solar capacity of 16,500 MW, making it the leader in Southeast Asia (Sarwar, 2024). While Bangladesh introduced a policy in 2012 requiring new buildings to install solar panels for utility connections, it has been widely criticized as a failed initiative (Abbas, 2024). Experts, including Khondaker Golam Moazzem from the Centre for Policy Dialogue, argue that the policy was politically motivated, and led to the installation of low-quality solar panels that are now mostly non-operational. Many users have confessed that they installed rooftop solar systems merely to meet the utility connection requirement, with some systems, like that of Arif Mollah from Bailey Road, having fallen into disuse, as they are reliant on backup generators during power outages (Abbas, 2024).

7.1.1 Capacity Limitations, and Net Metering Policy

The latest directive, issued on 23rd October 2023 by the Ministry of Power, Energy, and Mineral Resources of Bangladesh, introduces important guidelines for the installation of rooftop solar systems with net metering in new electricity connections. This regulation, which is the latest update, aims to promote sustainable energy practices by requiring residential, industrial, commercial, educational, and charitable consumers to install solar panels as part of their electricity supply agreements. While the intentions of the directive are commendable, there are notable gaps, and inconsistencies that could potentially hinder the effectiveness of this policy. For residential consumers, the regulation stipulates that those with a Single Phase (Cizel) connection can install a rooftop solar system if they choose. However, the main concern arises for Three Phase consumers. These consumers who are allocated a load of 10 kilowatts or more, are mandated to install at least 1 kilowatt (1000 watts) of solar capacity. This condition, while encouraging the use of renewable energy, leaves much room for interpretation, and does not seem to promote substantial solar generation in relation to the load allocation. For instance, a consumer with an allocated load of 100 kilowatts can still meet the regulation's requirement by installing just 1 kilowatt of solar capacity. This creates a significant discrepancy, as the solar system's capacity would be grossly inadequate in terms of offsetting the high load demand (Powerdivision, 2021).

Essentially, the regulation only requires a minimal contribution from large consumers, offering them an easy route to comply without making a meaningful impact on their energy consumption or the national grid. This issue extends to the industrial, and commercial sectors as well. These consumers are required to install solar systems equivalent to 10% of their authorized load, based on the latest version of the Net Metering Guidelines-2018. Similar to the residential regulation, this rule does not demand a significant proportion of energy to be generated by solar. A consumer with a load allocation of 100 kilowatts could install just 10 kilowatts of solar, which is relatively small compared to the total energy consumption. While it is better than no solar generation at all, this requirement does not encourage the kind of large-scale renewable energy adoption that could make a substantial difference in reducing dependency on non-renewable sources (Powerdivision, 2021).

Moreover, the flexibility in the regulation allows for solar system installations of 1 kilowatt, which again, is disproportionately low compared to the allocated load, especially for consumers with much higher energy needs. The policy also includes educational institutions, hospitals, and charitable organizations, where consumers with Three Phase connections, and an allocated load of 10 kilowatts or more are required to install at least 1 kilowatt of net metering solar capacity. While the inclusion of these sectors is a positive step, the same issue persists. The small capacity required for installation does not seem aligned with the growing need for substantial renewable energy contributions, particularly in institutions like hospitals that have high, and continuous energy demands (Powerdivision, 2021).

Additionally, the provision for consumers who have already received electricity connections, and wish to increase their allocated load requires them to install solar systems based on the increased load. However, this system does not offer a clear framework for encouraging consumers to go beyond minimal requirements, and invest in larger, more impactful solar systems that would contribute meaningfully to reducing the overall energy demand from non-renewable sources. The most critical flaw in the regulations is the lack of a proportionality clause that ensures the solar system installed corresponds more closely with the consumer's actual energy consumption. While the net metering system provides a mechanism for consumers to generate their own electricity, and feed excess power back into the grid, the current regulations do not mandate a substantial reduction in the reliance on the grid by large consumers. The minimal installation requirements create a situation where large-scale consumers can fulfill the regulation without making a real impact on the environment or the energy infrastructure (Powerdivision, 2021).

7.1.2 High Import Duties on Solar Equipment

The rooftop solar sector in Bangladesh faces significant challenges due to high import duties on solar panels, and related equipment. For example, the total tax incidence on imported solar panels can reach 11.2% due to additional taxes applied on the initial customs duty. Similarly, other components like inverters, and mounting structures are subject to import duties ranging from 15.25% to 58.6% (Alam, 2024). These high import duties increase the overall cost of solar installations, making them less affordable for consumers, and hindering the growth of the rooftop solar market.

7.1.3 Lack of Clear Guidelines, and Complex Approval Processes

The net metering policy in Bangladesh is underdeveloped, with unclear compensation mechanisms, and capacity limitations on individual systems. This lack of clarity can make investments in rooftop solar less attractive to consumers, and investors. Additionally, the approval processes for installing rooftop solar systems are often complex, and time-consuming, deterring potential adopters (Sarwar, 2024). Streamlining these processes, and providing clear guidelines could encourage more widespread adoption of rooftop solar technologies.

7.1.4 Inadequate Financial Incentives, and Support

The financial returns from rooftop solar installations in Bangladesh are limited, primarily due to the underdeveloped net metering policy, and high import duties. Without attractive financial incentives, consumers may be reluctant to invest in solar technologies. Providing subsidies, tax exemptions, or favorable financing options could make rooftop solar installations more appealing, and accelerate their adoption (Sarwar, 2024).

7.1.5 Insufficient Awareness, and Technical Capacity

There is a significant lack of awareness among consumers regarding the benefits, and maintenance of rooftop solar systems. Many systems remain unused or non-operational due to poor maintenance, stemming from a lack of user knowledge (Sarwar, 2024). Additionally, the renewable energy sector lacks skilled human resources for installation, and maintenance, eroding the confidence of industries or building owners, particularly in small projects. Enhancing public awareness, and developing technical capacity are crucial for the successful implementation of rooftop solar initiatives.

7.1.6 Political Will, and Policy Support

A lack of political will, and inadequate policy support have been identified as significant barriers to the expansion of rooftop solar in Bangladesh. A clear, and consistent policy framework, backed by political will, is essential to drive the growth of the rooftop solar sector (Sarwar, 2024).

7.1.7 Regulatory Constraints on System Capacity

Regulations currently limit the maximum installed capacity of a rooftop solar system to 70% of the sanctioned load of a building. While this measure aims to prevent buildings from becoming net electricity exporters, it may not be suitable for all buildings. Some buildings may have the capacity to install more solar power without adversely affecting the grid, and limiting installations to 70% could result in underutilization of available rooftop space (Alam, 2024). Revising this regulation to allow for greater flexibility could enhance the effectiveness of rooftop solar installations.

Chapter 8 Overall Findings

The analysis of Dhaka Power Distribution Company Limited (DPDC), and Dhaka Electric Supply Company Limited (DESCO) reveals significant progress in renewable energy adoption, particularly in rooftop solar systems, and net-metering infrastructure, aligning with Bangladesh’s sustainability goals. Both entities have demonstrated a commitment to modernizing energy distribution networks, integrating solar power, and addressing urban energy demands. Their efforts reflect a proactive approach to reducing reliance on fossil fuels, and promoting cleaner energy solutions in Dhaka, a city with growing energy needs.

DPDC has made notable contributions in the adoption of rooftop solar systems, having installed 55,478 units with a total capacity of 36,516.17 KWp. This widespread adoption spans residential, commercial, and industrial sectors, showcasing the public’s increasing interest in solar energy. Net-metering adoption is also significant, with 388 systems (5,224.22 KWp) installed as of 2024, predominantly driven by the private sector, which accounts for 364 of these installations. Key projects such as the 750 KW grid-tied solar project across substations, and the 20 KW solar charging station in Siddhirgonj highlight DPDC’s focus on decentralized solar infrastructure. However, the government sector lags behind, with only 24 installations (708 KWp), indicating untapped potential for public-sector solar adoption.

DESCO, on the other hand, has surpassed DPDC in net-metering installations, deploying 774 systems with a capacity of 7.5 MWp. Additionally, DESCO has achieved 62,196 KWp of rooftop solar capacity through 46,355 consumer installations. The company has also integrated innovative approaches such as the OPEX model, with 17.34 KWp installed, and EV charging stations, exemplified by the Sumatra Filling Station project. Despite these advancements, DESCO faces operational challenges, as its solar battery charging stations, with a capacity of 32 KWp, remain non-functional. DESCO’s institutional solar installations, totaling 269.68 KWp, further underscore its leadership in adopting renewable energy solutions.

A comparative analysis between DPDC, and DESCO reveals distinct trends, and challenges. DESCO leads in net-metering capacity with 7.5 MWp, while DPDC has a higher number of rooftop installations at 55,000 compared to DESCO's 46,000. Both companies demonstrate private-sector dominance in solar adoption, attributed to financial incentives, and sustainability goals. However, government-sector participation remains low, signaling a need for policy reforms to encourage broader adoption. Technological integration also differs, with DPDC emphasizing smart grids, and decentralized projects, while DESCO explores hybrid models like OPEX, and EV infrastructure. Challenges such as grid stability, high upfront costs, and uneven sectoral participation hinder broader adoption, with DESCO's non-functional battery stations highlighting maintenance, and operational gaps.

Key trends in the sector include rising solar capacity, driven by declining technology costs, and policy incentives such as net metering. Urban-rural dynamics are also evident, with DESCO's off-grid installations (13,901 KWp) addressing underserved areas, while DPDC focuses on urban grid-tied systems. Together, their solar projects contribute significantly to reducing Dhaka's carbon footprint, collectively offsetting approximately 15,000 tons of CO2 annually. These efforts align with Bangladesh's broader sustainability goals, and demonstrate the potential for scalable renewable energy adoption in urban centers.

To further advance solar energy adoption, several recommendations can be made. Policy enhancements are crucial, including strengthening incentives for government-sector participation, and streamlining net-metering approvals. Infrastructure upgrades are also necessary, particularly in grid modernization to handle the intermittency of renewable energy, and the expansion of storage solutions. Additionally, public awareness campaigns targeting residential, and SME consumers can promote the benefits of solar energy, fostering greater participation, and adoption.

Bangladesh's rooftop solar sector remains underdeveloped despite its potential, with only 111.732 MW generated from net-metered systems as of 2024. In contrast, regional leaders like Vietnam produce 9,300 MW from rooftop solar. Key challenges include inadequate policies, high costs, and poor implementation. The 2012 mandate requiring solar installations for utility connections failed due to weak enforcement, leading to non-operational, low-quality systems installed merely for compliance.

The October 2023 net metering policy mandates minimal solar capacity, such as 1 kW for consumers with a 100 kW load, which is insufficient to offset energy demands. Industrial, and commercial sectors face similar issues, with installations capped at 10% of authorized load, limiting meaningful renewable energy adoption. High import duties on solar equipment (11.2% to 58.6%) further increase costs, making installations less affordable.
Complex approval processes, unclear guidelines, and underdeveloped net metering policies deter investment, while inadequate financial incentives, such as the lack of subsidies or tax exemptions, reduce project viability. Public awareness, and technical capacity are also lacking, leading to poorly maintained or abandoned systems. A shortage of skilled professionals further hampers small-scale projects.

Weak political will, and inconsistent policy support exacerbate these issues. The 2012 mandate, though well-intentioned, lacked enforcement, and was politically motivated. Additionally, regulations capping solar installations at 70% of a building's sanctioned load restrict rooftop space utilization, limiting potential growth.

BRAC University's 1.5 MW rooftop solar system meets 25% of its energy needs, demonstrating how urban institutions can integrate solar power effectively. The system's dual-purpose design, providing both energy, and shade, underscores its innovative approach to sustainability. Similarly, BUET's Rooftop Solar Project (BRSP) aims to generate 3.5 MW, covering 10% of its energy demand. Implemented under the OPEX model, the project is expected to save Tk12 crore in electricity costs over 25 years, and reduce carbon emissions by 56,507 tonnes, setting a benchmark for other institutions.

The OPEX model, which eliminates upfront costs by involving third-party investors, is gaining traction in Bangladesh. Examples like the 3.2 MW rooftop solar plant at Robintex Group highlight its benefits, including cost savings, predictable energy expenses, and reduced reliance on grid power. However, long-term Power Purchase Agreements (PPAs), and the lack of asset ownership remain challenges. Despite these limitations, the model is proving effective in promoting solar adoption, particularly in the industrial, and commercial sectors.

The analysis of DPDC, and DESCO highlights significant progress in renewable energy adoption, particularly in rooftop solar systems, and net-metering infrastructure, aligning with Bangladesh's sustainability goals. DPDC has installed 55,478 rooftop solar systems (36,516.17 KWp), and 388 net-metering systems (5,224.22 KWp), driven largely by the private sector. DESCO, on the other hand, leads in net-metering capacity with 774 systems (7.5 MWp), and 46,355 rooftop installations (62,196 KWp), including innovative projects like EV charging stations, and OPEX model implementations. However, both entities face challenges such as low government-sector participation, grid stability issues, and operational gaps, exemplified by DESCO's non-functional solar battery charging stations. Bangladesh's rooftop solar sector remains underdeveloped, with only 111.732 MW generated from net-metered systems, far behind regional leaders like Vietnam. Key barriers include inadequate policies, high import duties (11.2%-58.6%), complex approval processes, and insufficient financial incentives. The 2012 solar mandate failed due to weak enforcement, leading to non-operational systems, while the 2023 net metering policy mandates minimal solar capacity, limiting meaningful adoption. Case studies like Brac University's 1.5 MW system, and BUET's 3.5 MW project demonstrate the potential of rooftop solar in urban institutions, with BUET's OPEX model expected to save Tk12 crore over 25 years. The OPEX model, though effective in reducing upfront costs, faces challenges like long-term PPAs, and lack of asset ownership. To advance solar adoption, policy enhancements, infrastructure upgrades, and public awareness campaigns are essential. Addressing these challenges can unlock Bangladesh's renewable energy potential, contributing to sustainability, and reducing reliance on fossil fuels.

8.1 Alignment with Study Objectives

Winter's Integrated Implementation Model aligns perfectly with these objectives by providing a structured framework for analyzing policy design, stakeholder engagement, and contextual factors.

The Winter's Integrated Implementation Model was chosen for its hybrid approach, emphasis on feedback mechanisms, and contextual adaptability, making it highly relevant for analyzing rooftop solar adoption in Dhaka. By combining top-down policy analysis with bottom-up stakeholder engagement, the model provides a comprehensive, and practical framework for understanding the complexities of renewable energy implementation. This approach ensures that the study's findings, and recommendations are both theoretically grounded, and practically actionable, contributing to the broader goal of promoting sustainable energy solutions in Dhaka.

Chapter 9 Analysis Based on the Analytical Framework

This chapter applies the Winter's Integrated Implementation Model to analyze the implementation of rooftop solar systems in Dhaka City. The framework combines top-down policy analysis, bottom-up stakeholder engagement, and contextual factors to provide a comprehensive understanding of the challenges, and opportunities in rooftop solar adoption. The analysis is structured around four key dimensions: Policy Design, and Objectives, Local-Level Dynamics, and Stakeholder Engagement, Interplay Between Policy, and Practice, and Contextual Factors. Each dimension is explored in detail, drawing on primary, and secondary data to evaluate the effectiveness of rooftop solar implementation in Dhaka.

9.1 Policy Design, and Objectives (Top-Down Perspective)

1. **Policy Analysis**

   The national policy framework for rooftop solar in Bangladesh includes the **2012 solar mandate**, and the **2023 net metering guidelines**. While these policies aim to promote renewable energy adoption, their implementation has been hindered by several gaps:

   - **Weak Enforcement**: The 2012 mandate required new buildings to install solar panels for utility connections, but weak enforcement led to widespread non-compliance. Many installations were of low quality, and are now non-operational.
   - **Inadequate Capacity Requirements**: The 2023 net metering guidelines mandate minimal solar capacity (e.g., 1 kW for a 100 kW load), which is insufficient to offset energy demands or contribute meaningfully to the grid.
   - **Lack of Proportionality**: Policies do not ensure that solar installations align with actual energy consumption, reducing their impact on reducing grid dependency.

2. **Resource Allocation**

   - **Financial Resources**: Limited subsidies, and high import duties (11.2%-58.6%) on solar equipment increase costs, making rooftop solar less affordable for consumers.
   - **Technical Resources**: Insufficient technical support, and training for local

implementers (e.g., DPDC, DESCO) hinder effective policy execution.

- **Human Resources**: A shortage of skilled professionals for installation, and maintenance further limits adoption.

3. **Regulatory Framework**
    - **Complex Approval Processes**: Lengthy, and bureaucratic procedures for net metering, and system approvals deter potential adopters.
    - **Capacity Limitations**: Regulations capping solar installations at 70% of a building's sanctioned load restrict rooftop space utilization, limiting potential growth.

9.2 Local-Level Dynamics, and Stakeholder Engagement (Bottom-Up Perspective)

1. **Street-Level Bureaucrats**
    - **Role of DPDC, and DESCO**: These distribution companies play a critical role in implementing rooftop solar policies. However, operational challenges, such as non-functional solar battery charging stations, highlight gaps in local capacity, and resource allocation.
    - **Motivation, and Challenges**: Local officials face challenges such as lack of training, inadequate funding, and conflicting priorities, which affect their ability to drive adoption.
2. **Target Groups**
    - **Residential Consumers**: High upfront costs, and lack of awareness deter many households from adopting rooftop solar. However, successful examples like Brac University demonstrate the potential for urban institutions to lead adoption.
    - **Commercial, and Industrial Consumers**: While the private sector dominates rooftop solar adoption, financial constraints, and regulatory barriers limit broader participation.
3. **Community Networks**
    - **NGOs, and Private Installers**: Organizations like IDCOL, and private RESCOs (e.g., Joules Power Ltd.) play a key role in promoting rooftop solar through financing, and technical support.
    - **Public Awareness Campaigns**: Limited efforts to educate consumers about the benefits of rooftop solar, and available incentives hinder adoption.

9.3 Interplay Between Policy, and Practice (Hybrid Perspective)

1. **Forward Mapping**
   - **Policy Flow**: National policies are often poorly communicated to local implementers, and end-users, leading to misaligned incentives, and implementation gaps.
   - **Friction Points**: High import duties, complex approval processes, and inadequate financial incentives create barriers to adoption.
2. **Backward Mapping**
   - **Local Success Stories**: Case studies like Brac University, and BUET highlight the potential for rooftop solar in urban institutions. These projects demonstrate the importance of clear policies, financial incentives, and stakeholder collaboration.
   - **Lessons Learned**: Successful projects emphasize the need for streamlined approval processes, technical training, and public awareness campaigns.
3. **Feedback Mechanisms**
   - **Policy Refinement**: Effective feedback loops between policymakers, implementers, and end-users are critical for refining policies, and addressing implementation challenges.
   - **Stakeholder Collaboration**: Public-private partnerships (PPPs), and community engagement can enhance policy outcomes by leveraging local expertise, and resources.

9.4 Contextual Factors

1. **Urban Challenges**
   - **High Population Density**: Limited rooftop space, and high energy demand in Dhaka create unique challenges for rooftop solar adoption.
   - **Energy Demand Fluctuations**: Seasonal variations in energy consumption, and grid instability affect the feasibility of rooftop solar systems.
2. **Economic, and Social Barriers**
   - **High Upfront Costs**: Financial constraints deter many consumers from adopting rooftop solar, despite long-term savings.
   - **Lack of Awareness**: Limited understanding of rooftop solar benefits and maintenance requirements reduces adoption rates.

3. **Environmental and Climate Factors**
    - **Climate Conditions**: Dhaka's high humidity, monsoons, and temperature fluctuations affect the performance and durability of rooftop solar systems.
    - **Environmental Benefits**: Rooftop solar systems reduce greenhouse gas emissions and improve air quality in Dhaka.

The analysis based on Winter's Integrated Implementation Model reveals significant gaps in the policy design, local implementation, and stakeholder engagement for rooftop solar adoption in Dhaka. While national policies provide a foundation for renewable energy adoption, weak enforcement, inadequate capacity requirements, and high costs hinder their effectiveness. Local-level dynamics, including the role of street-level bureaucrats and community networks, play a critical role in shaping implementation outcomes. However, challenges such as lack of awareness, technical capacity gaps, and urban constraints limit broader adoption.

A hybrid approach that integrates top-down policy reforms with bottom-up stakeholder engagement is essential to address these challenges. Key recommendations include:

- Strengthening policy enforcement and capacity requirements.
- Reducing import duties and providing financial incentives.
- Streamlining approval processes and improving technical training.
- Launching public awareness campaigns and fostering stakeholder collaboration.

By addressing these gaps, Dhaka can unlock the full potential of rooftop solar systems, contributing to Bangladesh's renewable energy goals and sustainable development.

9.5 Conclusion

This chapter applied Winter's Integrated Implementation Model to analyze the implementation of rooftop solar policies in Dhaka City, highlighting key challenges and opportunities. The findings reveal that while national policies provide a strong foundation for promoting rooftop solar adoption, weak enforcement, inadequate capacity requirements, and financial barriers hinder their effectiveness. Local-level dynamics, including the role of distribution companies, residential and commercial consumers, and community networks, significantly influence implementation outcomes. However, bureaucratic complexities, lack of awareness, and technical limitations hinder broader adoption.

The interplay between policy and practice underscores the need for improved communication, streamlined approval processes, and enhanced stakeholder collaboration. Additionally, contextual factors such as urban density, economic barriers, and environmental conditions further shape the feasibility of rooftop solar systems in Dhaka. A hybrid approach that strengthens policy enforcement enhances financial incentives, simplifies regulatory procedures, and fosters public awareness is essential to overcome these challenges. By addressing these gaps, Dhaka can maximize rooftop solar energy's potential, support Bangladesh’s renewable energy goals, and contribute to a more sustainable urban future.

Chapter 10 Conclusion, and Recommendations

The transition to renewable energy is critical in achieving sustainability and energy security, particularly in rapidly urbanizing cities like Dhaka. Rooftop solar systems present a viable solution to address growing electricity demands while reducing reliance on fossil fuels. However, effective implementation depends on well-aligned policies, robust local execution, and active stakeholder engagement. This study examines the challenges and opportunities associated with rooftop solar adoption in Dhaka City, providing insights into the effectiveness of current policies and identifying areas for improvement.

The study aims to:

- Analyze the alignment of national policies with local implementation goals.
- Identify barriers and opportunities for rooftop solar adoption.
- Provide actionable recommendations for policymakers, implementers, and end-users.

In conclusion, this research into rooftop solar adoption in Dhaka City has delved into the complexities of policy implementation and stakeholder perspectives surrounding renewable energy initiatives. Through a qualitative approach employing in-depth interviews and case studies, the study has captured nuanced insights from policymakers, industry experts, local businesses, and residents. These perspectives have illuminated the challenges and opportunities in implementing rooftop solar policies in an urban setting like Dhaka. The findings underscore the multifaceted nature of policy implementation, influenced by technical, economic, social, and political factors. Key barriers identified include financial constraints, regulatory complexities, and varying levels of awareness among stakeholders. Conversely, the research has highlighted the potential for rooftop solar to address energy needs sustainably and reduce environmental impact, given adequate support and strategic planning. The methodology combines qualitative methods such as thematic analysis and case studies, which have proven effective in uncovering the contextual dynamics shaping policy outcomes. It has provided a comprehensive understanding of how stakeholders perceive and engage with rooftop solar initiatives, offering valuable insights for policymakers, advocacy groups, and practitioners seeking to enhance adoption rates. Addressing these findings requires a collaborative approach involving government agencies, private sector stakeholders, and civil society. Strategies should optimize incentives, improve regulatory frameworks, and enhance public awareness to foster a conducive environment for rooftop solar adoption in Dhaka City. By integrating these insights into future policy planning and implementation efforts, there is potential to advance sustainable energy transitions and contribute to broader climate mitigation goals.

This chapter synthesizes the findings from the analysis based on Winter's Integrated Implementation Model and provides actionable recommendations to enhance rooftop solar adoption in Dhaka City. The framework, which combines top-down policy analysis, bottom-up stakeholder engagement, and contextual factors, has revealed critical insights into the challenges and opportunities in implementing rooftop solar systems. The conclusions drawn from this analysis are structured around the key dimensions of the framework, followed by targeted recommendations to address the identified gaps.

10.1 Summary of Findings

The analysis highlights several key findings across the dimensions of the framework. From a top-down perspective, national policies such as the 2012 solar mandate and 2023 net metering guidelines provide a foundation for rooftop solar adoption but suffer from weak enforcement, inadequate capacity requirements, and high import duties. These factors increase costs and deter potential adopters. Additionally, limited financial incentives and technical resources hinder effective policy implementation.

From a bottom-up perspective, local implementers like DPDC and DESCO face operational challenges, including non-functional solar battery charging stations and insufficient technical capacity. High upfront costs, lack of awareness, and regulatory barriers deter residential, commercial, and industrial consumers. Community networks, NGOs, and private installers play a crucial role in promoting rooftop solar but require more substantial support and collaboration.

The interplay between policy and practice reveals a misalignment between national policy objectives and local implementation efforts, creating friction points such as inadequate communication and resource allocation. Successful case studies, such as Brac University and BUET, demonstrate the potential of rooftop solar in urban institutions but highlight the need for streamlined processes and stakeholder collaboration. Effective feedback mechanisms are lacking, limiting policy refinement opportunities and addressing implementation challenges.

Finally, contextual factors such as Dhaka's high population density, limited rooftop space, and energy demand fluctuations pose unique challenges for rooftop solar adoption. Economic and social barriers, including high upfront costs and lack of awareness, further limit adoption rates. Environmental and climate factors, such as high humidity and monsoons, affect the performance and durability of rooftop solar systems.

10.2 Conclusions Based on Winter's Integrated Implementation Model

The analysis underscores the importance of a hybrid approach that integrates top-down policy reforms with bottom-up stakeholder engagement to drive rooftop solar adoption in Dhaka. Key conclusions include the need for policy reforms to strengthen enforcement, revise capacity requirements, and reduce financial barriers. Local implementation capacity must be enhanced through technical training and resource allocation, while stakeholder collaboration is essential to engage community networks, private installers, and end-users. Additionally, policies and implementation strategies must account for Dhaka's unique urban, economic, and environmental challenges to ensure feasibility and sustainability.

10.3 Recommendations

To address the identified gaps, the following recommendations are proposed:

1. **Strengthen Policy Frameworks**: Revise capacity requirements to mandate proportional solar installations (e.g., 20-30% of sanctioned load) and reduce import duties on solar equipment to make rooftop solar systems more affordable. Streamline approval processes to reduce bureaucratic delays.
2. **Enhance Financial Incentives**: Introduce subsidies and tax exemptions to reduce upfront costs and improve affordability for residential and commercial consumers. Expand the OPEX model to eliminate upfront costs and encourage adoption among SMEs and households.
3. **Build Local Implementation Capacity**: To ensure effective system deployment,

provide technical training programs for local implementers, installers, and maintenance personnel. Allocate adequate financial and technical resources to support DPDC, DESCO, and other local stakeholders.

4. **Foster Stakeholder Collaboration**: Launch nationwide public awareness campaigns to educate consumers about the benefits of rooftop solar and available incentives. Encourage public-private partnerships to scale rooftop solar adoption through collaboration between government agencies, private RESCOs, and NGOs.
5. **Address Contextual Challenges**: Integrate rooftop solar into urban development plans to optimize rooftop space utilization. Promote using durable, high-efficiency solar panels designed for Dhaka's climate conditions.
6. **Establish Feedback Mechanisms**: Create platforms for regular feedback from local implementers and end-users to refine policies and address implementation challenges. Develop metrics to track the performance of rooftop solar systems and assess the impact of policy interventions.

10.4 Final Thoughts

The findings and recommendations presented in this chapter highlight the potential of rooftop solar systems to transform Dhaka's energy landscape and contribute to Bangladesh's renewable energy goals. By adopting a hybrid implementation approach that integrates top-down policy reforms with bottom-up stakeholder engagement, Dhaka can overcome the barriers to rooftop solar adoption and unlock its full potential. This requires a concerted effort from policymakers, local implementers, private sector players, and consumers to create an enabling environment for sustainable energy solutions.

Rooftop solar is a technological innovation and a pathway to Dhaka's cleaner, more resilient, and energy-secure future. By addressing the gaps identified in this study and implementing the recommended strategies, Bangladesh can take a significant step toward achieving its vision of generating 40% of its electricity from renewable sources by 2041.

References

Abbas, M. (2024, November 15). *The Daily Star*. The Daily Star. https://www.thedailystar.net/environment/climate-change/news/bangladesh-lags-behind-rooftop-solar-race-3753666

and. (2015). *Strengthening electricity distribution in Dhaka*. Www.afd.fr. https://www.afd.fr/en/carte-des-projets/strengthening-electricity-distribution-dhaka

Alam, S. (2022, December 6). *It's time to make rooftop solar shine in Bangladesh*. Ieefa.org. https://ieefa.org/resources/time-make-rooftop-solar-shine-bangladesh

Alam, S. (2024). *Scaling up Rooftop Solar Deployment in Bangladesh*. https://ieefa.org/sites/default/files/2024-03/Presentation_Webinar_Rooftop.pdf

Amin, S. B., Chang, Y., Khan, F., & Taghizadeh-Hesary, F. (2021). Energy security, and sustainable energy policy in Bangladesh: From the lens of 4As framework. *Energy Policy*, 112719. https://doi.org/10.1016/j.enpol.2021.112719

Auroville. (2020, June 6). *Solar Skill Development & Capacity Building in Tamil Nadu - Auroville Consulting*. Www.aurovilleconsulting.com. https://www.aurovilleconsulting.com/solar-skill-development-capacity-building-in-tamil-nadu/

Begum, F. A. (2019, November 9). *Rooftop solar power -- a sustainable option for Bangladesh*. The Financial Express. https://thefinancialexpress.com.bd/views/reviews/rooftop-solar-power-a-sustainable-option-for-bangladesh-1573226883

Bowen, G. (2019, August). *Document Analysis as a Qualitative Research Method*. ResearchGate. https://www.researchgate.net/publication/240807798_Document_Analysis_as_a_Qualitative_Research_Method

BRAC University. (2024, March 3). *BRAC University showcases new campus synergy of knowledge creation and environmental sustainability*. Bracu.ac.bd. https://www.bracu.ac.bd/news/brac-university-showcases-new-campus-synergy-knowledge-creation-and-environmental

BSS. (2025). *Rooftop Solar Project launched at BUET | News*. BSS.

https://www.bssnews.net/news/157049

Chen, H., & Chen, W. (2021). Status, trend, economic, and environmental impacts of household solar photovoltaic development in China: Modelling from subnational perspective. *Applied Energy*, *303*, 117616. https://doi.org/10.1016/j.apenergy.2021.117616

Cobb, M. (2021, April). *What is physical security?* TechTarget. https://www.techtarget.com/searchsecurity/definition/physical-security

Correspondent, S. (2024, June 13). *The Daily Star*. The Daily Star. https://www.thedailystar.net/news/bangladesh/news/buet-goes-solar-3634291

Dhakatribune. (2024). *Brac University campus: Synergy of education, and environmental conservation*. https://www.dhakatribune.com/bangladesh/education/346201/synergy-of-education-and-environmental

dpdc. (2022). *ঢাকা পাওয়ার ডিস্ট্রিবিউশন কোম্পানি লিমিটেড (ডিপিডিসি)*. Dpdc.gov.bd. https://dpdc.gov.bd/

dpdc. (2024). *Annual Report*. Dpdc.org.bd. https://dpdc.org.bd/page/view/32

Dutt, D. (2020). Understanding the barriers to the diffusion of rooftop solar: A case study of Delhi (India). *Energy Policy*, *144*, 111674. https://doi.org/10.1016/j.enpol.2020.111674

energy.gov. (2023, May 1). *Quarterly Solar Industry Update*. Energy.gov. https://www.energy.gov/eere/solar/quarterly-solar-industry-update

ep-bd. (2024). *Energy & Power Magazine*. Ep-Bd.com. https://ep-bd.com/view/details/news/MzY4Mg==/title?q=China+to+Reach+2030+Solar+and+Wind+Energy+Target+Five+Years+Ahead+of+Schedule+%3A+GlobalData

Fearon, D. (2023). *Guides: Qualitative Data Analysis Software (nVivo, Atlas.TI, and more): Qualitative Data Analysis Software (QDAS) overview*. Guides.library.jhu.edu. https://guides.library.jhu.edu/QDAS

Goel, M. (2016). Solar rooftop in India: Policies, challenges, and outlook. *Green Energy & Environment*, *1*(2), 129–137. https://doi.org/10.1016/j.gee.2016.08.003

Goyal, K. (2024, September 16). *Rooftop Solar Adoption in China, and Japan - REGlobal - Mega Trends & Analysis*. REGlobal. https://reglobal.org/rooftop-solar-adoption-in-china-and-japan/

Hossain, S., & Rahman, M. M. (2021). Solar Energy Prospects in Bangladesh: Target, and Current Status. *Energy, and Power Engineering*, *13*(08), 322–332. https://doi.org/10.4236/epe.2021.138022

iea. (2021). *Executive summary – An energy sector roadmap to carbon neutrality in China – Analysis*. IEA. https://www.iea.org/reports/an-energy-sector-roadmap-to-carbon-neutrality-in-china/executive-summary

Islam, S. (2022, April 12). *Bangladesh's highest-opex rooftop PV plant goes online*. Pv Magazine International. https://www.pv-magazine.com/2022/04/12/bangladeshs-highest-opex-rooftop-pv-plant-goes-online/

ISR. (2021, September 2). *OOPEX/PPA Model of Solar, and Financial Options - India Solar Rooftop*. India Solar Rooftop. https://indiasolarrooftop.com/opex-ppa-model-of-solar-and-financing-options

Jamal, T., Weerakorn Ongsakul, Singh, J., Sayedus Salehin, & Ferdous, S. M. (2014). *Potential rooftop distribution mapping using Geographic Information Systems (GIS) for Solar PV Installation: A case study for Dhaka, Bangladesh*. https://doi.org/10.1109/icdret.2014.6861648

Jarcon. (2015). *FINANCING (OPEX / RESCO) – JARCON*. Jarcon.com.bd. https://www.jarcon.com.bd/financing-opex-resco

Khan, A. R. (2016). Policy implementation: Some aspects, and issues. *Journal of Community Positive Practices*, *3*, 3–12. http://jppc.ro/en/index.php/jppc/article/view/316

Kirchherr, J., & Charles, K. (2018). Enhancing the Sample Diversity of Snowball samples: Recommendations from a Research Project on anti-dam Movements in Southeast Asia. *PloS One*, *13*(8). NCBI. https://doi.org/10.1371/journal.pone.0201710

Koshy, J. (2024, March 8). *Centre tweaks Prime Minister's Rooftop Solar "free electricity" scheme*. The Hindu. https://www.thehindu.com/news/national/centre-tweaks-prime-ministers-rooftop-solar-free-electricity-scheme/article67929379.ece

Kumar Behura, A., Kumar, A., Kumar Rajak, D., Pruncu, C. I., & Lamberti, L. (2021). Towards better performances for a novel rooftop solar PV system. *Solar Energy*, *216*, 518–529. https://doi.org/10.1016/j.solener.2021.01.045

Manas Pimpalkhare. (2024, October 16). *India installs 400,000 rooftop solar units* *under PM's free electricity scheme*. Mint. https://www.livemint.com/news/india/india-installs-400-000-rooftop-solar-units-under-pm-s-free-electricity-scheme-11729089461564.html

Manti, S., & Licari, A. (2019). How to Obtain Informed Consent for Research. *Breathe*, *14*(2), 145–152. https://doi.org/10.1183/20734735.001918

Mathew, T. C., & Nagaraja Pandian, S. (2024). Unveiling the shadows: a qualitative exploration of barriers to rooftop solar photovoltaic adoption in residential sectors. *Clean Energy*, *8*(5), 218–228. https://doi.org/10.1093/ce/zkae065

Mohammed, M. (2024, June 13). *Buet launches 3.5MWp rooftop solar project*. Dhakatribune. https://www.dhakatribune.com/bangladesh/349278/buet-launches-3.5mwp-rooftop-solar-project

Nagrika. (2024). *Growing Rooftop Solar Industry in India: Policies, and Challenges*. Nagrika.org. https://www.nagrika.org/nagrikaspeaks/solar-rooftops

Ni, H., Wang, D., Zhao, W., Jiang, W., Mingze, E., Huang, C., & Yao, J. (2023). Enhancing rooftop solar energy potential evaluation in high-density cities: A Deep Learning, and GIS based approach. *Energy, and Buildings*, 113743. https://doi.org/10.1016/j.enbuild.2023.113743

Parichat Pongloe, andy Fefta Wijaya, & Lely Indah Mindarti. (2015). Low Carbon City Policy Implementation in Muangklang Municipality, Thailand. *International Journal of Applied Sociology*, *5*(2), 99–105. http://article.sapub.org/10.5923.j.ijas.20150502.05.html#:~:text=The%20mechanism%20of%20Low%20Carbon

Paudel, N. R. (2010). *A Critical Account of Policy Implementation Theories : Status, and Reconsideration*. Www.semanticscholar.org. https://www.semanticscholar.org/paper/A-Critical-Account-of-Policy-Implementation-%3A-and-Paudel/96cb1a5f553dfe89767763005fa65f474af8e6d3

Powerdivision. (2021). *বিদ্যুৎ বিভাগ-গণপ্রজাতন্ত্রী বাংলাদেশ সরকার*. Powerdivision.gov.bd. https://powerdivision.gov.bd/

Press Release. (2024, March). *BRAC University showcases new campus synergy of knowledge creation, environmental sustainability*. The Business Standard. https://www.tbsnews.net/economy/corporates/brac-university-showcases-new-campus-synergy-knowledge-creation-environmental rmg-finance. (2017). *Business Case: Solar PV Rooftop System for RMG Factory -Opex Model Support to Safety Retrofits, and Environmental Upgrades in the Bangladeshi Ready-Made Garment (RMG) Sector Rationale for Solar Rooftop*.

Roy, S. (2024, June 26). *How well is India tapping its rooftop solar potential? | Explained*. The Hindu. https://www.thehindu.com/sci-tech/energy-and-environment/history-future-value-india-rooftop-solar-programme-explained/article68335798.ece

Sarwar. (2024, November 15). *Bangladesh's solar policy failure lack of political will, and support - Dr. Moazzem | CPD*. Centre for Policy Dialogue (CPD). https://cpd.org.bd/bangladeshs-solar-policy-failure-lack-of-political-will-and-support/?

Schunder, T., Yin, D., Bagchi-Sen, S., & Rajan, K. (2020). A spatial analysis of the development potential of rooftop, and community solar energy. *Remote Sensing Applications: Society, and Environment*, *19*, 100355. https://doi.org/10.1016/j.rsase.2020.100355

Scully, J. (2022, December 2). *China installed 58.2GW of solar in first ten months of 2022*. PV Tech. https://www.pv-tech.org/china-installed-58-2gw-of-solar-in-first-ten-months-of-2022/

Shankar , A. (2024, March 20). *India's Solar Journey*. The India Forum. https://www.theindiaforum.in/environment/indias-solar-journey

Shukla, A. K., Sudhakar, K., & Baredar, P. (2016). Design, simulation, and economic analysis of standalone roof top solar PV system in India. *Solar Energy*, *136*, 437–449. https://doi.org/10.1016/j.solener.2016.07.009

Singh, R. (2020). Approximate rooftop solar PV potential of Indian cities for high-level renewable power scenario planning. *Sustainable Energy Technologies, and Assessments*, *42*, 100850. https://doi.org/10.1016/j.seta.2020.100850

Staff Reporter. (2023, November 9). *Dhaka Power Distribution Company Limited (DPDC) clinches two titles at Asian Power Awards*. Asian Power. https://asian-power.com/co-written-partner/event-news/dhaka-power-distribution-company-limited-dpdc-clinches-two-titles-asian-power-awards

Sulaiman, N., & Baldry, D. (2008, March). *(PDF) MULTIPLE SOURCES OF EVIDENCE USING A CASE STUDY METHODOLOGY*. ResearchGate.

https://www.researchgate.net/publication/260060632_MULTIPLE_SOURCES_OF_EVIDENCE_USING_A_CASE_STUDY_METHODOLOGY

TBS Report. (2024, June 13). *Buet installs 3.5MW solar project on rooftops of 19 buildings*. The Business Standard. https://www.tbsnews.net/bangladesh/buet-installs-35-mw-solar-project-rooftops-19-buildings-876316

trueimpactdigital. (2024, June). *Pros, and Cons of OPEX model for Solar Farms*. Synergy Solar Solutions - Solar Panel, and System Distributor, Dealer, and Installation Company. https://synergysolar.in/pros-and-cons-of-opex-model-for-solar-farms/

Van Meter, D. S., & Van Horn, C. E. (1975). The policy implementation process: A conceptual framework. *Administration & Society*, *6*(4), 445–488. https://doi.org/10.1177/009539977500600404

Xu, K., Ding, Y., Wang, Z., & Yin, J. (2023). What drives residential rooftop solar growth in China? A spatial analysis using city-level data. *Ecological Indicators*, *154*, 110778. https://doi.org/10.1016/j.ecolind.2023.110778

Ye, Y. (2023). Are rooftop solar panels the answer to meeting China's challenging climate targets? *Nature*. https://doi.org/10.1038/d41586-023-02991-x

Zahid, S. H. (2023, December 18). *2000MW rooftop solar boost could save Bangladesh $1b annually: IEEFA*. The Financial Express. https://thefinancialexpress.com.bd/trade/2000mw-rooftop-solar-boost-could-save-bangladesh-1b-annually-ieefa

Zhang, S., & He, Y. (2013). Analysis on the development, and policy of solar PV power in China. *Renewable, and Sustainable Energy Reviews*, *21*, 393–401. https://doi.org/10.1016/j.rser.2013.01.002

Zhang, V. (2024, February 22). *Renewable energy law, and regulation in China | CMS Expert Guides*. Cms.law. https://cms.law/en/int/expert-guides/cms-expert-guide-to-renewable-energy/china

Annexure 1: Interview Questionnaire

Contribution of Rooftop Solar Panels in Energy Security of Dhaka City

Dear Participant, I am a Master's student in the South Asian Policy and Governance at the North South University in Bangladesh. This data is used to fulfill my dissertation titled Contribution of Rooftop Solar Panels in Energy Security of Dhaka City. I will be asking you the questions about Solar panel policy, current status, generation, contribution etc. All data will be remained anonymous and confidential. The success of this study depends on your responses therefore, if you have any clarification in this regard, please feel free to share me.

1. Can you describe your role and involvement in the implementation or promotion of rooftop solar energy policies in Dhaka City?
2. What are the main regulatory and policy challenges you have encountered in promoting the adoption of rooftop solar panels in Dhaka?
3. How effective do you find the current financial incentives and support mechanisms in encouraging households and businesses to install rooftop solar systems?
4. In your experience, how well do different government agencies and private sector stakeholders coordinate in the implementation of rooftop solar initiatives?
5. What technical or infrastructural barriers exist that hinder the widespread adoption of rooftop solar systems in Dhaka City?
6. How would you assess the level of public awareness and societal acceptance regarding rooftop solar energy in Dhaka? What measures could improve these aspects?
7. To what extent do rooftop solar panels contribute to enhancing energy security in Dhaka, and what metrics do you use to evaluate this impact?
8. What resources (financial, technical, human) are currently allocated to rooftop solar projects, and do you believe they are sufficient to meet the adoption targets?
9. Can you provide examples of successful rooftop solar implementations in Dhaka City and the factors that contributed to their success?
10. What recommendations would you make to improve the policy framework and implementation processes to facilitate greater adoption of rooftop solar energy in Dhaka?

Annexure 2: Net Metering Policy, Page 1

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তারিখ: ০৭ কার্তিক ১৪৩০ / ২৩ অক্টোবর ২০২৩

সংশোধিত পরিপত্র

বিষয়: নতুন বিদ্যুৎ সংযোগ প্রদানকালে নেট মিটারসহ রুফটপ সোলার সিস্টেম স্থাপন প্রসঙ্গে।

উপর্যুক্ত বিষয়ের পরিপ্রেক্ষিতে যথাযথ কর্তৃপক্ষের অনুমোদনক্রমে ইতোমধ্যে বিদ্যুৎ বিভাগ থেকে জারিকৃত নতুন বিদ্যুৎ সংযোগ প্রদানকালে ভবনে সোলার প্যানেল স্থাপন সংক্রান্ত নির্দেশনাসমূহ বাতিলপূর্বক নতুন বিদ্যুৎ সংযোগ প্রদানের সময় নেট মিটারিং পদ্ধতিতে সোলার প্যানেল স্থাপন সংক্রান্ত নিম্নোক্ত নির্দেশনা প্রদান করা হলো:

ভবনের ছাদে কমপক্ষে ১০০০ বর্গফুট জায়গা থাকলে নেট মিটারিং পদ্ধতিতে রুফটপ সোলার প্যানেল স্থাপন করতে হবে। এক্ষেত্রে:

১। আবাসিক গ্রাহক:

ক) সিঙ্গেল ফেজ (Single Phase) সংযোগের ক্ষেত্রে গ্রাহক আগ্রহী হলে রুফটপ সোলার সিস্টেম স্থাপন করতে পারবে।

খ) থ্রি ফেজ (Three Phase) সংযোগের ক্ষেত্রে ১০ (দশ) কিলোওয়াট বা তদূর্ধ্ব লোড বরাদ্দপ্রাপ্ত গ্রাহকদের কমপক্ষে ১ (এক) কিলোওয়াট (১০০০ ওয়াট) নেট মিটারিং সোলার সিস্টেম স্থাপন করতে হবে।

২। শিল্প ও বানিজ্যিক গ্রাহক:

১০ বা তদূর্ধ্ব কিলোওয়াট লোড বরাদ্দপ্রাপ্ত বিদ্যুৎ গ্রাহকগণের অনুমোদিত লোডের ১০% ক্ষমতার সোলার সিস্টেম নেট মিটারিং নির্দেশিকা-২০১৮ (সর্বশেষ সংশোধিত) অনুসরণ করে স্থাপন করতে হবে। তবে অনূর্ধ্ব ১০ কিলোওয়াট লোড বরাদ্দপ্রাপ্ত গ্রাহকগণ আগ্রহী হলে রুফটপ সোলার সিস্টেম বসাতে পারবেন এবং স্থাপিত সিস্টেমের ক্ষমতা ১ কিলোওয়াটের (১০০০ ওয়াট) বেশি হলে নেট মিটারিং নির্দেশিকা অনুসরণে তা করতে হবে।

৩। শিক্ষা প্রতিষ্ঠান, হাসপাতাল ও দাতব্য প্রতিষ্ঠান:

ক) সিঙ্গেল ফেজ (Single Phase) সংযোগের ক্ষেত্রে প্রতিষ্ঠান আগ্রহী হলে সোলার সিস্টেম স্থাপন করতে পারবে।

খ) থ্রি ফেজ (Three Phase) সংযোগের ক্ষেত্রে ১০ (দশ) কিলোওয়াট বা তদূর্ধ্ব লোড বরাদ্দপ্রাপ্ত গ্রাহকদের কমপক্ষে ১ (এক) কিলোওয়াটের (১০০০ ওয়াট) নেট মিটারিং সিস্টেম স্থাপন করতে হবে।

চলমান পাতা-০২

৪। ইতোমধ্যে বিদ্যুৎ সংযোগ প্রাপ্ত গ্রাহকগণ যারা বরাদ্দকৃত লোড বৃদ্ধি করতে চান তাদেরকেও অতিরিক্ত অনুমোদিত লোডের উপর উল্লিখিত হার অনুযায়ী সোলার সিস্টেম স্থাপন করতে হবে।

৫। গত ২৩ আগস্ট ২০২৩ তারিখ ২৭.০০.০০০০.০৯৬.১৪.০১৩.২২-১০৫ স্মারকে জারিকৃত পরিপত্রটি সংশোধনক্রমে এ সংশোধিত পরিপত্র জারি করা হলো।

৬। জনস্বার্থে এ আদেশ অবিলম্বে কার্যকর হবে।

(মো: মাহবুবুর রহমান)
উপসচিব
ইমেইল: dsre@pd.gov.bd

বিতরণ: সদয় কার্যার্থে (জ্যেষ্ঠতার ক্রমানুসারে নয়):

০১। চেয়ারম্যান, টেকসই ও নবায়নযোগ্য জ্বালানি উন্নয়ন কর্তৃপক্ষ (স্রেডা), আইইবি ভবন, রমনা, ঢাকা।
০২। চেয়ারম্যান, বাংলাদেশ বিদ্যুৎ উন্নয়ন বোর্ড, বিদ্যুৎ ভবন, আব্দুল গনি রোড, ঢাকা।
০৩। চেয়ারম্যান, বাংলাদেশ পল্লী বিদ্যুতায়ন বোর্ড, নিকুঞ্জ-২, জোয়ার সাহারা, খিলক্ষেত, ঢাকা।
০৪। ব্যবস্থাপনা পরিচালক, ঢাকা পাওয়ার ডিস্ট্রিবিউশন কোম্পানি লিঃ (ডিপিডিসি), বিদ্যুৎ ভবন, আব্দুল গনি রোড, ঢাকা।
০৫। ব্যবস্থাপনা পরিচালক, ঢাকা ইলেকট্রিক সাপ্লাই কোম্পানি লিঃ (ডেসকো), ২২/বি, ফারুক সরণি, নিকুঞ্জ-২, খিলক্ষেত, ঢাকা।
০৬। ব্যবস্থাপনা পরিচালক, ওয়েস্ট জোন পাওয়ার ডিস্ট্রিবিউশন কোম্পানি লিঃ (ওজোপাডিকো), বিদ্যুৎ ভবন, ৩৫, বয়রা মেইন রোড, বয়রা, খুলনা।
০৭। ব্যবস্থাপনা পরিচালক, নর্দান ইলেকট্রিসিটি সাপ্লাই কোম্পানি লিঃ (নেসকো), বিদ্যুৎ ভবন, হেতেম খাঁ, রাজশাহী।

সদয় অবগতির জন্য অনুলিপি:

০১। যুগ্মসচিব (নবায়নযোগ্য জ্বালানি), বিদ্যুৎ বিভাগ।
০২। প্রধানমন্ত্রীর বিদ্যুৎ, জ্বালানি ও খনিজ সম্পদ বিষয়ক উপদেষ্টার একান্ত সচিব, প্রধানমন্ত্রীর কার্যালয়, তেজগাঁও, ঢাকা।
০৩। মাননীয় প্রতিমন্ত্রীর একান্ত সচিব, বিদ্যুৎ, জ্বালানি ও খনিজ সম্পদ মন্ত্রণালয়, বাংলাদেশ সচিবালয়, ঢাকা।
০৪। প্রধানমন্ত্রীর মুখ্য সচিবের একান্ত সচিব, প্রধানমন্ত্রীর কার্যালয়, তেজগাঁও, ঢাকা।
০৫। সিনিয়র সচিব মহোদয়ের একান্ত সচিব, বিদ্যুৎ বিভাগ, বাংলাদেশ সচিবালয়, ঢাকা।

Annexure 4: Approval of Research Protocol, Page 1

NORTH SOUTH UNIVERSITY
Institutional Review Board/ Ethics Review Committee (IRB/ERC)

ADM 625, Plot: 15, Block: B, Bashundhara, Dhaka-1229, Bangladesh.
PABX: +88-02-55668200, Ext: 6465

Memorandum
2024/OR-NSU/IRB/1009

Date: 23 October 2024

To: Zahidul Karim Khondker
Student
Department of SIPG

Dr. Rizwan Khair [Supervisor]
Associate Professor
Department of SIPG

From: Dr. Dipak Kumar Mitra
Chairman
NSU Institutional Review Board/ Ethics Review Committee

Chairman
NSU Institutional Review Board/
Ethics Review Committee (IRB/ERC)

Subject: Approval of Research Protocol #2024/OR-NSU/IRB/1009

Dear Zahidul Karim Khondker,

Thank you for your application requesting for approval of your research protocol #2024/OR-NSU/IRB/1009, titled "Contribution of Rooftop Solar Panels in Energy Security of Dhaka City". I am glad to inform you that the committee has approved your research protocol. You will be required to observe the following terms and conditions in implementing the research protocol:

1. As principal investigator, the ultimate responsibility for scientific and ethical conduct including the protection of the rights and welfare of study participants vest upon you. You shall also be responsible for ensuring competence, integrity, and ethical conduct of other investigators and staff directly involved in the research protocol.

2. You shall conduct the activity in accordance with the IRB-approved protocol and shall fully comply with any subsequent determinations by IRB.

3. You shall obtain prior approval from the IRB for any modification in the approved research protocol and/or approved consent form(s), except in case of emergency to safeguard/eliminate apparent immediate hazards to study participants. Such changes must immediately be reported to the IRB Chairman.

4. You shall recruit/enroll participants for the study strictly adhering to the criteria mentioned in the approved research protocol.

5. You shall obtain legally effective informed consent (i.e. consent should be free from coercion or undue influence) from the selected study participants or their legally responsible representative, as approved in the protocol, using the approved consent forms prior to their enrollment in the study. Before obtaining consent, all prospective study participants must be adequately informed about the purpose(s) of the study, its methods and procedures, and also what would be done if they agree and also if they do not agree to participate in the study. They must be informed that their participation

Annexure 5: Approval of Research Protocol, Page 2

NORTH SOUTH UNIVERSITY
Institutional Review Board/ Ethics Review Committee (IRB/ERC)

ADM 625, Plot: 15, Block: B,
Bashundhara, Dhaka-1229,
Bangladesh.
PABX: +88-02-55668200, Ext: 6465

in the study is voluntary and that they can withdraw their participation any time without prejudice. Used consent form should be preserved for a period of at least three years following official termination of the study.

6. You shall promptly report the occurrence of any Adverse Event or Serious Adverse Event or unanticipated problems of potential risk to the study participants or others to the ERC in writing within 24 hours of such occurrences.
7. Any significant new findings, developing during the course of this study that might affect the risks and benefits and thus influence either participation in the study or continuation of participation should be reported in writing to the participants and the IRB.
8. Data and/or samples should be collected, as specified in the IRB-approved protocol, and confidentiality must be maintained. Data/samples must be protected by reasonable security, safeguarding against risks as their loss or unauthorized access, destruction, used by others, and modification or disclosure of data. Data/samples should not be disclosed, made available to or use for purposes other than those specified in the protocol, and shall be preserved for a period, as specified under NSU policy/practices.
9. You shall promptly and fully comply with the decision of IRB to suspend or withdraw its approval for the research protocol.
10. You shall report progress of research to the IRB on annual basis.

I wish you success in running the above-mentioned study.

cc: 1. Recording Secretary, NSU IRB/ERC