ENERGY CHOICES IN DEVELOPING COUNTRIES: THE CASE OF BANGLADESH

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Author's Declaration

I, the undersigned, **Moshahida Sultana**, candidate for the PhD degree in Environmental Sciences and Policy declare herewith that the present thesis is exclusively my own work, based on my research and only such external information as properly credited in notes and bibliography. I declare that no unidentified and illegitimate use was made of the work of others, and no part of the thesis infringes on any person's or institution's copyright. I also declare that no part of the thesis has been submitted in this form to any other institution of higher education for an academic degree.

Vienna, 31 July 2024

Moshahida Sultana
Signature

Statement of Contribution

This thesis incorporates intellectual material from two published research paper authored by the candidate.

• Section 2.3.1 of the Literature Review (Chapter 2) and Section 8.5.3 of the New Fossil Fuels (Chapter 8) are partially based on the following paper, where the candidate was the single author:

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• Sections 6.2 and 6.6 in the Solar Energy in Bangladesh (Chapter 6) uses the historical context, mechanisms, some interviews of the following paper, where the candidate was the single author particularly focusing in a different research questions and structure of the paper.

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Table of Contents

List of Tables viii

List of Figures ix

List of Abbreviations x

Abstract xii

Acknowledgements xiv

1 Introduction 1

1.1 Background *1*

1.2 Motivation for research *3*

1.3 The missing perspectives *4*

1.4 Research Puzzle *5*

1.5 Research objectives *7*

1.6 Expected contribution in recent ongoing debates *7*

1.7 Structure of the dissertation *8*

2 Literature Review 11

2.1 Neoclassical economic theory *12*
2.1.1 How does neoclassical theory relate to energy transitions? 12
2.1.2 What are the gaps? 15

2.2 Technology diffusion *17*
2.2.1 From core to periphery 17
2.2.2 From national innovation system to global innovation system 19
2.2.3 From lumpy to granular energy technology 23
2.2.4 From ascending energy ladder to leapfrogging 25

2.3 Political Theories *28*
2.3.1 Rent seeking theory 28
2.3.2 Energy geopolitics 31
2.3.2.1 Energy security: stability versus instability 31
2.3.2.2 Energy trade: expansion versus reduction 31
2.3.2.3 Geopolitics of energy: from oil to natural gas, LNG, nuclear, and solar 32
2.3.2.4 Three conceptual frameworks for geopolitics in global south 33
2.3.3 Policy diffusion 37
2.3.3.1 State-centric and state-structural approach: 37
2.3.3.2 International harmonization 38
2.3.3.3 Coercion 39
2.3.3.4 Interventionist policy 39
2.3.3.5 Hegemonic ideas 40

2.4 Energy market regulations *41*
2.4.1 Price setting under liberalized market 41
2.4.2 Pricing policy design: feed-in-tariff versus net metering 45
2.4.2.1 Feed-in-tariff 45
2.4.2.2 Net metering policy 46

2.5 Path dependence and lock-in *47*
2.5.1 Path dependence and lock-in: theory and causal process 47
2.5.2 Carbon lock-in 48
2.5.3 Institutional lock-in 49
2.5.4 Types of path dependence 50
2.5.5 Randomness of source of path dependence 51
2.5.6 Critical junctures in path dependence 52

3 Conceptual Framework 53

3.1 Introduction *53*

3.2 Conceptualization of rational choice in mainstream theories and the puzzle in a developing country 55
3.2.1 Neo-classical economic theory 55
3.2.2 Socio-technical theory 56
3.2.3 Political theory 56
3.2.4 The puzzle: why does Bangladesh make irrational choice? 57

3.3 Distinction between variables and mechanisms *58*

3.4 Causal chain *58*

3.5 The three perspectives *59*

3.6 Differences between mechanisms of developed and developing countries *62*

3.7 Ontological and epistemological position of energy transition research *65*
3.7.1.1 Ontological and epistemological challenges in interdisciplinary research of energy transitions 65
3.7.1.2 Critical realism in interdisciplinary research 68

3.8 Conceptual framework for developing countries *69*

4 Research Design 72

4.1 Introduction *72*

4.2 Method *73*
4.2.1 Case Study 73
4.2.2 Process Tracing 74

4.3 The Longitudinal National Case Study *75*
4.3.1 Case Selection 75
4.3.2 Focus of Analysis 75
4.3.3 Structure of Analysis 76
4.3.4 Data Collection 77

4.4 Within-unit case studies *77*
4.4.1 Case selection 78
4.4.2 Focus of analysis 78
4.4.3 Structure of within-case analyses 78
4.4.4 Data collection 80

4.5 The comparative national case study *80*
4.5.1 Case selection 81
4.5.2 Focus of analysis 82
4.5.3 Structure of analysis 83

4.6 Summary *84*

5 The Structure and Evolution of Energy System in Bangladesh 85

5.1 Introduction *85*

5.2 Method of longitudinal case study *87*
5.2.1 Longitudinal case study 87
5.2.2 Process tracing 87

5.3 Changes in the power and energy indicators (1970 -2020) ... 88

5.4 Empirical Analysis ... 95
5.4.1 Episode 1: 1970s ... 95
5.4.1.1 Response to the international oil crisis ... 96
5.4.1.2 National institutional capacity development and state ownership ... 96
5.4.1.3 International participation in domestic energy resource extraction ... 97
5.4.1.4 Oil exploration ... 97
5.4.1.5 Gas sector development ... 98
5.4.1.6 Rural electrification ... 98
5.4.2 Episode 2: 1980s ... 99
5.4.2.1 Petroleum exploration led by the World Bank ... 99
5.4.2.2 Gas exploration and failed PSC ... 100
5.4.2.3 National capacity building effort ... 101
5.4.3 Episode 3: 1990s ... 102
5.4.3.1 Policy reform ... 102
5.4.3.2 IOC's interest in gas exploration ... 104
5.4.3.3 National capacity building initiative ... 104
5.4.4 Episode 4: 2000s ... 105
5.4.4.1 Policy, roadmap, and master plan ... 105
5.4.4.2 Gas sector reform, production and use, resistance against export ... 106
5.4.4.3 Coal politics ... 108
5.4.4.4 Regulatory reform ... 108
5.4.5 Episode 5: 2010s ... 109
5.4.5.1 Master Plans Prepared by Foreign Consultants ... 109
5.4.5.2 Import dependency in energy mix ... 113
5.4.5.3 Accelerated Private Sector Participation in Power Generation ... 115
5.4.5.4 Cost increase ... 117

5.5 Discussion ... 119
5.5.1 Early crises periods and path selection ... 120
5.5.2 Common pattern in crises responses ... 120
5.5.3 Repeated reliance on external resources ... 123
5.5.4 Why potential alternative path was not taken? ... 125
5.5.5 Evolution of actors and institutions in crises ... 126
5.5.6 The constraints in breaking path dependency ... 128
5.5.6.1 Domestic constraints ... 128
5.5.6.2 External constraints ... 129

5.6 Summary ... 129

6 Solar Power in Bangladesh ... 134

6.1 Introduction ... 134

6.2 Context ... 136

6.3 Method ... 142

6.4 Existing explanations ... 143

6.5 Techno-economic mechanisms ... 145
6.5.1 Decline in global cost of solar of utility scale solar in Bangladesh ... 145
6.5.2 Pricing policy of net metering system for rooftop solar ... 147

6.6 Socio-technical mechanisms ... 151
6.6.1 Learning by doing ... 151
6.6.2 Low trust to the society ... 156
6.6.3 Research, human resource, financial, and institutional capacity ... 156

6.7 Political and policy mechanisms ... 159
6.7.1 Rent seeking ... 159
6.7.2 Import duty ... 161
6.7.3 Income tax waiver ... 162
6.7.4 Infrastructural support ... 163

6.7.5 Net metering system in solar rooftop as a poor policy design 164
6.7.6 Unsolicited proposal..165
6.7.7 Protecting local manufacturing 166

6.8 Summary 167

6.9 List of interviewees 170
6.9.1 [1] Experts/ Consultants/ Policy Makers...170
6.9.2 [2] Financial Institutions 170
6.9.3 [3] Solar Developers/ Equipment Suppliers...171
6.9.4 [4] Public Utility/ Renewable Energy Authority 171
6.9.5 [5] UN Organizations...171
6.9.6 [6] Journalists..171
6.9.7 [7] Residential Prosumers 171
6.9.8 [8] Renewable Energy Entrepreneur 171

7 Geopolitics and Nuclear Power in Bangladesh 172

7.1 Introduction...172

7.2 Bangladesh nuclear roadmap 174

7.3 Framework for analysis 176

7.4 Gaps in existing explanations 180

7.5 Geopolitical mechanisms 183
7.5.1 Global geopolitics: getting foothold of economic expansion by core...183
7.5.2 Regional geopolitics: India-Pakistan, India-China tension, and Bangladesh's nuclear energy development 184

7.6 Mechanisms of rent seeking 187
7.6.1 Regulatory capture: regulation in favor of nuclear 187
7.6.2 Resistance capture...188

7.7 Mechanisms of public demand..189

7.8 Mechanisms of Internal Political Gain 191
7.8.1 National pride...191
7.8.2 Aspiration for development and political gain...192

7.9 Mechanisms of technology diffusion 192
7.9.1 Core's strategy of exploiting potential technology cluster 192
7.9.2 Diffusion incentive: flexible financial conditions..193

7.10 Summary 194

8 New Fossil Fuels: Coal and LNG 197

8.1 Introduction...197

8.2 Context 198

8.3 Existing Explanations 200

8.4 History of adopting coal and LNG..202
8.4.1 History of coal adoption..202
8.4.2 History of LNG adoption 206

8.5 Mechanisms of transition (empirical analysis)...210
8.5.1 Politics of demand and supply 211
8.5.1.1 Politics of demand in liquefied natural gas (LNG) market 212
8.5.1.2 Politics of demand in coal 215
8.5.2 Rent seeking in coal sector..218
8.5.2.1 Regulatory capture in coal sector 218
8.5.2.2 Resistance capture in coal sector...219
8.5.2.3 License for importing coal...220
8.5.2.4 Indirect lobby behind coal adoption 220

8.5.3 Rent seeking in liquefied natural gas (LNG) 220
8.5.3.1 Regulatory capture in LNG adoption 221
8.5.3.2 Lobby in LNG industry 222
8.5.3.3 Rent for learning 223

8.6 Discussion 223
8.6.1 Politics of demand 224
8.6.2 Rent seeking embedded in institutions 227
8.6.3 Gas depletion: random consequence versus intentional destabilization of incumbent technology 227
8.6.4 The outdated idea that coal is cheap 229

8.7 Summary 230

9 Comparing Electricity Transition of Bangladesh and Vietnam 232

9.1 Introduction 232

9.2 Brief context of new energy adoption in Bangladesh and Vietnam 234
9.2.1 History of oil use 236
9.2.2 History of natural gas and LNG adoption in Bangladesh and Vietnam 236
9.2.3 History of coal adoption in Bangladesh and Vietnam 237
9.2.4 Hydropower use in Bangladesh and Vietnam 238
9.2.5 Solar adoption in Bangladesh and Vietnam 238
9.2.6 Nuclear adoption in Bangladesh and Vietnam 239

9.3 Method 240

9.4 Existing explanations in literature 241
9.4.1 Technology diffusion 242
9.4.2 Cost decline 242
9.4.3 Technology characteristic 243
9.4.4 Configuration of global innovation system on diffusion 243
9.4.5 State action: securing supply-demand balance 245
9.4.6 Climate policy diffusion 245
9.4.7 Economic incentives 246
9.4.8 Public demand for reducing environmental pollution 247
9.4.9 Summary of the gaps in existing explanations 248

9.5 Energy transition mechanisms and observations from cases 249

9.6 Historical energy transition in Bangladesh and Vietnam 250

9.7 Discussion 252
9.7.1 Why solar growth is faster in Vietnam than in Bangladesh? 252
9.7.1.1 Policy design 252
9.7.1.2 Presence of actors 253
9.7.1.3 Support of interest groups 254
9.7.1.4 Regional innovation system 254
9.7.2 Why nuclear power plant was cancelled in Vietnam and adopted in Bangladesh? 255
9.7.2.1 NPP's contribution to the electricity supply 255
9.7.2.2 Cost escalation 255
9.7.2.3 Lack of foreign reserve 256
9.7.2.4 Governance index and capacity 256
9.7.2.5 Public acceptance 256
9.7.2.6 Regional geopolitical context 257
9.7.2.7 Political value 258

9.8 Conclusion 259

10 Discussion 261

10.1 Mechanism of path dependence 262
10.1.1 Crisis driven short term solutions 263
10.1.2 Incremental planning 263

10.1.3 Electricity liberalization 264
10.1.4 External influence in comprehensive plan 264
10.1.5 Institutional lock-in and evolution of actors....265
10.1.6 Rent seeking mechanism in the institutional structure (1990 onwards)....267
10.1.7 Regulatory capture (2010 onwards) 268
10.1.8 Continuous dependence on external actors 269

10.2 Interaction of multiple causal mechanisms in an institutionally locked-in energy system....272
10.2.1 Technological regionalism 272
10.2.1.1 Regional innovation system 272
10.2.1.2 Regional geopolitical motivation 273
10.2.2 Role of state....274
10.2.2.1 State-led marketization vs. state supported liberalization 274
10.2.2.2 State centrism versus state structuralism....274
10.2.3 Politics of demand....275
10.2.3.1 Global geopolitical motivation 275
10.2.3.2 Global energy technology suppliers' rent seeking motivations....277

10.3 The major debates....277
10.3.1 Diffusion speed and spillover of knowledge....277
10.3.2 Technological characteristics and the speed of diffusion....278
10.3.3 Technological innovation systems 278
10.3.4 The role of electricity liberalization in solar growth....279

11 Conclusion....280

11.1 Achieving the research objectives....280
11.1.1 Development of conceptual framework 280
11.1.2 Identifying the mechanisms and contributions to literature and ongoing debates 281
11.1.3 Validation of the findings using comparative case study....284
11.1.2.1 Findings from empirical chapters....285
11.1.2.2 Findings from comparative case study....286

11.2 Policy implications....287

11.3 Limitations and further scope of research....289

12 Bibliography....292

List of Tables

Table 3-1 Variables and Concepts in Three Systems 60
Table 3-2 Difference Between Developed and Developing Countries and its Implications to Energy Transition Mechanisms 63
Table 4-1 Case Selection Criteria 81
Table 4-2 Research design and method 84
Table 5-1 Steps of process tracing 88
Table 5-2 Current Capacity and Future Targets of Power Generation Technologies............110
Table 5-3 Evolution of actors 127
Table 6-1 Share of solar technology 138
Table 6-2 Categorizing countries according to growth and duration of solar technology use 155
Table 8-1 Major Rent Seekers and Strategies Employed 229
Table 9-1 Summary of the gaps in existing explanations 248
Table 9-2 Energy transition mechanisms...249
Table 9-3 Historical energy transition of Bangladesh and Vietnam......................................250
Table 11-1 Relative strength of causal mechanisms..282
Table 11-2 Specific contribution to major ongoing debates 282
Table 11-3 Additional contributions to literature 283

List of Figures

Figure 1-1 The Structure of the Dissertation 10
Figure 3-1 Interconnectedness of Variables from Three Systems 61
Figure 3-2 Conceptual Framework 64
Figure 3-3 Causal mechanisms of energy transition in developing countries 70
Figure 4-1 Longitudinal case study: structure of analysis 77
Figure 4-2 Within-case Study: Structure of Analysis 79
Figure 5-1 Maximum forecasted demand and maximum supply in MW (1970's-2010's) 89
Figure 5-2 Installed capacity against maximum demand in MW (1971-2020) 89
Figure 5-3 Power generation by public and private sector (1970-2019) 90
Figure 5-4 Power generation by fuel source 91
Figure 5-5 Energy consumption in Bangladesh (1973-2018) 92
Figure 5-6 Energy import (1973-2020) 93
Figure 5-7 Total energy consumption by sector (1973-2018) 93
Figure 5-8 Industrial consumption by energy sources (1970s-2010s) 94
Figure 5-9 Rural electrification (1980 -2020) 95
Figure 5-10 Coal production and coal import (2015-2020) 114
Figure 5-11 LPG production and import (2015-2020) 117
Figure 5-12 Per unit generation cost (2008-2020) Tk./kwh 118
Figure 6-1 Capacity addition of large solar projects (2010-2024) 137
Figure 6-2 Share of solar in electricity supply of Bangladesh (2000-2022) 137
Figure 6-3 Solar capacity addition (MWp) (2006-2023) 139
Figure 6-4 Global LCOE and Utility Scale Solar Power Tariff in Bangladesh 146
Figure 6-5 Relationship Between Capacity (MW) and Traiff (USD/kwh) in Bangladesh 146
Figure 6-6 Share of Solar Electricity Supply for Lower Middle-Income Countries 153
Figure 6-7 Solar share as a percentage of total electricity supply (2000-2020) 154
Figure 6-8 Solar growth from the year of initial deployment 154
Figure 8-1 Coal Production and Coal Import (2015-2023) in Ton 204
Figure 8-2 LNG import in billion cubic feet (2018-2023) 207
Figure 8-3 Gas price increase after LNG import (Taka) 209
Figure 8-4 Causal Chain of Coal and LNG Adoption 230
Figure 9-1 Electricity supply in Bangladesh and Vietnam 234
Figure 9-2 Electricity supply by fuel source in Vietnam 235
Figure 9-3 Electricity supply by fuel source in Bangladesh 235
Figure 9-4 Coal Capacity Addition in Bangladesh and Vietnam 238
Figure 9-5 Share of Electricity Supply for Bangladesh and Vietnam 239
Figure 10-1 Mechanisms of path dependence and interaction of multiple mechanisms 262
Figure 11-1 Causal chain: mechanisms-based explanation 281
Figure 11-2 Comparing energy transition mechanisms in Bangladesh and Vietnam 287

List of Abbreviations

ADB	Asian Development Bank
AIIB	Asian Infrastructure Investment Bank
AL	Awami League
BAPEX	Bangladesh Petroleum Exploration Company
BAERA	Bangladesh Atomic Energy Regulatory Authority
BAEC	Bangladesh Atomic Energy Commission
BERC	Bangladesh Energy Regulatory Commission
BNP	Bangladesh National Party
BPDB	Bangladesh Power Development Board
DANIDA	Danish International Development Agency
DICE	Dynamic Integrated Climate Economy Model
EPC	Engineering, Procurement, and Construction
EKC	Environmental Kuznets Curve
FSRU	Floating Gas Regasification Unit
FIT	Feed in Tariff
GDP	Gross Domestic Product
GIS	Global Innovation System
GPE	Global Political Economy
IAM	Integrated Assessment Model
IAEA	International Atomic Energy Institute
IEA	International Energy Agency
IEPMP	Integrated Energy and Power Master Plan
IRENA	International Renewable Energy Agency
IMF	International Monetary Fund
IPE	International Political Economy
IPP	Independent Power Producer
IS	Innovation System
JICA	Japanese International Cooperation Agency
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
METI	Ministry of Economy, Trade, and Industry
MLP	Multi Level Perspective
MPEMR	Ministry of Power Energy and Mineral Resources
NIS	National Innovation System
NEM	Net Metering
NPP	Nuclear Power Plant
NSG	Nuclear Suppliers Group
RNPP	Rooppur Nuclear Power Plant
PSC	Production Sharing Contract
PSMP	Power System Master Plan
PSRB	Power Sector Reform of Bangladesh
RIS	Regional Innovation System
SHS	Solar Home System
SREDA	Sustainable Renewable Energy Development Authority
QEEES	Quick Enhancement of Electricity and Energy Supply

SAARC	South Asian Association of Regional Cooperation
SPP	Small Power Plant
STI	Science and Technology Innovation
STS	Science and Technology Studies

Abstract

Climate change mitigation requires the substitution of fossil fuels with low-carbon energy, while the emerging economies require rapidly expanding electricity supply. The current understanding of energy transitions in developing countries is fragmented across several disciplines and insufficient to inform policy choices. This thesis aims to advance the understanding of the mechanisms of energy transitions in developing countries, using Bangladesh as the main case study and integrating techno-economic, socio-technical, and political perspectives.

The thesis uses a three-stage research design. The first stage traces technological and institutional path dependencies emerging over the fifty years of evolution of Bangladesh's energy systems. This longitudinal case study focuses on how energy policies responded to persistent "energy crises" and distills common patterns and salient institutional characteristics that structure Bangladesh's energy choices. The second stage identifies energy transition mechanisms by examining the adoption of four energy technologies: low-carbon solar and nuclear power, as well as fossil-based LNG and coal power. The four technology cases address several paradoxes in which neither costs nor resource availability can account for the observed technology choices. The third stage is a comparative case study of Bangladesh and Vietnam to refine and validate the understanding of energy transition mechanisms through contrasting energy choices: solar in Vietnam and nuclear in Bangladesh.

The thesis finds that socio-political mechanisms dominate techno-economic ones in energy transitions in Bangladesh. This contrasts with the widespread claim that declining costs of low-carbon technologies would immediately accelerate global adoption. It also questions a common policy prescription for liberalizing electricity markets and increasing electricity prices as a way to ensure the fast uptake of renewables. The thesis identifies institutional lock-in based on rent-seeking as the dominant energy transition mechanism in Bangladesh. This mechanism makes Bangladesh dependent on external resources and responsive to external pressures, thus amplifying the impact of geopolitically driven strategies on Bangladesh's energy choices. At the same time, the institutional lock-in weakens the national innovation system, thus making the adoption of new technologies contingent on international private actors. These findings contribute to two debates in the literature. The first concerns the speed of adoption of granular vs. lumpy energy technologies. Granular technologies are often presumed to be simpler and diffuses faster. However, the thesis shows that lumpy technologies like nuclear, coal, and LNG may grow faster in institutionally locked-in and external resource dependent countries like Bangladesh under geopolitically motivated external pressures than granular technologies like solar, which require national capacity. The second question concerns the relative importance of global or national innovation systems in facilitating the diffusion of technology. The thesis identifies regional innovation systems as playing a more important role than global innovation system in the solar power adoption in both Vietnam and Bangladesh.

More generally, the contribution of this thesis is a framework for the study of energy transitions in developing countries, with special attention to the international landscape, regional innovation systems, and institutional path dependence. It provides insights into developing countries' energy choices, which may explain their slow adoption of clean energy despite falling costs and the worldwide drive for decarbonization.

Keywords: Energy Transition in Developing Countries, Path Dependence, Causal Mechanisms, Institutional Lock-in

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1 Introduction

1.1 Background

The main challenges limiting rapid decarbonization include slow expansion of accessible and inexpensive renewable energy sources, as well as the complexities of reducing fossil fuel reliance. Both the growth of clean sources of energy with low carbon footprints, such as solar and wind power, and the decline of carbon-intensive fuels such as oil, liquefied natural gas, and coal are crucial to reducing emissions. In addition to these challenges, emerging countries are facing rapidly growing demand and unequal access to energy resources, which presents additional obstacles. These challenges are more difficult for developing countries because of the limitations in technological and financial resources. These limitations are exacerbating the likelihood of reducing carbon emissions and presenting significant obstacles for developing countries to tackle the climate crisis.

Yet, developing and emerging countries are increasingly important for the future of global energy and climate change mitigation. On the demand side, such economies in Asia will account for two-thirds of the total global energy growth. (IEA 2017) On the supply side, developing countries are becoming the major markets and testing grounds for both old and new energy technologies ranging from coal power, LNG, and nuclear to renewables. Being technologically less advanced and financially constrained, these countries rely on advanced nations for technology and finance. Because of this dependence, the energy transition mechanisms of these countries are different from those of the core countries where technology was developed.

While rapid deployment of renewables is desirable across the globe to achieve the climate target, the challenges faced by developing and emerging countries today are not the same as what developed countries faced in their initial stage of diffusion. Therefore, when late adopters' potential to switch to new energy technology is compared to that of early adopters, there remains a gap in understanding the speed and feasibility of the transition. Scholars like Grübler et al. (2016) pointed out that technology diffuses faster in the periphery than it does in the core because of spillover of knowledge, declining costs from economies of scale, and globalization of technology. Although this is a widely accepted view, the real causes of slow adoption cannot be sufficiently explained by the availability of clean technology and cost. Because not all emerging countries could increase their share of solar as a response to the global decline of solar cost and its availability.

In the case of fossil fuel decline, a similar anomaly can be observed. Not all emerging countries adopt nuclear, LNG, and coal, despite their high investment requirements. Therefore, why some late adopting countries adopt some energy technologies faster than other technologies among the late adopting countries remains ambiguous. Specifically, why, despite lacking sufficient capacity, some countries adopt more complex technologies like nuclear while undermining the use of simple technologies like solar reflects a paradoxical outcome that needs in-depth understanding.

The aforementioned obstacles in emerging economies and the corresponding paradoxical responses of some of these countries have made me interested in learning about the rationale behind a country's adoption of a self-contradictory solution like this. This has interested me and led me to choose Bangladesh and Vietnam as case studies for my dissertation, which evolved and solidified with their continued progressive development at various phases.

Bangladesh is now classified as a lower middle-income country and has set a goal to achieve high-income status by the year 2041. Bangladesh, a small South Asian country, is situated in a geopolitically strategic location and possesses significant potential for implementing renewable energy. Consequently, it attracts a variety of energy technologies from more prosperous countries. The energy transition case study of Bangladesh is intriguing due to the rapid expansion of fossil fuel usage, the adoption of nuclear energy, and the sluggish progress of renewable energy deployment over the past decade. The case of Vietnam is interesting because Vietnam had a divergent outcome as it adopted solar and cancelled nuclear power plant.

Studies on four different new technologies in Bangladesh and a comparative case study between Bangladesh and Vietnam are empirically grounded, relevant to the ongoing debate on energy transition, and globally important because they distinguish between developed and developing countries.

1.2 Motivation for research

First, I was motivated to explore why the cases of emerging economies are different from the cases of developed ones. The previous studies identified that there is a relationship between low renewable energy adoption and low capacity due to the low-income level of the country. (Vinichenko 2018) I was interested to know what other mechanisms there are beyond capacity. Because capacity as a cause is ambiguous when it is important for some technologies and not for others. Based on my initial observations, I contend that it is not appropriate to directly differentiate industrialized and developing countries because of their differing capacities, which are closely tied to GDP levels. By adopting this approach, we fail to consider other equally significant aspects that contribute to the adoption of energy technology in emerging countries. To explore other factors, I was motivated to do a case study on a country facing typical problems of an emerging country while at the same time exhibiting paradoxes in its energy transition outcome.

As I was researching further, at the second stage, I found that Bangladesh falls into the typical case of an emerging economy with a paradox in its energy choice. Then, I was motivated to have an in-depth understanding of the mechanisms through which a country like Bangladesh increases its dependency on fossil fuel technologies, makes high investments in nuclear, and underinvests in solar. I observed that while the cost of solar was declining, the adoption of coal and LNG was already being regarded as environmentally costly and socially inefficient, and nuclear required outrageously high upfront investment. Despite the drawbacks, Bangladesh started to adopt coal, LNG, and nuclear. So, I selected four newly adopted technologies: solar, nuclear, coal, and LNG, which Bangladesh has gradually adopted in the past decade, but at different speed, and with different level of priority. The construction of some of the LNG terminals, coal power projects, utility-scale solar projects, that started before 2018 started commercial operations during my PhD years between 2018 and 2024. The nuclear power plant is still under construction and has been delayed for more than two years.

The selection of these particular technologies allowed me to observe the formative phase of each technology's adoption. So, I decided to focus on only these new energies instead of also selecting incumbent industries like natural gas and oil in addition to the new energies. Out of the four technologies, coal is renowned for its significant carbon footprint. While LNG does have a reduced carbon footprint compared to coal, it is still classified as a fossil fuel. Nuclear power is recognized for its comparatively lower carbon footprint in comparison to LNG. However, it cannot be disregarded due to its enduring environmental consequences. Solar power is widely acknowledged as a low-carbon technology. Solar energy can be classified as a kind of granular technology, whereas nuclear power, coal, and liquefied natural gas (LNG) can be classified as forms of lumpy technology. The diversity of technological characteristics in terms of scale and capacity requirements is an intriguing case of inter-technology variance within a single country. So, I chose to do an in-depth case study of the four technologies in a single country, Bangladesh.

The fourth dimension evolved gradually when I was closely observing recent trends in other developing countries. Vietnam appeared as a country with the fastest-growing solar share in the world in just two years between 2018 and 2020. As an emerging country, Vietnam's spearheading in solar growth compared to other emerging countries grabbed worldwide attention. It raised a new debate about capacity and the speed of diffusion. I found that Vietnam is another interesting country, having similarities with Bangladesh and at the same time exhibiting a deviating outcome. Vietnam cancelled its plan to build a nuclear power project in 2016 and focused on solar growth. This prompted me to do an in-depth comparative case study between Bangladesh and Vietnam. At that time, I did not know to what extent this comparative study could contribute to the debate. With systematic observations of the evolving scenario, I delved into the critical exploration of the mechanisms that worked in Vietnam but did not work in Bangladesh.

1.3 The missing perspectives

Numerous studies have been carried out on the energy transition in emerging and developing countries. A recent study reveals that the majority of the research is empirical and quantitative, mostly focusing on economic models, energy scenarios, and energy models. In a large number of these studies, techno-economic perspectives dominated. They mostly employed geoinformatics, input/output analyses, cost-benefit analyses, and other tools to analyze the techno-economic perspectives. Political and social perspectives in most of these studies are still under-researched. (Apfel et al., 2021)

Among the past research done on energy transition in the global south, there are single case studies (Qureshi et al., 2023; Urakami, 2023; Do et al., 2020; Freitas and Jehling, 2023; Apfel, 2023; Ahmad and Tahar, 2014) and comparative case studies. (Jakob et al., 2020)

Research on the energy transition encompasses multiple disciplines. The energy shift encompasses more than just technology innovation, cost effectiveness, profitability, and return on investment. The subject matter encompasses institutions, regulations, stakeholders, national capacity, political motivation, and stakeholders' interests. Consequently, examining the energy transition from a single perspective fails to adequately elucidate the reasons behind the differing paces of adoption for different technologies. However, it is rare to find studies that incorporate three perspectives. The study conducted by Vinichenko (2018) compares the energy outcomes and the causal mechanisms behind the outcomes for Japan and Germany. It focuses on three different perspectives: the techno-economic perspective, the socio-technical perspective, and the political perspective. However, this comparison specifically targeted wealthy countries. There is a notable deficiency in the existing literature about the analysis of emerging countries, particularly in terms of utilizing three distinct perspectives. Some studies are conducted with a political lens, while others are approached from a purely socio-technical standpoint. The primary focus of the majority of the studies revolved around the techno-economic approach.

In summary, the gap in the existing literature is twofold. First, there is not sufficient research on the energy transition mechanisms of emerging countries. Second, the existing national case studies did not use an interdisciplinary approach to include different perspectives in the analysis of energy transition mechanisms in emerging and developing countries. Hence, it is necessary to conduct both individual case studies and comparative case studies in order to obtain comprehensive explanations of specific energy outcomes.

1.4 Research Puzzle

The example of Bangladesh's energy choice is puzzling since it violates rational predictions consistent with widely recognized theories. Energy transition in Bangladesh exhibits a notable paradox as it cannot be explained by mainstream energy transition theories. These theories

- predict more support for lower cost technologies (Fouquet 2016)
- predict that countries would avoid choosing energy sources (such as imported coal and LNG) that increase their dependence on imported fuels (Yergin 1991, Cherp et al. 2018)
- expect countries like Bangladesh to ascend the ‘electricity ladder’ (Burke 2010) moving from less advanced and polluting technologies like coal to more advanced like solar,
- predict that simpler granular technologies like solar would grow faster than complex and lumpy ones like nuclear (Wilson et al. 2020)
- explain persistence of coal in terms of ‘lock-in’ of socio-technical regimes (Trencher 2020)

In contradiction to these theories, Bangladesh has recently invested much more funds and effort in expensive and complex technologies based on imported fuels, such as nuclear, coal and LNG rather than in cheaper and simpler technologies that require less imports such as solar power and domestic natural gas. Furthermore, Bangladesh’s choice of coal cannot be explained by ‘lock-in’ because the country used only minute quantities of coal merely a few years ago.

The case of Bangladesh is even more puzzling because its energy choices are in no way common for emerging economies. In fact, Vietnam, a country similar in many relevant aspects made quite different choices: it rapidly expanded its solar capacity and cancelled its nuclear project.

My ovararching hypothesis is that the case of Bangladesh cannot be explained by mainstream theories of energy transitions because these theories have been constructed for developed countries. Energy transitions in developing countries like Bangladesh are dominated by different causal mechanisms and require different explanations. In my search for a framework to explain energy choices of Bangladesh I seek to answer the following research questions motivated by the above paradoxes.

- Why did Bangladesh adopt nuclear and fail to adopt solar?
- Why did Bangladesh develop its coal and LNG?
- What can explain the differences in energy choices between Bangladesh and Vietnam?

1.5 Research objectives

The research of the dissertation has three main objectives:

1) The research intends to develop a conceptual framework to reveal the causal mechanisms of energy transition of developing countries.
2) This case study aims to enhance the current body of literature on mechanisms of energy transition by providing insights into the reasons for the adoption of expensive technologies such as coal, LNG, and nuclear, while simultaneously exploring the factors that delay the adoption of solar technology.
3) Following an extensive analysis of a specific case in Bangladesh involving four energy technologies, this research aims to validate the findings from single case study by conducting a comparative study between Bangladesh and Vietnam. The purpose of this study is to investigate the reasons behind the different energy outcomes in these two countries, despite their shared goal of transitioning from a lower middle-income country to a high-income country.

1.6 Expected contribution in recent ongoing debates

Ultimately, I consider it of utmost significance to actively contribute to the current debates surrounding crucial issues. I envision that the answers to these questions will not only clarify the mechanisms of energy transitions in Bangladesh but also contribute to wider scholarly debates:

The first debate is about the speed of technology diffusion in emerging economies, which are on technological ‘periphery’. It boils down to the role of economic costs and institutional capacities in diffusion of clean energy technologies. With declining costs of solar and other renewables many scholars expect that emerging economies will adopt them faster leading to global acceleration of energy transitions (Grübler 2016) because of spillover of knowledge and economies of scale. Others believe that lower capacities of developing countries may slow technology diffusion at the ‘periphery’ (Cherp et al. 2021). My research directly engages with theoretical arguments and empirical evidence on whether cost decline is a more dominant mechanism than weaker institutional capacity.

The second debate is about technological characteristics which facilitate or hinder diffusion of new energy technologies. The widespread arguments articulated by Wilson et al. (2020) are that granular technologies such as solar PV should diffuse faster because of their more effective learning, simplicity, and lower investment requirements. Yet empirically lumpy technologies such as nuclear sometimes grew faster historically (Vinichenko et al. 2023). Most of the evidence in this domain relates to developed countries and I hope to contribute to this debate with evidence from Bangladesh where both nuclear and solar PV are introduced in the same context.

The third debate is between technological nationalism and technological globalism. The former (Nelson and Rosenberg 1993, Freeman 1987, Lundvall 2007, Patel and Pavitt 1997) stresses the importance of national innovation systems in technology diffusion, whereas the latter emphasises the global innovation system (Binz and Truffer 2017) and considers most individual countries as 'takers' of technology. I contribute to the debate by investigating the mechanisms of solar and nuclear power diffusion that unfold at the global, national and regional levels.

The fourth debate is about the role of liberalisation in diffusion of clean technologies. With declining costs of solar PV, there are increasing arguments that it could be very rapidly adopted provided markets for electricity are liberalised. This is sometimes supported with empirical evidence from advanced economies where market liberalisation and rapid adoption of renewables often co-occur. (Lee 2020, William et al. 2021) Other scholars (Dos Reis et al 2023) argue that modern renewables are of sufficient novelty and complexity to require increasing rather than decreasing policy intervention to be successfully introduced. This debate is particularly relevant to developing countries where markets are often not liberalised but state institutions are weaker than in advanced economies.

1.7 Structure of the dissertation

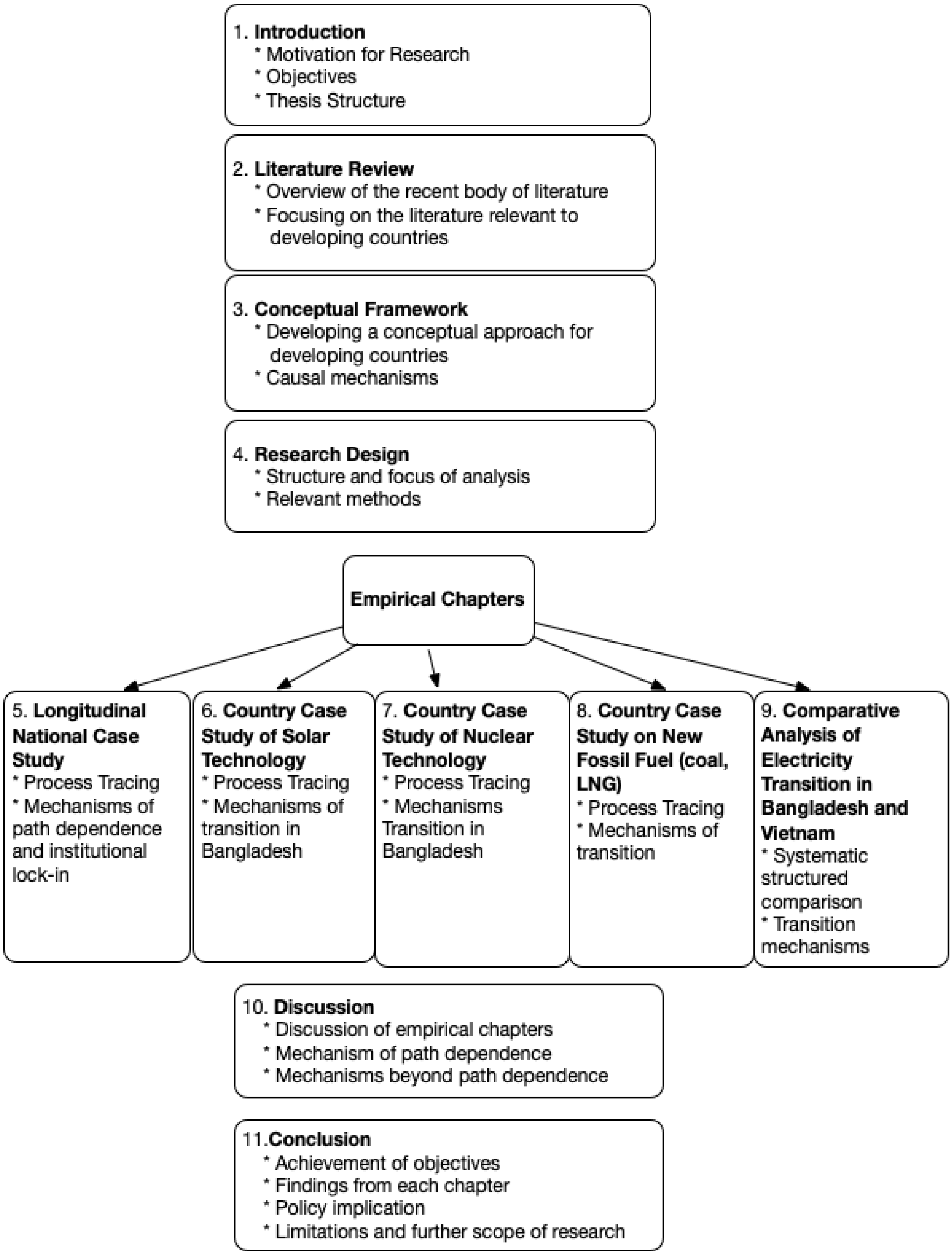
Chapter 5 lays the foundation for understanding energy transitions in Bangladesh in terms of its energy history and the economic, political, and geopolitical circumstances in which societal actors evolved to adopt certain policies and not others. This chapter aims to explore the development of energy sectors by dividing it into five episodes. It analyzes the policies of each episode of one decade from the 1970s to 2020 using process tracing. This chapter aims to define the institutional characters that gradually created the ground for the energy transition mechanisms to function in line with the evolution of institutions.

The next four chapters, from chapter 6 to chapter 9, are single-country within-unit case study across four energy technologies. In all of these case studies, I used process tracing to identify the mechanisms for adopting these new technologies in the formative phase. The first two technologies, solar and nuclear, are chosen for their comparatively low carbon footprint. The second two technologies, coal and LNG, are chosen as examples of fossil fuel technologies. While Chapter 6 focuses on solar technology adoption, Chapter 7 deals with nuclear adoption. Chapter 8 brings both LNG and coal power adoption into one single framework of analysis to address the commonalities in the mechanisms of adoption of new fossil fuels. Chapters 7 and 8 use the geopolitical and rent-seeking frameworks to explore the mechanisms of adoption of these new technologies. Chapter 9 compares electricity transition of Bangladesh and Vietnam and focused on why Bangladesh adopted nuclear power and Vietnam cancelled it and why Vietnam's had a fast solar growth and Bangladesh lagged behind.

Finally, chapter 10 discusses the empirical observations of chapters 5, 6, 7, 8, and 9 to analyze how the findings engage in recent debates. It summarizes how the findings from chapters 5, 6, 7, 8, and 9 are linked together to cumulatively address contemporary debates and provide a succinct explanation of the causes of typical energy outcomes in an emerging country like Bangladesh. In light of the mechanisms identified in previous chapters, chapter 10 discusses the mechanisms of path dependence, the interrelated mechanisms of energy transition and how they relate to the existing debates.

Chapter 11 draws conclusions by summarizing the findings of each chapter. This chapter summarizes how the findings challenge some of the existing explanations in the literature and how the findings contribute to the existing literature and debates. The chapter concludes with discussing the policy implications of the findings and identifying the areas for further research.

Figure 1-1 The Structure of the Dissertation



2 Literature Review

The literature review covers interdisciplinary literature seeking to construct a basis for a metatheoretical framework for explaining energy transitions. Energy transitions have been explained by different disciplines from different perspectives. Although some perspectives were more widely accepted than others at different points of “perceived transition," recent developments in the literature show that different mechanisms of energy transition co-evolved towards a certain energy outcome. The three-perspective framework on energy transition encompasses socio-technical, techno-economic, and political perspectives. This literature review brings together literature from these three perspectives and discusses their interlinkages, limitations, and complementarities.

Section 2.1 discusses how historically the paradigm of neoclassical economic theories dominated and formed the basis of the techno-economic perspective and how scholars have identified the limitations of the theories at different transition junctures. Section 2.2 reviews the technology diffusion literature, identifies the factors that differentiate developing countries from the developed ones, and explains the gap in the literature in explaining energy transition in developing countries. Literature on environmental Kuznets curves and energy ladders complements the technology diffusion literature. The literature on the energy ladder based on the correlation between availability of capital and adoption of advanced technology is relevant to the development level of the countries. This section also introduces the literature on technology characteristics that differentiate one technology from the others. Section 2.3 discusses political theories. The theories covered in the literature include rent-seeking theory, energy geopolitics, and policy diffusion. Section 2.4 focuses on the energy market regulations, including price setting mechanisms under liberalization and its implication to energy transition in developing countries. It also introduces the literature on pricing policy design. Lastly, section 2.5 discusses the literature on path dependence and institutional lock-in.

2.1 Neoclassical economic theory

Neoclassical economic theory is a constellation of economic theories based on the assumption of rational choice and scarcity of resources. Veblen in 1900 first coined the term to distinguish between classical approach from the new marginalist approach in the study of individual behavior. This genre of economic theories exemplify market as free market in which equilibrium price is determined by the demand and supply. Any kind of interventions like tax, subsidy, quota and other information and entry barriers used by the government distort markets. Therefore, an optimum outcome is the most efficient one when there is no government intervention in the market, the price adjusts by itself as market forces response to any supply or demand shock. Consumers respond by maximizing the utility, while the suppliers respond in order to maximize profit. According to the theories the social cost is minimized and consumption and production are optimum when the demand supply balance each other without any government intervention.

Although the neoclassical static-equilibrium type theories have been criticized since the time of its inception this genre of economic theories remained influential during the last centuries both within economics discipline and multidisciplinary research where the economic theories are relevant. For example, in the study of energy transition and climate science, that use multidisciplinary approach, neoclassical economic theories have secured an influential place among other relevant theories like technology diffusion theories and political theories.

2.1.1 How does neoclassical theory relate to energy transitions?

Historically, the relevance and limitations of neoclassical economic theories in energy transition study have been identified by many scholars in different energy transition conjuncture. For example, in 1930s when coal use was rising towards its peak, and use of oil got a momentum with new inventions in energy services, (Marchetti 1979) the potential future scarcity of energy necessitated application of neoclassical approach as well as identifying the limitations of the theories. Similarly, in the 1970s oil crisis, scholars needed to use neoclassical framework to analyze the historical energy transition to develop a new model to predict future energy transition. During the 2010s, with the decline in the cost of renewable energy use, the neoclassical economic theories again came to be relevant in policy design to promote renewable energy growth.

In the 1930s, Harold Hotelling first pointed out the limitations of neoclassical economic approach and advocated for government intervention to reduce the consumption of fossil fuel.

"*The static-equilibrium type of economic theory which is now so well developed is plainly inadequate for an industry in which the indefinite maintenance of a steady rate of production is a physical impossibility, and which is therefore bound to decline. How much of the proceeds of a mine should be reckoned as income, and how much as return of capital? What is the value of a mine when its contents are supposedly fully known, and what is the effect of uncertainty of estimate? If a mine-owner produces too rapidly, he will depress the price, perhaps to zero. If he produces too slowly, his profits, though larger, may be postponed farther into the future than the rate of interest warrants. Where is his golden mean? And how does this most profitable rate of production vary as exhaustion approaches?*"

In 1931, in the journal of political economy, Harold Hotelling (Hotelling 1931, p.139) wrote these sentences in his article "The Economics of Exhaustible Resources". At that time scarcity or exhaustibility of energy was the driving concern in allocating optimum resources for economic growth. When Hotelling raised these questions, conservationists believed that excessive cheapness of resources are causing rapid exploitation of exhaustible resources. Hotelling also pointed out that the conservation movement may be accused of serving the interest groups that intend to maintain high price for profit rather than from posterity, if they aim absolute prohibition instead of taxation and regulations

Since then, the question of optimum energy use has been addressed by economists mainly from neoclassical theory of demand supply balance and use of regulations, taxation, import duty to control production and consumption. After the oil crisis of 1973, economists started to rethink new frameworks to study the production and consumption pattern of exhaustible resources. (Solow 1974, Dasgupta and Heal 1979) The theories began to include energy in the models along with labor, capital, and land. Quantitative economists started to analyze the past empirical evidence to explore the relationship between economic growth and energy use.

Following the 1973 oil crisis, Italian nuclear physicist Cesare Marchetti used data from 1850 to develop a simple and predictive model in which he showed rise and fall of coal, oil, natural gas, and predicted rise of nuclear and solar power in the future. At that time Marchetti was working with International Institute for Applied Systems Analysis (IIASA). In the 70s IIASA was established to enhance cooperation between the East and the West to bridge the cold war divide and addressing global problems. The research output of Marchetti was embraced by the policymakers at a global level during the oil crisis. According to Marchetti the replacement of wood by coal, then oil, and natural gas is like a clockwork overtime. Each energy "had a schedule, a will, and a clock" and it is the matter of time and right price to trigger the transition, as if by an invisible hand. Without any relation to policy, politics, or external interruption, the regular transition gripped experts around the world. (Gross and Needham 2023)

The techno-economic perspective has largely been at the heart of most of the analysis that was continued from the 1970s onward. In fact, In the 1970s, the early Integrated Assessment Modelling (IAM) were actually extension of the neoclassical growth model. The models intended to figure out how the global economy interact with the human caused climate change. For example, Nordhuas (2013) invented economic climate system, which was later called IAM. Besides land, labor, and capital, he introduced natural capital as a variable to show how natural capital may deplete and affect growth. He also introduced Dynamic Integrated Climate Economy model (DICE) in which he quantified the long-run economic costs and benefits of various possible scenarios. Nordhuas' argument that a uniform tax rate can optimize welfare of future generation is congruent with the neoclassical economic theory. Later, all types of IAM, including optimal growth or welfare maximization models, general equilibrium models, partial equilibrium models, and macroeconomic models were derived from neoclassical economic theories. (Beek et al. 2020)

Throughout the decade of 2010, when the cost of solar has started to decrease the dominant techno-economic perspective that solar would be the next energy as a response to price decline, raised expectation about yet another energy transition. Solar has been perceived as one of the alternatives to fossil fuel to reduce the carbon emission. While the policy makers have started to become more optimistic than ever about the future of solar growth, and creating ambitious targets, another group of scholars have started to question the feasibility of those targets.

Fouquet distinguished between the previous transitions and prospective transition to the low carbon energy technologies and argued that unlike previous transitions, where private benefits of switching to new technology for both consumers and producers were clear, the private benefits of switching to low carbon technology like solar and wind is less obvious. (Fouquet 2012)

Besides, the current transition to low carbon energy contributes towards the public good as long as the risks, costs, and other barriers do not create private benefit, the low carbon technology needs deliberate intervention to create incentives to adopt the technologies. This difference along with other differences (Fouquet 2016) in intermittency, land requirements, uncertainties in quality of services, and energy carrier requirement (just electricity for solar and wind), make current energy transition different from previous transitions. The differences violate the assumption of perfect information and justification of laissez fair (profitability based on competition) untenable.

2.1.2 What are the gaps?

Some scholars have started to find out the limitations of the previous studies. For example, Arnulf Grübler (2012) pointed out the limitations of the past energy transition studies and pointed out when the scholars discovered a potential rise of new fuel sources, they rarely relate it to labor struggles, cultural changes, or the role of states in previous transitions.

Other scholar (Fouquet, 2012, 2016) emphasized on historical learnings from energy transition to use in understanding what could potentially work in present and future energy transition. Fouquet pointed out how learning historical transitions, their causes, dynamics, and catalysts might help better understand the nature, challenges and prospects of future potential transitions and what can be done to achieve them. Despite finding positive association between high electricity demand and energy transition, Fouquet argued that increasing demand for electricity does not increase only adoption of new energy, but also incumbent energy. Although demand is an important cause of energy transition, it does not sufficiently explain why transition occurred. Similarly, short term price decline does not ensure immediate adoption of cheaper energy technology. A long-term price decline is necessary for a full transition to occur. (Fouquet 2016, p.9)

Over the last one decade the main debates on what policies need to be used to promote low carbon energy technology centered on the application of neoclassical theories and their limitations. Three main debates relevant mostly for developing countries are:

What ideological preference (laissez faire or government interventions) is suitable for solar growth? Is there any need for public agencies to intervene in the market when a new energy technology is readily available? How do real-life investors actually behave? Do they have perfect information about the fast-changing technology and signal of profitability? Do they need government support like feed in tariff, land access, infrastructure, less trade barriers once the technology is readily available in developing countries? Or leaving it to the market to fix the price will ensure solar growth? Does electricity price increase as a result of electricity liberalization signals profitability to the investors and promote solar growth?

Fouquet pointed out that at particular time broader ideological preferences (for or against free market) have had a major influence on the institutions and adoption of certain types of technologies. (Fouquet 2012) The Kyoto protocol amplifies the effect of both energy policy and liberalization. (Nicolli 2016). Energy market liberalization is a long and complex process, involving myriad aspects that can exert opposite effects on the development of renewable energy. (Pollitt, 2012) Pollitt conclude that it is not liberalization per se that will determine the movement towards a low carbon energy transition, but the willingness of societies to bear the cost, which will be significant no matter what the extent of liberalization.

Another gap remained as a question. Are demand and supply objectively determined in the market or politics of demand and politics of supply can have an impact on demand creation and supply availability? The neoclassical economic theory defines law of demand and supply by assuming that when all other things are constant, demand and supply depends on the price. When the ceteris paribus assumption is violated demand and supply change as a response to factors other than price. Neoclassical theory does not consider explaining the role of actors using power and capacity to manipulate changes in demand and supply. The theory gives more emphasis on the price, cost, income, and population etc. as factors behind changing demand and supply. This limitation has been overcome by the political economy approach.

Grigas (2017) used the term politics of supply in the book New Geopolitics of Natural Gas. The politics of supply is defined as the process through which energy supplier countries exercise power to maneuver energy market to gain market share or cooperate with other suppliers to stabilize price to their desired level. (Grigas 2017) An example is Saudi Arabia dumping oil in 1986 to drive US and Russia out from the market.

Grigas (2017) also defined the politics of demand as the process through which energy suppliers use the demand for the energy as a means to exert influence on the energy importing countries. Russia's consciously creating and then exploiting import dependency of Europe on Russian natural gas is an example of politics of demand.

2.2 Technology diffusion

2.2.1 From core to periphery

The study on the diffusion of technology is abundant with material pertaining to industrialized nations. Technology diffusion studies have presented two analytical frameworks: temporal diffusion and spatial diffusion frameworks. Temporal diffusion examines the spread of innovation inside a certain place, whereas spatial research of innovation diffusion distinguishes between "core" markets, where innovation is initially adopted, and "periphery" or later-adopting sectors. (Grübler et al. 2016, p.19),
The power and energy systems of emerging countries diverge from those in developed countries as a result of disparities in technology adoption, innovation, and growth levels. The configuration of technology innovation systems is influenced by the integration of humans, networks, and institutions that together constitute the system. The study of how the system changes in emerging countries, specifically in the power and energy industry, is still developing as new aspects are being investigated during the shift to alternative energy sources.

Grübler and Wilson highlighted the importance of local knowledge and institutions in peripheral areas in order to build the ability to adapt to new technology. Grübler (1991; 1998) states that diffusion rates in peripheral markets are typically higher than in core markets due to the transfer of information from the core markets. Global diffusion of technology typically requires more time than diffusion within a single market, as it is not adopted immediately across all markets (Grübler et al., 2016). Local knowledge and institutions are essential for late adopters to successfully install, adjust to, and effectively utilize new technology. (Wilson 2012, p.92).

Another factor of technology dissemination that may vary in developing nations is the fluctuation in cost over time. Energy technologies undergo changes during their spread, which might last for several decades. An essential element of this transformation is the reduction in expenses. Enhanced performance might lead to a decrease in costs. The significance of gradual cost drop lies in its ability to elucidate the fact that adoption does not occur instantaneously. The process of technology becoming more affordable is time-consuming. There are various factors that contribute to the differing durations of time it takes in different countries. For instance, the cost of renewable energy has decreased at a quicker rate in India than in Bangladesh. This is encompassed by the notion of learning. Grübler et al. (1999) state that the mechanisms of learning by doing may involve the acquisition of experience by people, enhancements in organizational processes, or the realization of economies of scale.

Grübler 's approach to analysis for examining various stages of diffusion is applicable to developing nations as well. Grübler (1991) states that in the case of energy infrastructures and other widespread systems, a regular S-shaped pattern does not arise from a single underlying mechanism, but rather from a combination of various adoption processes. The diffusion of a system refers to the progression of stages that occur during the lifespan of a technology. According to Grübler et al. (1999), each stage is propelled by a distinct set of mechanisms. The initial stage is characterized by a sluggish pace and a significant degree of unpredictability and instability. Typically, this phase results in the emergence of a dominant design, which is a distinct technical style that is widely recognized as the most effective and efficient approach in terms of technological and engineering techniques. Additionally, it concludes by establishing a comprehensive system of social and institutional structures that can effectively facilitate the spread of the aforementioned.

The second phase typically involves rapid technological advancement, attaining economies of scale, cost reduction, and increased demand. During this stage, a multitude of advantages give rise to multiple constructive feedback cycles, which ultimately result in exponential expansion. At a certain point, the expansion begins to decelerate due to the rising negative social and environmental impacts and the diminishing potential for future growth caused by a finite market size, ultimately resulting in saturation (Grübler 1991). During the final stage, known as "senescence" or contraction, new technology replaces outdated technology. (Grübler et al. in 1999). The variations in market size, institutional capacity, capacity to learn by doing, and technical capacity in developing nations compared to industrialized ones can account for the differences in the transition mechanism. A deeper comprehension of the individuals, networks, and institutions is necessary to fully grasp the distinctions between these mechanisms and those in industrialized countries.

2.2.2 From national innovation system to global innovation system

Bengt-Ake Lundvall had been recognized to be the first person to introduce the term 'National System of Innovation'. However, as an editor of a groundbreaking and intellectually stimulating book National Systems of Innovation: “Towards a Theory of Innovation Interactive Learning” published in 1992 on this topic, he and his colleagues acknowledged (as emphasized by Lundvall) that the concept can be traced back to Friedrich List's work on 'The National System of Political Economy' (1841), which could have equally been named 'The National System of Innovation'.

Freeman (1995) also acknowledged that List not only predicted these fundamental characteristics of contemporary research on national innovation systems, but also acknowledged the interconnectedness between the importation of foreign technology and the advancement of national technical capabilities. Nations should not just adopt the accomplishments of more developed nations, but rather enhance them via their own endeavors.

Since the time of List’s work, a great deal of literature of 1990s dealt with national innovation system (eg, Nelson and Rosenberg 1993, Freeman 1987, Lundvall 2007, Patel and Pavitt 1997). After the decade of 1990s the focus started to shift to sectoral systems of innovation (Spencer 2003; Malerba 2005; McKelvey, Orsenigo, and Pammoli 2004,) and on regional systems of innovation (Cooke 1992; Cooke, Gomez Uranga, and Etxebarria 1997). Since late 2000s global innovation system literature (Carlsson 2006, Linden et al 2009, Brown and Levey 2015, Binz and Truffer 2017 and Hipp and Binz 2020, Heiburg and Truffer 2022) started to evolve.

In the globalizing knowledge economy, the mobility and movement of people, knowledge, and money increasingly connects distant creative processes. The growing geographical complexity prompts us to doubt the validity of a territorial system perspective, as the boundaries of the system become more blurred and permeable. Binz and Truffer (2017) refutes this stance and asserts that a systemic approach still has significant explanatory power, particularly when applied to innovation processes that are becoming more globalized. In order to fully harness this potential, they developed a conceptual framework to integrate the existing emphasis on actor networks and institutions that influence innovation in regional and national systems with a greater attention on the function of multi-scalar networks and the systematic variations in innovation processes across different industries. Binz and Truffer (2017, p.1287–1288) propose a multi-scalar approach to innovation systems, which includes a new layer focused on the global dimension.

They employed the concept of "structural coupling of subsystems" to elucidate the external connections between global, transnational, national, and regional subsystems. The authors emphasized that innovation systems are comprised of actor networks and institutional contexts at several scales, which collectively facilitate the creation and spread of innovation resources. This paradigm lacks the capacity to analyze the influence of the state in the development of resources and does not address the question of whether market forces or the state are responsible for driving structural coupling. The Innovation System (IS) framework offers guidance on how to define the participants, connections, and components of a system. However, it fails to address the players' interests, which are crucial in elucidating the cause-and-effect relationship between external influence and energy outcomes.

Binz and Truffer (2017) draws on recent insights from the sectorial systems literature to explain differences in the spatial configuration of global innovation system (GIS) in various industry types. It differentiates between an industry's dominant innovation mode, science and technology innovation (STI) and the economic system of valuation in which markets for the innovation are constructed (standardized products for global mass markets vs. customized products depending on symbolic valuation in local contexts). This heuristic creates new hypotheses on why in some industries national and regional innovation system boundaries remain relevant, while in others territorial boundaries are increasingly transcended by international interdependencies.

Binz and Truffer (2017) categorized solar PV as a technology having footloose GIS configuration. Solar photovoltaics (PV) is an illustration of footloose GIS, which pertains to companies that have limited geographical ties and rely heavily on worldwide networks and commerce for technological advancement and valuation subsystems. This industry relies on advancements in analytical knowledge bases such as material sciences or nano-technology to drive innovation. Economic value is currently structured inside standardized, worldwide mass marketplaces. They argued that the development of system resources in photovoltaics (PV) was formerly dependent on specific territorial subsystems only during the early stages of the life cycle. However, technology latecomers, especially from China, are now able to mobilize and integrate these resources into their own industry formation processes. Currently, the PV industry relies on intricate networks spanning several countries in developed and emerging nations.

In Binz and Truffer (2017) Nuclear Industries are classified as market-anchored Global Innovation Systems (GIS) due to their adoption of the STI innovation paradigm and implementation of a customized valuation system. These configurations will allow knowledge-related subsystems to go beyond territorial bounds, while product valuation will be integrated into specific territorial contexts.

Britto et al (2021) introduced a new layer after Binz and Truffer introduced a framework of global innovation system. They noted that the emergence of a new layer in innovation systems is a result of the integration of a network of international knowledge flows led by both firms and universities, driven by advancements in information and communication technology. The convergence, intersection, and intertwining of these two networks of international knowledge flows form a novel layer within an emerging global innovation system. This novel layer reconfigures the functions of regional, sectoral, and national innovation systems.

The mechanisms that build, shape, and enhance this new layer are driven by dynamic factors that are well-known in the innovation system literature. This novel layer reconfigures the functions of regional, sectoral, and national innovation systems, necessitating that policy recommendations be generated from these reconfigurations. Each policy recommendation must explore how to capitalize on these changes.

The introduction of this new layer by Britto et al (2021) raises the question of how the periphery may establish connections with international flows and develop the necessary capacity to effectively utilize the expanded networks for learning purposes. It is important to consider the reorganization of layers and hierarchies while reshaping local, sectoral, and national innovation systems. Britto et al stressed that none of these systems should be developed independently. Rather, the primary focus of domestic policy making may revolve around establishing a proactive role in the expanding global distribution of cutting-edge labor. Introducing a new layer can create a new hierarchy, as new structures come together to provide a distinct set of dynamics. This could potentially impact the levels of complexity in the overall system of innovation and development.

Steffen et al (2018) addressed the dimension of globalization of renewable energy supply chain and the impact of the country that owns the technology on the country that receives it. Their research gave some important directions about answering the questions: who are the key first movers? Who are the majority of project developers? from where the policies originated? and from where tacit knowledge flows? They found that the globalization of renewable energy supply chains has significantly influenced national clean energy transitions, with domestic policies driving the deployment of renewables. Their study analyzed the global market openings for wind, solar PV, and biomass, focusing on private project developers in developing countries. Results show that technology characteristics significantly shape market openings, with international private developers being key first movers. The study explores drivers for internationalization, including the impact of home country policies and the accumulation of tacit knowledge from home markets. Their study suggests that national renewable energy support policies in frontrunner countries can create companies willing to develop projects in new countries, transferring technology and capabilities, and creating positive externalities for followers.

In Steffen et al (2018) interviewees indicated that tacit knowledge accumulated by realizing projects in other countries, including knowledge related to the technology itself, project management, and navigating regulatory frameworks provided key advantages for international players in the market-opening phase.

Steffen et al (2018) also found that developers from forerunner countries often expand into countries with post-colonial ties and shared languages, such as Latin America for Spanish developers and parts of Africa for French developers, aligning with the Uppsala Model, suggesting internationalization begins with host countries with similar cultures and institutions.

2.2.3 From lumpy to granular energy technology

Wilson et al (2020) adopted the term "granularity" to describe technologies based on their scale—physical, economic, or both. Energy technologies that are more granular are more likely to scale through replication because they have smaller and more variable unit sizes (MW/unit), lower unit investment costs in absolute terms ($/unit), and are more modular or divisible. The opposite was denoted by the term "lumpiness": increased non-divisibility, larger units, higher unit investment costs, and a greater probability of unit size upscaling. Granular-lumpy is not a clear-cut dichotomous classification but rather a continuum.

They found that more-granular technologies offer faster diffusion, lower investment risk, faster learning, equitable access, job creation, and higher social returns on innovation investment. Unit scale is a useful criterion for evaluating net-zero emission pathways, clean energy R&D portfolios, industrial strategies, and technology demonstration programs. Social legitimacy allows for rapid technology deployment, destabilizing fossil-fuel-dependent regimes. Lower investment risks and shorter diffusion times increase market share, leading to greater equality and job creation. More-granular technologies enable simple project planning, especially in weaker governance institutions. Therefore, governments, firms, investors, and civil society organizations should consider granularity in mitigation strategies, policy support, R&D investments, and low-carbon innovation.

Wilson et al also argued that lock-in is characterized by increased alignment between incumbent enterprises and regulatory frameworks. Throughout the 20th century, the energy system promoted lumpiness. The large upfront costs, non-divisible risks, and significant repercussions of failure in lumpy technologies highlight the need for public action to ensure returns, collectivize risks, and defend market positions. Historically, public innovation efforts have primarily focused on centralized energy supply. Lumpy technologies are politically appealing because they showcase dedication and tangible evidence of mobilizing human, financial, and physical resources.

Choi and Kim (2022) used Korea as a case study to evaluate the learning curve of granular and lumpy technology. They found that granular technologies, such as solar and wind, are more likely to play a key role in Korea in mitigating climate change because of rapid decline in their costs. The spillover of knowledge is limited in current energy system mostly relying on lumpy technologies, such as coal and nuclear. To benefit from greater spillover of knowledge Korea need to adopt more granular technologies for decarbonization.

Cherp et al (2021) questioned the prevailing perspectives on the expansion of solar and wind power and their capacity to alleviate climate change. The data indicates that the growth rate in most nations is no longer exponential. Instead, it reaches a point of no further acceleration at approximately 1% of the total electrical supply every year. While maximum growth varies by country, only leading countries, such as Germany, approach the speed required worldwide to meet climate targets. Moreover, their findings indicate that emerging nations that implement wind and solar energy at a later stage do not see accelerated development in these sectors, likely due to unfavorable socio-economic and political conditions. This poses a particular challenge in terms of reproducing or surpassing the growth rates achieved by national leaders on a continental or global level. The study clearly illustrates the immense magnitude of the task of substituting conventional energy sources with renewable ones, as well as the necessity to investigate various climate solutions and scenarios.

2.2.4 From ascending energy ladder to leapfrogging

The Environmental Kuznets Curve (EKC), named after Simon Kuznets, is a graphical representation of correlation between indicators of environmental deterioration and per capita wealth. The fundamental concept is that when income levels are low, growth leads to environmental degradation, which can be measured by per capita emissions. Once a particular threshold is reached, growth becomes correlated with environmental enhancement. The changing pattern implies that the Environmental Kuznets Curve (EKC) exhibits an inverted U-shaped curve. Some scholars assumed that environmental quality is classified as a normal good, meaning that when income increases, the demand for environmental quality also increases (Beckerman, 1992; Barrett and Graddy, 2000). Grossman and Krueger (Grossman and Krueger, 1995) explained that as income increases, there is a trend to choose less environmentally harmful technologies, including low carbon energy sources. (Grossman and Krueger, 1995). Another explanation is that as the proportion of service sectors increases, the proportion of pollution-intensive industries in overall output decreases. This trend is often linked to an increase in income, as demonstrated by Jänicke et al. (1997). When applied in the field of energy, as income increases these factors result in an increase in more advanced technology, indicating an improvement in environmental quality.

During the decade of 2000 and the early 2010 when solar home systems were flourishing in rural areas, leapfrogging in energy technologies used to be frequently touted as a means for emerging countries to meet the need for a carbon-intensive economy, as they have not yet established a significant portion of their national energy infrastructure. Many scholars (Goldemberg 1998; Murphy 2001; Ockwell and Mallett 2012) used to point out at the examples of sustainable practices including the installation of solar panels in impoverished rural regions and the utilization of ethanol biofuels and biomass gasification in Brazil. However, there were also opposing views. For examples, Gallagher (2006) argues that the presence of leapfrog technologies alone is not enough to ensure their adoption. This is particularly true when there are incentives for energy use and a lack of strong environmental regulation.

Burke (Burke 2012, 2013) used data of 134 countries from 1960 – 2010 to show that there exists "national-level energy ladder" in which nations advance in tandem with their GDP per capita. Nations with low incomes depend significantly on biomass as their main source of energy, making biomass the primary energy source at the national level. As these countries transition from low-income status, they are increasingly shifting towards the use of fossil fuels and hydroelectricity as their primary energy sources. Hydro and fossil fuels are considered to be intermediate energy sources in this context. During this process, there is not a complete shift away from biomass usage, but the proportion of biomass in a country's energy mix decreases. At greater income levels, countries tend to reduce their reliance on hydroelectricity, oil, and coal. Instead, they increase their dependency on natural gas and adopt more capital-intensive energy sources like nuclear power and modern renewables such as wind.

According to Burke (2013) nuclear power and modern renewables are at the top of the national energy hierarchy. Endowment effects play a role in determining country differences in energy sources. Countries with substantial endowments in a single kind are less likely to progress to greater levels. Economic development often leads to an initial shift towards fossil fuels, followed by a shift away from the most carbon-intensive fuels (coal and oil), resulting in carbonization and eventually decarbonization of energy as economies grow. The findings suggest that countries with limited domestic fossil fuel resources are more likely to achieve significant decarbonization of their energy systems at higher income levels. These countries are more inclined to adopt low-carbon energy sources such as nuclear power and modern renewables. The national-level energy ladder offers a conceptual model for understanding the relationship between income and CO2 emissions, which has been extensively explored in the environmental Kuznets curve literature mentioned before.

According to Burke (2012), there is evidence suggesting that the transition to advanced forms of electricity generation, such as nuclear power and modern renewables, is the primary factor responsible for the decline in long-term per capita CO2-income pathways, as predicted by the Kuznets curve. The significant reductions in per capita CO2 emissions achieved by nations like Sweden, France, Belgium, and Denmark can be attributed mostly to their substantial shifts towards nuclear and/or modern renewable energy sources. The result shows evidence that the adoption of nuclear power and modern renewables is influenced by income levels, as shown by Burke (2010). This suggests that long-term growth in wealth can potentially contribute to reductions in CO2 emissions. The data suggests that the shift towards nuclear and modern renewable energy sources has had a more significant role in reducing CO2 emissions than other methods in the previous instances of carbon Kuznets curve downturns.

The findings suggests that countries seeking to decrease CO2 emissions should consider emulating countries like Sweden and Denmark, who have successfully transitioned to high-ranking low-carbon electricity sources. The feasibility of transitioning to nuclear power and modern renewables is influenced by income levels and fossil fuel resources, which also impact the motivation to pursue such alternatives (Burke 2010). However, there is still room for government intervention to promote the adoption of these low-carbon technologies at higher levels of the electricity hierarchy.

According to Goldemberg (2011) technological leapfrogging suggests that emerging countries have a wide range of options for determining their development routes, and they do not have to retrace the steps taken by today's industrialized countries in previous decades. The ability of scientists and engineers in developing countries to comprehend and utilize new technology worldwide is crucial for leapfrogging. Policy makers and business enterprises depend on these knowledgeable groups to offer valuable perspectives that can expedite the growth of these nations, while minimizing their environmental footprint.
In 2015, Benthem (2015) conducted research on 76 least Developed countries and industrialized countries and found that although there have been significant advancements in energy efficiency, there is little empirical support for the concept of energy leapfrogging. The energy intensity in developing countries has not been lower than that of industrialized countries in the past, and economic growth in developing countries has not yet become less energy heavy. He concluded that technological change alone is not enough to guarantee a decrease in energy consumption during economic expansion in emerging nations.
By replicating the method of Benthem, and using the data for 136 countries for 60 years of IEA, Fetter (2022) found that significant leapfrogging occurred. He pointed out that the reason of the different research is different data set and definition of sectors.

2.3 Political Theories

2.3.1 Rent seeking theory

Rent seeking refers to a process that results in the creation of societal costs. This process involves exerting effort (in the form of monetary spending or any other non-monetary methods of expending resources) in order to capture the transfer of resources that occurs as a consequence of monopolization and regulation. Prior to Tullock (1967) The transfer of resources was regarded as a redistribution among market actors without incurring any costs. Following Tullock's introduction of the concept that expenses incurred to obtain a transfer are a type of social cost, researchers began to utilize the concept of rent seeking to understand the social costs associated with different forms of rent seeking activities.

Khan (2000) emphasized that the value and variations of rent produced by rent seeking activities, as well as the diversity of rent seekers, must be understood as a process in which the effect of rent seeking on society is determined by the social cost of devoting resources to rent seeking and the social benefit or cost of renting. Rent-seeking theories have redirected attention from the traditional notion of identifying social costs to comprehending the various aspects of rent-seeking, including the value and effectiveness of seeking benefits from government intervention (such as subsidies, taxes, quotas, etc.), selective privileges (such as licensing, occupational permits), and regulatory capture that restricts competition (such as industrial regulation, environmental regulation, special acts, etc.). The economic study did not confine itself to competition, efficiency, monopolization, and regulation; rather, it acknowledged the political and institutional variables in determining the input cost of rent seeking and the output as a result of rent seeking.

Neoclassical economics argues that in order to attain efficiency and strong economic performance, institutions and rights that protect rents should be eliminated. One method to achieve this is by implementing regulations to ensure the presence of open and equitable competition in marketplaces. However, Schumpeter (1934) contested this notion by establishing the concept of "entrepreneurial rent" (also known as Schumpeterian rent). According to Schumpeter, firms generate profit by creating new processes that disrupt economic equilibrium, leading to temporary increases in revenue that surpass resource costs. Innovators can generate entrepreneurial rent as long as the innovation is not effectively disseminated. The entrepreneurial rent is regarded as a motivating factor for increased economic efficiency.

Another type of rent, known as "rent for learning," bears strong analytical resemblance to Schumpeterian rent, as both serve as incentives for cost reduction over time. While Schumpeterian rent can be obtained subsequent to an innovation, rent for learning can be obtained before to the occurrence of innovation. Rent for learning, in contrast to Schumpeterian rent generated by innovation, is a consequence of policies implemented to promote learning and innovation.

Amsden (1989) contended that the process of learning necessitates more than substantial innovation. Learning encompasses not only the acquisition of technological skills, but also the ability to adapt to the social, political, economic, and institutional conditions of the recipient country. Policy-induced conditional subsidies can expedite technological learning and generate rent for learning. The primary distinction between rent for learning through subsidy and simple subsidy transfer lies in the fact that subsidy for learning is contingent upon achieving educational goals within a designated timeframe, whereas simple subsidy transfer may be driven by other political and economic motivations.

Regulatory capture is an economic theory that posits that regulatory agencies enact regulations not motivated by the public interest, but rather to facilitate rent-seeking opportunities for the prevailing interest groups in society. The term was initially coined in the 1970s by Stigler. Stigler (1971) argued that governments do not inadvertently establish monopolies in industries. Instead, they intentionally safeguard the interests of producers who gain control over the regulatory agency, and employ regulations to restricts competition. Selective bidding to give monopoly power to certain private firms, justified under the guise of liberalization and competition, frequently lead to the transfer of public resources to private producers through increased prices, resulting in excessively high social costs. (Sultana 2023)

Economic rent is distinct from political rent due to the nature of the reward. Economic rent refers to the income derived from the use of a resource that provides tangible economic advantages. Political rents refer to rents that do not provide tangible advantages, but rather fulfill non-essential desires of political players, such as getting vote or gaining political status.

Sekowski (2021) made a distinction between political rent and economic rent in another way. Sekowski distinguished between the two rents by focusing on the function of the state. He clarified that not all sources of rents seeking opportunities are mistakenly provided by natural monopolies, but rather purposely created by rent seekers. Sekowski argues that economic rents arise as a result of specific economic conditions, such as a monopolistic market structure, particularly in the case of natural monopolies. Political rent necessitates government intervention in the economy to enable rent seekers to pursue it. Sekowski employed both definitions in his research of the advantages and disadvantages of rent seeking.

Tollison and Wagner (1991) Contended that monopolists and individuals receiving transfers will allocate resources to oppose any economic reform that jeopardizes their rent-seeking activities, with the aim of safeguarding their benefits. This is comparable to expenses for rent protection. Furthermore, these expenses do not necessarily undermine political reform proposals; instead, they undermine the practical justification for reform. In this particular instance, the rent seeker is not required to obtain a monopoly, but rather to safeguard the monopolistic power it has already obtained. It is advantageous for a monopolist in power to thwart a reformer who prioritizes the overall welfare by investing a sufficient amount of its profits from the monopoly to render the reform economically unviable.

Academics have categorized the expenses associated with lobbying, bribery, and commissions as the cost of rent seeking. However, they have not yet made a distinction between the cost of managing people's resistance and other costs related to rent seeking. I used the term "resistance management cost" or “resistance capture” to refer to one of the expenses incurred to protect rental income. (Sultana 2023) While it may not be feasible to accurately quantify the cost of resistance management, it is reasonable to conceptually describe it as a social cost. The social cost of failing to meet the demands of the community can be described as the expenditure on managing resistance that does not contribute to any productive activity but instead enables specific interest groups to acquire resources. The act of suppressing social movements and manipulating communities in order to generate consent through various methods was referred to as "resistance capture". Rent seeking opportunities vary across energy technologies.

2.3.2 Energy geopolitics

2.3.2.1 Energy security: stability versus instability

The study of the geopolitics of energy transition is going through a major transformation as a result of global shift of energy sources. According to Goldthau (2020) there may be two consequences of this shift. The ongoing energy transition has the potential to enhance the energy security of nations that now rely on oil and natural gas imports. These countries can take advantage of the industrial opportunities arising from this development. Conversely, the geopolitics could lead to instability in the nations that rely on exporting oil and gas. These countries may need to adapt and evolve in order to continue developing in the changing energy landscape. Additionally, there may be new security issues associated with power grids and mineral resources.

2.3.2.2 Energy trade: expansion versus reduction

The global energy transition is vulnerable to the complex trade patterns that currently dominate the global energy and electricity sectors. One crucial inquiry is whether there would be an escalation or reduction in global energy trade. The underlying premise of this debate is that the worldwide shift towards renewable energy allows each country to generate renewable energy, albeit with varying levels of efficiency and cost. According to Scholten (2018), as a result of renewable energy adoption, countries would increase their self-sufficiency and global energy trade will decline. This might provide an advantage to importing countries because they can reduce the burden of energy import bill. An alternative perspective argues that trade volumes in the energy sector will remain stable or potentially rise (Schmidt et al. 2019). The advancement of technology in renewable fuels and Power-to-X is being recognized as a key factor in facilitating international trade in renewable energy. Varying production conditions and acceptance levels in different nations result in price disparities, which in turn stimulate international trade. Gas pipelines, which are part of fossil fuel infrastructure, might potentially be repurposed for hydrogen trading. Implementing this strategy could mitigate the potential for investments to become unprofitable and so protect against potential financial losses associated with decarbonization (Schmidt et al. 2019). The outcome of several scenarios will have a significant effect on the relationships between countries that import energy, countries that serve as transit points, and countries that export energy. Countries in the Global South will need to strategically realign themselves in response to the growing energy trade dynamics.

2.3.2.3 Geopolitics of energy: from oil to natural gas, LNG, nuclear, and solar

Oil has been the fundamental basis of global energy geopolitics since World War I. The transition from the dependable coal supplies to the oil supplies from oil-rich Middle East made Middle East a crucial hub of global geopolitics. Oil also became significant national security concern since then. Oil resources have been a key factor in numerous wars since the beginning of the twentieth century. Examples of such conflicts include the Biafran War from 1967 to 1970, the Iran-Iraq War from 1980 to 1988, the Gulf War from 1990 to 1991, the Iraq War from 2003 to 2011, and the ongoing struggle in the Niger Delta since 2004. In the latter part of the twentieth century, there was a notable rise in tensions between nations that produced oil and those that used it. These tensions led to two significant oil crises in 1970s and 1980s.

However, energy geopolitics now extends beyond the realm of oil. Natural gas, nuclear energy, and even renewable energy sources like wind and solar have geopolitical implications, which can range from moderately significant to highly significant. Now, Natural gas is regarded as having greater geopolitical significance than oil in specific regions of the world. In Europe, natural gas markets have been established since the 1960s by building extensive pipeline networks that connect major producers like Russia and Norway to consumers in the region. Europe's dependence on a small number of key suppliers has increased as a result of this circumstance. Indeed, natural gas imports from Russia continue to account for one-third of Europe's overall natural gas supply. For many years, this condition has not caused any concerns regarding energy security in Europe. In the 1970s and 1980s, amidst the Cold War, Europe actively pushed the construction of extensive pipes to connect the vast Siberian natural gas deposits with Europe. These pipelines, which continue to serve as the primary routes for Russian natural gas export, were strategically significant. Europe undertook these projects despite the Reagan Administration's vehement resistance, which even imposed sanctions on German and French corporations involved in the construction of the 'Brotherhood' pipeline. (Scholten 2018) This pipeline remains the primary route for supplying natural gas to Europe.

The excessive dependence on Russian natural gas supplies began to be viewed as a significant geopolitical menace in Europe when, initially in January 2006 and subsequently in January 2009, a pricing dispute over natural gas between Russia and Ukraine resulted in the suspension of Russian natural gas deliveries to Europe through Ukraine, which serves as its main transit route. Some scholars argued that Russia used its natural gas a weapon for war, by creating demand for Russian natural gas.

After Ukraine war has started in 2022 Europe countered these natural gas crises by implementing an energy security strategy primarily centered on diminishing its reliance on Russian natural gas provision. (Bollfrass 2022) They planned to increase dependency on LNG, renewable, and nuclear. The shale gas revolution, combined with the expansion of liquefied natural gas (LNG) export capabilities in nations like the US, Qatar, and Australia, has already led to a surplus of gas worldwide. This surplus has bolstered the position of natural gas as a formidable rival to oil.

Geopolitical conflict already exists between the United States and Russia regarding the expansion of the nuclear business. If Russia surpasses the United States governments as a primary exporter of nuclear power, it has the potential to increase its group of client governments in the developing world, so diminishing the diplomatic influence of the United States. If countries globally compete to safeguard emerging industries in order to secure a portion of the expanding clean energy economy, there is a risk that the international trade system, which has contributed to America's success after World War II, may collapse.

2.3.2.4 Three conceptual frameworks for geopolitics in global south

There are currently three distinct conceptual frameworks that deal with the energy geopolitics of global south. 1) Realist International Political Economy (IPE), 2) Critical IPE, and 3) Dependency Theory, to analyze and understand the current dynamics surrounding the low-carbon transition and its implications for the Global South. Each of these represents a particular aspect in ongoing policy discussions on the global energy transition, and provides a unique perspective on the technology, finance, and trade within that framework.

2.3.2.4.1 Realist international political economy

Realist International Political Economy (IPE) is based on a state-centered perspective on International Political Economy (Gilpin 1987) Realist PE strongly connects economics and high politics by asserting that state interests play a crucial role in shaping and governing international economic relations. States endeavor to achieve economic security, a goal that is regarded as being on par with military security. Realist International Political Economy (IPE) perceives economics as a means of acquiring power and dominance, leading to a mercantilist approach in the global political economy (Hamilton 1791). A crucial factor to consider is the trade balance, which economic nationalists often perceive as a measure of a country's comparative strength or vulnerability in relation to competitors in the global arena.

From this perspective, the type of fuel being imported, whether it is derived from fossil or green sources, does not significantly impact the trade balance as both contribute to its deterioration. It is possible that states would attempt to restrict imports of renewable energy, not due to climate denial, but because it is not deemed to be in the national interest. Global markets will have little growth despite the potential for technical advancements to drive expansion.

From a realist perspective in International Political Economy (IPE), it cannot be expected that low-carbon solutions will spread worldwide due to the influence of free market dynamics, strong demand, and decreasing costs per unit. Instead, its availability may rely on whether it aligns with the geopolitical interests of the states that developed these technologies, as well as the established authorities in the receiving countries.

2.3.2.4.2 Critical realist international political economy

Critical International Political Economy (IPE) offers valuable perspectives on the dynamics between the state, markets, and society, focusing on the fundamental power structures at play. The framework aligns with Karl Polanyi’s (1957) concept of a 'Great Transformation' in which Polanyi proposed that the market system is reliant on government intervention. His assertion that "laissez-faire was planned" suggests that laissez-faire is intricately intertwined with the management of the market economy. The critical realist approach recognizes that the worldwide shift towards alternative energy sources is expected to not only impact interstate relations and international trade as previously said, but also significantly alter the socioeconomic framework. Polanyi recognizes that marketization and social protection against marketization causes great transformation in a dialectical process. Unlike state-centered view of realists, critical realists view role of state, market, and society evolving and shaping the geopolitics of interstate relations and international trade.

The extensive decarbonization required by the Paris Agreement will likely result in significant and transformative change. According to Newell (2019a) an analysis rooted in critical Global Political Economy (GPE) provides insights into the historical and current connections between changes happening in various regions of the world. These changes reflect the unequal distribution of power in the international system and help to position a state within the global political economy. The critical GPE scholarship that is highly useful in this pursuit focuses on the essence of neo-liberalism and the spatial and temporal strategies frequently utilized by influential states to evade domestic reorganization (Harvey 2003).

Newell (2019b) states that the literature on socio-technical transitions continues to neglect questions of politics and power beyond specific management strategies and governance practices. He developed an account that examines the fundamental questions of who, how, and for whom production is organized and reorganized in a specific historical period. This account also explores the power dynamics that support this organization and the potential implications for current endeavors to shift to a new production system, along with its associated political consequences. The account is formed on the basis of Neo-Gramscian scholarship, particularly (Cox,1987; Gill,1993; Rupert, 1995), that focuses on the interplay between production, power, and world order. It emphasizes the significance of historic blocs in maintaining specific energy orders and recognizes the potential for transformative changes both within and outside of these blocs.

According to Newell (2019a) critical IPE can help us comprehend the role of the state in global energy transitions. There is clearly unequal power, capability, and inclination among states to take on the roles assigned to them in transition plans, their own NDCs (Nationally Determined Contributions) submitted to climate negotiations, and global sustainability strategies such as the SDGs. This is a function of capacity (political and economic) as well as willingness to participate in transition processes, given the close ties that frequently exist with incumbent economic interests that are threatened by interventions that jeopardize their ability to maximize profits from their current control over production, technology, and finance. In many cases, incumbent players have the ability to influence the terms and pace of transition by limiting access to new market entrants.

In explaining why states are so sensitive to such pressures, Newell (2019a) referred to Cox's reflections on the internationalization of the state whereby, 'adjustment to global competitiveness is the new categorical imperative'(Cox,1993: 260). According to Cox (1993) emerging societies forms around the interstate system, and states become internationalized as their mechanisms and policies adapt to the rhythms of the global order. During nonhegemonic periods of world order, these trends are reversed. The state is increasingly central to social classes and production structure. States pursue and safeguard the interests of certain national social groups and industrial organizations, employing all available political, economic, and military methods as needed.

Swilling & Annecke (2012) emphasizes competition between different fractions of capital and their reliance on specific types of energy for the success of their accumulation strategies, the central role of labor in struggles over control of the means of production, and the proposed beneficiaries of a "just transition" to a lower carbon economy. In the process of transition, understanding this transfer in power is critical for understanding how changes in the global economic 'landscape' affect national energy transition policies. The ways in which countries' freedom of maneuver to select energy pathways may be limited by the disciplinary power of donors or international agencies. (Newell & Phillips, 2016).

2.3.2.4.3 Dependency theory

Dependency theory (Prebisch 1950, Singer 2012) suggests that a country's economic development potential is influenced by its place in a global system's economic structure. From the perspective of energy transitions in the Global South the distinction between core and periphery is an important analytical category in this system. According to dependency theorists, some nations in the Global South may struggle to keep up with technological growth due to their peripheral status. While the core exports advanced products the periphery provides raw materials and natural resources in exchange. According to the Prebisch-Singer effect (Prebisch 1950; Vernengo 2016), primary commodity exporters' terms of trade decline as global affluence rises and relative demand for resources decreases (Engel's law). The abundance of rare earth minerals in the Global South may not lead to a competitive advantage over developed countries. The pattern indicates they will remain in a state of underdevelopment.

Countries in Africa and Latin America have historically exported oil, gas, and rare earth elements, which are essential for renewable energy and electric vehicles. (Goldthau et al 2020) Following the trend dependency school expects that the OECD and China may lead the export of renewable technologies, allied products, and services due to their innovative leadership. The pattern here shows the theory's structural assumptions on the international division of labor between center and periphery countries, which perpetuates dependent relationships. According to Vernengo (2016), while foreign cash can facilitate technological transfer, innovation remains concentrated in the center. The concentration of renewable technology patents in the global energy transition suggests that the established OECD 'core' in the global economic system will continue to exist alongside the growth of new core countries, particularly China.

2.3.3 Policy diffusion

2.3.3.1 State-centric and state-structural approach:

While governments often create and implement energy policies on behalf of nation states, there is ongoing dispute on whether the state should be considered the primary analytical unit in policy studies. Hall (1993) categorized theories of state into two main categories: state-centric and state-structural. State-centric models argue that states are independent entities that pursue their own national interests or prioritize objectives such as maintaining internal stability, external sovereignty, and economic development. The state-centric approach suggests that energy policies are driven by national interests. These interests include achieving a stable balance between energy supply and demand, reducing dependence on energy imports, increasing energy exports, ensuring reliable access to electricity, promoting industrial competitiveness, and boosting employment opportunities.

State-structural views believe that the actions of governments bring together and harmonize the conflicting interests of different players, such as voters, political parties, social movements, and industrial lobbies. This area of research examines the "politics of energy policies" as studied by some scholars (Jacobson and Lauber 2006, Stokes and Breetz 2018).

2.3.3.2 International harmonization

Harmonization refers to a specific result of international cooperation, specifically constellations in which national governments are legally compelled to adopt comparable policies and programs as part of their commitments as members of international organizations. International harmonization, and more broadly, international cooperation, presuppose the existence of interdependencies or externalities that force governments to solve common problems through cooperation within international institutions, sacrificing some independence for the good of the community (Drezner 2003, 2005; Hoberg 2001). For example, the common goal of reducing carbon emissions may drive governments to implement renewable-friendly laws. Countries may be motivated to embrace a particular policy for more than just intellectual reasons or a desire for uniformity. They may also be pushed to do so by legitimacy pressures resulting from the promotion of policy models by international organizations. It is motivated by the active engagement of international institutions in supporting the spread of unique policy approaches that they believe are particularly promising. (Holzinger, 2005).

Developing and developed countries may react differently to the obligation or legitimacy requirements. For example, affluent countries that contribute the most to carbon emissions are under more pressure to decarbonize through renewable expansion, but developing countries with a long colonial history of exploitation place a greater emphasis on financial support to decarbonize through renewable energy.

2.3.3.3 Coercion

Dobbin (2007), along with other important policy diffusion explanations, highlighted coercion as one of the processes of policy spread. Governments, international organizations, and nonprofit entities can use physical force, manipulate economic costs and rewards, or even monopolize knowledge or expertise to impose coercion. Thus, the preferences of the United States government, the European Union (EU), the International Monetary Fund (IMF), and the World Bank may influence energy policy in countries that rely on those institutions for trade, foreign direct investment, aid, grants, loans, or security. (Dobbin 2007.)

For example, these institutions may directly participate in the policymaking process and provide funds to only those areas in which they believe investment is essential. In the instance of Bangladesh, where the World Bank, IMF, and ADB have played an active role in power sector reform measures, they have consistently recommended the elimination of power sector subsidies. In numerous cases, the IMF has explicitly said that electricity and gas prices must be raised in order to recover costs. These institutions have resisted subsidies in general, including feed-in tariffs in renewables. Unlike Bangladesh, Germany was never held accountable to any of these bodies for its domestic measures to encourage renewables.

2.3.3.4 Interventionist policy

The international political economy of energy has multiple layers, ranging from global to regional to national. With the evolving power dynamic between energy users and producers, interventionist policies are redefining global energy relations. International relations scholars would describe this tendency as more realist, in the sense that: state-centered approaches to energy supply have replaced market-based approaches as the dominant paradigm for most producers; governments have put their hands back on resource ownership and access, and many exercise more direct forms of control than at the height of the liberal era; and many states openly use oil and gas to achieve other foreign policy goals (or (Goldthau 2015).

This particular method of policy dispersion may be significant in the case of China and Russia. For example, China aims to extend its coal and renewable energy investments abroad by tying their interests to foreign policy goals and occasionally imposing limits on access to energy markets in developing nations. It has to be seen how robust or weak this interventionist mechanism of policy transmission is in comparison to other mechanisms. Developed countries are less vulnerable to such interventionist measures due to their ability to withstand prospective interventions.

2.3.3.5 Hegemonic ideas

The weakest, but possibly most pervasive, kind of policy diffusion is based on hegemonic ideas. The Gramscian concept of hegemony refers to a group or class's dominance over social life through cultural methods (Femia 1983). Dominant actors can exert influence through ideational channels without using physical force or changing costs or rewards. The focus is that prevailing beliefs are justified, often with attractive theoretical arguments, and affect how policymakers understand issues and prioritize alternative remedies. (Dobbin, 2007.) Social acceptance of a policy approach can occur in three ways: (a) leading countries serve as exemplars (follow-the-leader); (b) expert groups theorize the effects of a new policy, providing policymakers with rationales for implementing it; or (c) specialists make contingent arguments about a policy's appropriateness, defining it as right under certain conditions.

Expert advice allows international assistance agencies and financial institutions to influence developing countries' power and energy policies. These institutions can prescribe their preferred policies to developing countries by participating in policy development and supporting the creation of master plans. Kahler (1994) observes that international financial organizations use learning to justify their policy preferences. Indeed, the IMF sees its research job as a means of disseminating the lessons of earlier liberalizers (typically wealthy countries) to the rest of the globe, especially emerging countries (Quirk 1994). In many examples, international organizations, whether as agents or as sets of norms that improve transparency, appear to have had a significant impact on information flows and policy transmission. In the case of Bangladesh, JICA's (Japanese Agency for International Co-operation) preparation of the Power Sector Master Plan, which proposes increasing coal from less than 1% to 35% by 2041 while not emphasizing the role of renewables by 2041, demonstrates how they conceptualized the problems and used elegant theoretical justification for their prescribed solution. It is difficult to conceive a Japanese agency creating a master plan for a developed country like Germany.

2.4 Energy market regulations

2.4.1 Price setting under liberalized market

One of the basic differences between advanced and emerging nations is the differences in price-setting mechanism, which may stem from varying levels of competition in the electricity sector. The level of competitiveness is crucial in explaining price-setting mechanisms because it influences the involvement of actors, institutions, and market forces in price determination. Even after several reforms have been implemented, the issue of investment and profitability remains crucial in emerging countries. Whether pricing mechanisms in developing nations are an impediment to attracting investment is still an open question. We still don't have any sufficient explanation of why, in the absence of investment subsidies and cost-reflective pricing, some investors continue to invest in renewables while others do not. To address this conundrum, we must first have a thorough grasp of the price-setting mechanisms and how profitability is tied to investment.

There are considerable disparities between the aims that motivated liberalization and the types of reforms implemented in rich and developing nations. Advanced industrial economies have developed commercial law and institutions to the point where private ownership of natural monopolies could be managed to benefit consumers while safeguarding the owners' ability to fund investment. In contrast, when electricity reforms were implemented, developing and transition economies lacked examples to assist the construction of regulatory structures. Thus, adopting appropriate regulations has proven to be one of the most difficult components of the restructuring process in developing countries. (Kelsides, 2004). The power sector in underdeveloped nations has partially embraced some of the initial steps of the conventional reform model, whereas most industrialized countries have progressed power sector reform by boosting the sector's competitiveness. As a result, the reforms fell into two categories: hybrid reform[1] and standard model of reform or textbook[2] reform.

According to Urpemanien et al. (2019), the dominance of the hybrid over the traditional reform model is driven by relatively impoverished nations, authoritarian regimes, and governments with little institutional ability. When they examined the patterns of power sector reform by income group, regime type, and institutional capacity, they discovered significant success in textbook reforms in middle-income, democratic, and high-capacity countries. According to their findings, hybrid power markets are most likely to emerge in impoverished, autocratic, and low-capacity countries. The World Bank's textbook model has gradually been embraced by moderately wealthy countries with strong institutional capability. For example, wholesale level policy is not a top priority for electricity sector changes in Least Developed Countries (LDC). (Teplitz-Sembitzky, 1990, page 81)

This means that while renewable deployment is in its early stages and scaling up, market forces have a greater impact on price determination in rich countries than in developing countries. According to Grubb (2014), prices have the most distributional impact of any instrument, and therefore provoke strong resistance. According to Nepal (2012), a more serious issue with power sector reforms in developing countries is that there is often strong opposition to them compared to developed countries, and even when reforms are implemented, political processes and institutions in developing countries frequently adapt to counter the effect of reforms in various ways.

Bashmakov (2007) investigated how the price-setting mechanism evolved over time to accommodate expanding tendencies of privatization and gradual reform in the electricity and

[1] "Hybrid" power markets consist of corporatized, state-owned electric utilities and regulatory bodies, as well as independent power providers. This change was intended to reduce inefficiencies in financial management and technical delivery. As a result, tariffs were frequently raised to levels sufficient to generate income. Reform initiatives also aimed to create a space for private participation, as the state sector could no longer supply the necessary money for system expansion (Jamasb, 2002, pp. 1-2).

[2] The term "textbook" reform refers to reforming power systems through corporatization, commercialization, increasing private/foreign participation/ownership, establishing an independent regulator, allowing independent power producers, divesting generation and distribution assets, and introducing wholesale and retail markets. This standard reform model was begun to promote economic efficiency, particularly in terms of power prices, resulting in tariff reductions. (Gratwick and Eberhard, 2008).

energy sectors. This helps us comprehend the price setting mechanism throughout the current phase of the energy transition. Bashmakov (2007) identifies three broad energy transition laws: the law of constant long-term energy expenses to income ratio, the rule of improving energy quality, and the law of increasing energy productivity. Among these three laws, I shall concentrate on the first one. According to this rule, the existence of energy affordability thresholds and behavioral constants leads to the stability of the energy cost-to-income ratio. When the energy cost-to-income ratio falls below the threshold, there is no relationship between the burden of energy expenses, energy efficiency, and activity levels. However, when this threshold is exceeded, economic activity slows; energy productivity increases; and energy demand slows or drops until the ratio returns to the sustainable range.

Bashmakov's long-term energy cost-to-income ratio threshold hypothesis can help to understand why suppliers choose to invest, particularly in emerging countries. As the amount of new energy (i.e. renewables) increases in developing countries, the government may find it costly to provide subsidies for an extended period of time while keeping prices affordable. If the energy cost-to-income ratio skyrockets as a result of increased energy deployment, the load on consumers will be politically unsustainable. At the same time, the risk to suppliers will be too high for investment. Thus, for developing countries, the energy cost to income ratio may be an important/useful determinant of energy transition.

$(\text{Energy cost/GDP})_{\text{Transition}} < (\text{EnergyCost/GDP})_{\text{Threshhold}}$ --- > transition is economically rational but may not be politically feasible[3].

$(\text{Energy cost/GDP})_{\text{Transition}} > (\text{EnergyCost/GDP})_{\text{Threshhold}}$ --- > transition is NOT economically rational and hence NOT politically feasible.

Grubb, Hourcade, and Neuhoff (2014) developed the notion of the 'Three Domains' framework, in which they recognized three domains: (i) the satisficing domain, which corresponds to cheap prices, significant dominance of behavioral effects, and so on; (ii) the markets domain; and (iii) the transforming domain. According to classical theory, relying

[3]Political feasibility: Being economically rational does not ensure that the power system is politically feasible. The reasons are (i) High GDP are not necessarily accompanied by sufficient purchasing power because of the persistent inequality in income. (ii) Very expensive energy transition may occur at the expense of cross subsidy and high price burden on the consumers, which may not be reflected in the energy cost. (iii) Environmental pollutions from fossil fuel-based power generation, gradual loss of biodiversity, and displacement could be very costly and its long-term political impact cannot be measured.

solely on price is the preferred instrument since it maximizes market transaction efficiency. However, it assumes criteria that are not met in the first or third domains, and political impediments have significantly slowed the introduction of price controls.

To demonstrate the distinctions stated above, consider Germany and Bangladesh. Germany's renewable energy contribution of total electricity output has risen from 7% in 2000 to 35% by 2019. Germans pay the highest electricity rates. The EEG (Renewable Energy Act) fee accounts for approximately 23% of consumers' final bills, making it the most significant and symbolic investment under Germany's Energiewende goal to shift to renewables. From 2014-2018), the Energiewende has cost Germany €32 billion ($36 billion) per year. Comparing this position to that of developing countries such as Bangladesh, raising prices comes with very high social cost. The government's continued provision of subsidies for an extended length of time is also not a viable answer. As Germany's renewable energy share expanded, more subsidies were required, forcing customers and the government to spend even more money to expand renewable energy. The German government has set feed-in prices for 20 years, which are supported by consumers and businesses through electricity surcharges. However, after 16 years of operation and a burgeoning renewables industry, it was determined that the program needed to be reformed to decrease costs.

Under the newly amended law of 2017, 80% of renewable installations must bid for government subsidies rather than receiving them automatically. Under this new reform, producers' contracts are now being awarded through auctions. Fair auctioning is intended to improve competition among providers while lowering prices in Germany's open power market. Germany's efforts to make the renewable sector more competitive cannot be simply copied in developing nations such as Bangladesh, which has implemented a mixed reform model. Furthermore, Bangladesh relies on external resources for renewable energy investment rather than national funds. This implies that the funding mechanism is inextricably related to the price-setting system. Wholesale level competitiveness has not been a priority for developing countries since the outset. In emerging countries, increasing competition and keeping prices low for customers' benefit still necessitates government actions.

2.4.2 Pricing policy design: feed-in-tariff versus net metering

The pricing policies of solar electricity have evolved significantly with the introduction of distributive energy resources like solar. Initially, high costs necessitated government intervention to encourage producers and make solar energy available to consumers at a subsidized price (Gautier, 2019). However, as prices declined globally, with China becoming major player in solar panel manufacturing, competitive pricing policies are being adopted gradually (Li, 2020). The presumed underlying cause is higher retail prices encourage the deployment of decentralized production units under net metering systems. (Gautier, 2019). Solar power has been expected to become more economically attractive despite technological uncertainty and regulatory challenges. (Lorenz 2008) Despite these changes, scholars (Kihlström, 2021, Karakaya, 2015) thinks that market barriers are still there and solar energy is still not competitive and there is a need for government interventions. These barriers include high upfront costs, unfamiliarity with the technology, and regulatory and market barriers.

Feed-in tariffs have spurred significant deployment of solar photovoltaics in Germany and later in other countries. (Yuliya 2017) Following Germany many countries have started to adopt feed-in-tariff scheme. Government intervention, particularly in the form of feed-in tariffs, has been crucial in driving the rapid growth of solar rooftop installations in developing countries like Vietnam and Thailand (Le et al 2022, Do et al 2020, Tantisattayakul 2017). After the rapid growth of solar in Vietnam, the question has revived, whether government intervention is still required to subsidize pricing in developing nations, or whether the high market price of electricity as a result of liberalization will inevitably make solar rooftop investment profitable enough to encourage investment.
In this section of the literature review I distinguish between the concept of market-based pricing policy and interventionist pricing policy. I introduce the concept of feed-in-tariff scheme and net metering.

2.4.2.1 Feed-in-tariff

Feed-in tariffs (FIT) are a policy tool used to promote the use of specific products or services, particularly in the energy market, by providing a government set payment for electricity generated from renewable sources (Chalvatzis, 2011). These tariffs are evaluated and optimized based on their payoff structure, which directly impacts the net present value of the investment, and other relevant parameters (Kim, 2012). A feed-in tariff (FIT) is used to encourage the development of new renewable energy projects by providing long-term purchase agreements for the sale of renewable electricity. These purchase agreements are typically offered in 10- to 25-year contracts and are renewed for each kilowatt-hour of electricity produced. Payment levels for each kilowatt-hour can be differentiated based on technology type, project size, resource quality, and project location to better reflect actual project costs. Policymakers might also reduce payment amounts for installations in later years, thereby tracking and encouraging technical advancement. In an alternative way, FIT payments might be provided as a premium, or bonus, above the current market price. (Klobasa 2013)

Feed-in-tariff pricing is effective in promoting solar when the government-set price is above the existing market price of electricity. When feed-in-tariff is offered to producers at a price higher than the cost, it provides incentive to the producers because the producers can earn from the higher difference between future falling cost of solar and the guaranteed price offered for a long period of time. This is an interventionist policy because government set the feed-in tariff rate to provide incentive to the producers.

2.4.2.2 Net metering policy

The concept of net metering, which allows customers to offset their electricity consumption with excess energy they generate, is a key component of smart grid systems. However, the impact of net metering on the cost competitiveness of residential solar PV systems is a subject of debate, with some arguing that it provides a subsidy for these installations (Comello, 2016). Christoforidis (2016) explored the effectiveness of different net metering policies in terms of profitability for the prosumer, with a proposed methodology for assessment. These studies highlight the complexity of net metering pricing policies and the need for further research to optimize their effectiveness.

When the per unit market price of electricity is higher than the cost of per unit solar electricity and net metering allows the producers to supply surplus electricity to the grid and adjust quantity consumed by net metering, there is no need for the government subsidy in the market because the estimated cost of per unit solar electricity is already lower than the market price. In this situation net metering can be categorized as the market-based pricing which is profit generating and at the same time competitive by itself. For example, the levelized cost of energy (LCOE) from rooftop solar is Bangladeshi Taka 5/kilowatt hour (kWh) or (US$0.046/kWh), compared to power tariffs of Tk9.9/kWh (US$0.09/kWh) and Tk10.55 (US$0.096/kWh) for industrial and commercial buildings, respectively. These tariffs are not only appealing to industrial and commercial buildings looking to install rooftop solar systems, but they are also lower than the rates that resulted in 9 gigawatts (GW) of such capacity increase in Vietnam in 2020. (Alam 2023) However, this does not ensure that this high difference between market price and cost signals profitability if unforeseen costs are not included in cost estimation.

2.5 Path dependence and lock-in

2.5.1 Path dependence and lock-in: theory and causal process

The key idea behind path dependence is that in a sequence of events, the subsequent events are dependent on the previous ones. The concept of path dependence has been used in economics, social science, technology studies, sociology, environmental and innovation studies to explain technological and institutional lock-in. As a result, there is a variety of ways events can be defined as a source of path dependence. The economics literature on path dependency highlights the significance of previous events in forecasting future technological trajectories. (David 1985, Arthur 1994). The degree to which each aspect contributes to lock-in is contingent upon the particular trajectory being examined. For instance, eco-innovations do not adhere to a singular path and are contingent upon the context.

Thelen (2003) argues that the concept of path-dependence, as proposed by economic theory, is appealing to other social sciences because it recognizes that social life involves making choices, such as selecting a preferred technology for economics. However, once a particular path is chosen and relevant actors adapt their strategies accordingly, other feasible alternatives become progressively less likely. The concept of path-dependence is intriguing since it prompts inquiries about the chronological connection between structure and activity within a social order.

Bennet et al. (2006) came up with a systematic identification of causal process through which path dependence and lock-in occurs. Observing the variations among political scientists regarding interpretation of path dependence they identified four fundamental components that are present in most explanations: causal possibility, contingency, closure, and constraint. Firstly, the concept of *causal possibility* implies that there could have been other alternative paths that could have been chosen. Second, *contingency* suggests that the causal narrative is altered by an unpredictable or unconsidered element. There should be a contingent factor that disrupts the cause-and-effect relation: one or more of the factors that shape the course of events should be random or external to the main theory of interest. Third, *closure* implies that due to this influence, certain causal pathways become less feasible or completely unattainable. As a consequence, certain causal paths increase in likelihood while others decrease. Ultimately, after choosing a course, it is necessary to establish some limitations and mechanisms that ensure participants stay on that road. The *constraints* imply that the actors are bound to the chosen course of action and would incur significant expenses if they deviate from this path after it has been defined.

Goldstein et al. (2023) used the example of green revolution to demonstrate that the factors contributing to the persistence of chemical input intensive monoculture include technological advancements, political influence, changes in regulations, and market motivations. This is supported by previous scholars (Fairbairn 2020, Goldstein and Yates 2017). Goldstein et al. highlighted that lock-in is a potent analytical instrument for retrospectively detecting significant turning points. They used the concept of critical juncture, which refers to a sudden and impactful occurrence that leads to large changes. However, it may not provide strong evidence to help us predict future outcomes because many systems are vulnerable to unexpected shocks and disruptions.

2.5.2 Carbon lock-in

The concept of "carbon lock-in," as proposed by Unruh in 2000, suggests that industrialized nations have been trapped in energy systems that rely heavily on fossil fuels. This is due to a path-dependent process driven by the benefits of economies of scale. Carbon lock-in occurs when there is a simultaneous development and interaction of technological, organizational, social, and institutional factors, resulting in the establishment of a techno-institutional complex (TIC). Unruh (2002) proposed that in order to solve the climate crisis, we must break free from the lock-in situation. However, escaping circumstances are unlikely to be developed internally, and outside pressures are likely necessary. Trencher et al (2020) demonstrates that carbon lock-in can emerge from an intricate interaction of several causes. The intricate nature of carbon lock-in highlights the challenge of overcoming it, since it may not be enough to modify just one or a few components. However, by reversing this logic, the significance of several elements indicates various possibilities for implementing intervention actions to disrupt the state of being locked in.

2.5.3 Institutional lock-in

Seto et al (2016) categorized carbon lock-in into three primary forms: (a) infrastructural and technological, (b) institutional, and (c) behavioral. They also explained how these types coevolve. While each form of lock-in has its distinct procedures, all three are closely interconnected and collectively contribute to the persistence of carbon emissions.

According to Mahoney (2000) path dependence characterizes the historical processes in which contingent events set into action institutional patterns or event chains with deterministic features. To identify path dependence, it is necessary to trace a given outcome back to a specific collection of historical events and demonstrate that these events are contingent and cannot be explained by past historical conditions.

Trencher et al (2020) used an analytical framework in which socio-technical lock-in is described as an inertia resulting from co-evolution of socio-technical systems, material, human, and non-material components and the components reinforcing each other. Socio-technical lock-in occurs when system stability is achieved by interlinkages or feedbacks, preventing the incorporation of better technologies and configurations. The socio-technical ‘regimes’ of incumbent actors and locked-in institutions play a vital role in determining lock-in by reproducing or sustaining material and non-material system features. Thus, this insight is integrated into the framework's conceptual basis.

2.5.4 Types of path dependence

Liebowitz and Margolis (1990) identified path dependence. The first-degree of path dependence occurs when the selected solution and alternative solution continue to be equivalent in terms of payoff. That is, there is no gain for a society to switch from one convention to another. It could be the result of imperfect information or there is no immediate gain from choosing any efficient solution.

Liebowitz and Margolis (1990) described second-degree path dependence as the choice of technology or institutions that become outdated or inefficient in comparison to more modern technologies or superior institutions. If the agents' unwillingness to deploy superior technologies, either owing to the difficulties required or because they did not predict their potential for improvement, led to the selection of inefficient options, then it is more advantageous to choose the inefficient option. During the second-degree, the cost of converting outweighs the incremental benefits of adopting the new technology.

Liebowitz and Margolis (1990) classified institutional lock-in as a "third-degree of path dependency" when the act of replacing a current institution with a better one could result in costs that exceed the anticipated benefits of the superior institution. If the expenses associated with transitioning to a higher institution are not justified, it would be efficient for an inferior institution to persist. In order to demonstrate the inefficiency of institutions, it is necessary to propose the following thesis: Although the predicted benefit of the superior institution outweighs the switching cost, agents nonetheless resist adopting it due to the strong influence of historical inertia or path dependence.

Herbert Simon’s notion of “procedural rationality” tried to explain what justifies third-degree of path-dependence which causes inefficient institutions persist. For Simon, agents persistently employ the same habits or heuristics regardless of changing circumstances. The concept of third-degree path dependency posits that agents initially do not select institutions based on their efficiency. They tend to accept the status quo out of inertia. They question the default habits only when a crisis or shock renders those habits unworkable.

Sovacool (2016) argued that although there is increasing agreement among different levels of society, organizations, and the general public that locked-in situations are not ideal, there are instances where proactive state planning, with the participation of important stakeholders, has effectively addressed specific events (such as scarcity, accidents, environmental disasters, and global crises) by unexpectedly disrupting established technologies, infrastructures, and practices.

2.5.5 Randomness of source of path dependence

Bassanini and Dosi (2001) distinguish between actions of different degrees of randomness. And Brenner et al (2024) distinguish three kinds of randomness in actions, which they think occur simultaneously in large systems.

Random actions: Brenner et al (2024) pointed out that certain actions are performed inadvertently, without deliberation, or as a result of a choice made without any preference between alternatives. At times, humans exhibit apathy or lack the ability to foresee the result, and thus make a decision based on random chance. Although these judgments can be retrospectively justified, but the authors categorize them as arbitrary acts and presume that they occur to some degree in all systems on a regular basis.

Intentionally deviating actions: Certain activities may appear unexpected to an observer as they deviate from the anticipated or probable course of action, yet they are deliberately chosen.

Random change of external circumstances: Changes in external circumstances can modify the system's processes, actions, and dynamics, making them a third source of randomness in the system's development. In essence, they originate from external sources. For example, random changes from natural disasters, or a change in demand due to crisis.

2.5.6 Critical junctures in path dependence

The concept of critical junctures (such as drought crises, war, and pandemics) provides a time-based perspective for interdisciplinary communication to comprehend the persistence of existing patterns and the opportunities for groundbreaking changes. According to Mahoney (2001), critical junctures occur when a specific option is chosen from among two or more possibilities. These junctures are 'important' because once an option is chosen, it becomes increasingly difficult to return to the original point where several alternatives were still open.

Berins Collier and Collier (1991) examined key junctures as a series of steps. The first stage is the pre-critical juncture era, often known as antecedent conditions. The second is the 'cleavage' or 'crisis' that causes the critical juncture. The third stage is the critical crossroads, in which a new institution or policy (the 'legacy') is chosen from among several options using mechanisms of production' and becomes path dependent due to mechanisms of reproduction'.

According to Soresen (2023, pp. 943), "*This conception of institutional change suggests specific kinds of research questions: what were the antecedent conditions before the critical juncture; what were the permissive conditions that opened potential for change to major social institutions; what were the productive conditions that shaped the particular outcomes in each case; what were the characteristics of the reactive sequence following major change during which greater institutional stability emerged; what can we learn from each critical juncture about the nature of institutional change mechanisms regulating and permitting change to specific sets of institutions*?"

3 Conceptual Framework

3.1 Introduction

The process of energy transition involves the co-evolution of complex systems. An interdisciplinary approach is necessary to evaluate the energy transition in various systems and uncover the unobserved reality that underlies the observable evidence in each discipline. The literature review identifies the gaps in individual disciplines and acknowledges the necessity of studying energy transition by connecting different disciplines in a coordinated and cohesive manner.

In this chapter, I develop a conceptual framework to analyze the energy transition, particularly in developing countries, using an interdisciplinary approach. In building my conceptual framework, I employ three different disciplinary perspectives on national energy transitions, following the meta-theoretical framework developed by Cherp et al. (2018). This framework recognizes the co-evolution of three main systems in the process of energy transition. These three main systems align with three perspectives: techno-economic, which is based on energy systems analysis and economics; sociotechnical, which is grounded in sociology of technology, Science and Technology Studies (STS), and evolutionary economics and focuses on knowledge, practices, and networks associated with energy technologies; and political, which is based in political science and addresses systems of political action. According to this framework, the energy transitions are portrayed as a result of the simultaneous development of three interconnected systems: the flow of energy through markets, the technologies used to extract, utilize, and transform energy, and the policies that govern the social and political aspects of energy systems.

The three-perspective approach adheres to Grübler et al.'s (2016) definition of energy transition, which refers to a transformation in the overall condition of an energy system rather than a specific alteration in an individual energy technology or fuel source. From a political economy standpoint, techno-economic and socio-technical practices, networks, and forms of political action are highly political. This means that the insights provided by global political economy (GPE) analysis are not limited to just one perspective. When it comes to how society deals with sustainability challenges, transitions involve integrating social, economic, and technical aspects of finance and innovation, technologies, infrastructures, regulation, cultural change, and social pressure. Various literary works mentioned in the literature review prioritize different factors as the main catalysts of transitions and offer varying perspectives on the most effective ways to comprehend them.

The objective of the energy transition is to disrupt and replace the previous methods of doing things. Although this objective may seem straightforward and appear to be a transformation from one state to another, in reality, the destabilization of the traditional energy regime and resource formation for new energy use occur simultaneously over a longer span of time and in a complex way. This slow progression towards an energy transition in each phase (formative phase, takeoff phase, growth phase, and saturation phase) makes the transition process even more complicated because studying energy transition incrementally based solely on short-term empirical evidence is insufficient for providing a scientifically rigorous explanation. Since the analysis of energy transition has a temporal dimension, the framework of energy transition defines the energy system as an evolving system. This framework defines the energy system by not only recognizing its scope of transition from one energy infrastructure to another, but also by defining it as an evolving system consisting of co-evolving techno-economic, socio-technical, and political systems.

Conceived as a co-evolutionary phenomenon, a transition encompasses two categories of processes: (1) those taking place within each of the systems, and (2) those that establish connections between these systems. Hence, researching transitions through isolated analyses of exclusively additive systems or by encompassing all systems as a whole is not an effective approach. Studying the separate development of each historical stream, as well as their interdependencies, loss of integration, and subsequent reintegration, is crucial. (Freeman and Louçã 2001, p.127) The energy transition framework in my analysis recognizes the crucialness of the flexibility of switching between the two categories of the process to augment deductive reasoning. Based on the need for research, this framework sometimes takes the system as a whole and sometimes separately studies them. The objective is to identify the unobserved reality behind the observed evidence in each co-evolving system.

First, I conceptualize why the energy outcome of a developing country like Bangladesh shows a paradox which cannot be explained by mainstream theories. Second, identify the distinctions between variables and mechanisms and introduce the concept of causal chain.

This provides a premise for conceptualization of framework. Third, I introduce interdisciplinary approach that I use as a pillar to develop the conceptual framework. Here, I discuss the three-perspective framework and define the variables and concepts in three systems and their interconnectedness and their potential for defining the causal mechanisms. Fourth, I distinguish between the energy transition mechanisms of developing and developed countries. Fifth, I discuss the ontological and epistemological challenges in interdisciplinary research on energy transition and describe why the philosophical tradition of critical realism best describes the ontological and epistemological position of my research. Finally, I elaborate on the concepts of mechanisms of energy transition in developing countries and how the multiplicity of mechanisms and their interactions lead to the outcome.

3.2 Conceptualization of rational choice in mainstream theories and the puzzle in a developing country

The choices of developing countries could theoretically be considered rational or irrational when taking into account the rationales presented in existing scholarship. The common explanations of rational choices are consistent with the prevailing neoclassical economic theory, socio-technical theory, and political theory across three disciplines. To begin, I delineate the pertinent theories across three distinct disciplines. Secondly, I explain why the energy choices of Bangladesh appear to be irrational and creates a puzzle when contrasted to the tendency to make rational choices as outlined by existing theories.

3.2.1 Neo-classical economic theory

The understanding that the cost of energy services is a vital factor that provides incentives for fostering energy transitions (Fouquet 2016) is consistent with neoclassical economic theory. According to Neoclassical theory the adoption of low carbon energy technology (such as solar and nuclear) grows as income rises, assuming that low carbon energy technology is a normal good. This relationship is explained by the environmental Kuznets curve. (Grossman and Krueger, 1995),The national-level-energy-ladder hypothesis, proposed by Burke in 2010, suggests that the usage of solar and nuclear energy technologies, which are considered superior in terms of energy sources, tends to spread primarily in high-income nations that have low fossil fuel endowment. Countries ascend up the ladder of energy hierarchy when their income rises in conjunction with the adoption of increasingly sophisticated technologies such as nuclear and solar power.

3.2.2 Socio-technical theory

The socio-technical theory highlights that having a strong national capability is necessary before modern technology can be adopted. The establishment of nuclear power necessitates a strong state capacity (Brutschin et al. 2021, Jewell 2011) considering the sophisticated technology and risks associated with it.

The argument that carbon-lock-in (Trencher 2021) is most likely to occur in countries where socio-technical regime has already been formed aligns with the mainstream socio-technical theory.

The technology characteristic literature suggests that it is more advantageous to adopt granular technology like solar over lumpy technology like nuclear.

3.2.3 Political theory

Political risk minimization within sovereignty framework suggests that states ensure energy security by replacing imported energy with domestic energy sources [Yergin, Cherp et al. 2018]

The civilian use of nuclear energy carries inherent political risks. The civilian nuclear power plants in areas affected by war can be converted into weapons and used by hostile forces. This not only disrupts the energy supply, which undermines the morale of the enemy, but also allows for blackmail and coercion of decision-makers in the targeted country and their international allies, using the threat of a man-made nuclear disaster. (Przybylak 2024)

3.2.4 The puzzle: why does Bangladesh make irrational choice?

The puzzle is in why Bangladesh opted for an energy choice that contradicts the prevailing pattern of rational choice-making. The puzzle involves two distinct energy choices:

(i) The preference for coal, LNG, and nuclear power over solar power and domestic natural gas

The preference for nuclear power, LNG, and coal power over solar power contradicts the idea that the presence of low-cost energy technologies will encourage a shift towards that particular affordable technology. The decision to prioritize investments in coal and LNG instead of utilizing domestic natural gas and solar power goes against the current rationale that carbon lock-in occurs due to reliance on the established socio-technical system, which is difficult to dismantle.

The preference for imported energy sources like coal and LNG, as well as energy infrastructure like nuclear power, goes against the goal of ensuring political sovereignty in maintaining energy security. This preference for imported energy leads to a higher reliance on imports, exposing the country to financial and political risks.

(ii) The preference for nuclear over solar

The choice of nuclear energy over solar energy contradicts the expectation that low-income countries tend to choose solar energy due to its lower capital investment requirements. Being a lower middle-income country with low national capital and without significant source of foreign currency inflow to pay foreign debt, Bangladesh's decision to adopt expensive nuclear goes against the expectation. This choice also violates the rational expectation that complex, risky, and advanced technology requires high national capacity. The preference for a lumpy technology like nuclear over solar contradicts the expectation that granular technology adoption is more advantageous than a lumpy technology.

While this paradox can be tentatively explained by poor ability of developing countries to make rational energy choices, this explanation is refuted by the case of Vietnam that cancelled nuclear power in favor of solar. Thus, my overarching hypothesis is that the case of

Bangladesh cannot be explained by mainstream theories of energy transitions because these theories have been constructed for developed countries. Energy transitions in developing countries like Bangladesh are dominated by different causal mechanisms and require different explanations.

3.3 Distinction between variables and mechanisms

In this dissertation I distinguish between variables and causal mechanisms and explained how mechanisms can explain the explanatory power of variables in each discipline.
Variables are any character, policy, network that can be measured by quantity or quality and are liable to change at different conditions. Mechanism, on the other hand, is a process through which variables cause an outcome. While in quantitative studies variable take values and they are analyzed based on the quantity, in qualitative study variables are analyzed through their contributions to the mechanisms. Mechanisms exist in a black box and are unobservable without scientific explanations of underlying causal processes. Variables on the other hand are surface level indicators and events that exude symptoms of existence of reality beyond human perceptions.

3.4 Causal chain

The causal chain in this framework involves multiple mechanisms, sometimes causally linked to each other, and sometimes complementary to each other, through a complex web of interactions. The underlying mechanisms, irrespective of their tendency to recur or not recur, generate energy transition outcomes in congregation of three co-evolving system. Causal chain is especially useful in the longitudinal case study where there are multiple mechanisms interact with each other and contribute to a unique outcome. In this dissertation I present a case study in which I use causal chain to identify path dependence.

3.5 The three perspectives

In this section I introduce the variables of three systems across the disciplines that align with three perspectives. After identifying the variables and concepts, I show how techno-economic, socio-technical, and political variables are connected to each other. This interrelatedness forms the basis of conceptual framing. This sections also helps distinguish between variables and mechanisms. The variables and concepts are used to explain mechanisms of energy transition. Mechanisms are the process through which variables create an energy outcome.

Techno-economic explanations are insufficient without understanding the objective or motivation of actors. Similarly, actors are not only influenced by other actors, and the power dynamics, their actions also evolve as a result continuous interaction with the institutions. Socio-technical system is necessary to accommodate changes in shift of technological paradigm and evolving institutional needs. Political system is necessary to define the power dynamics within which the actors take certain decisions and reject others. Actors and institutions are in a dialectic relationship which define their interactions with each other through certain mechanisms.

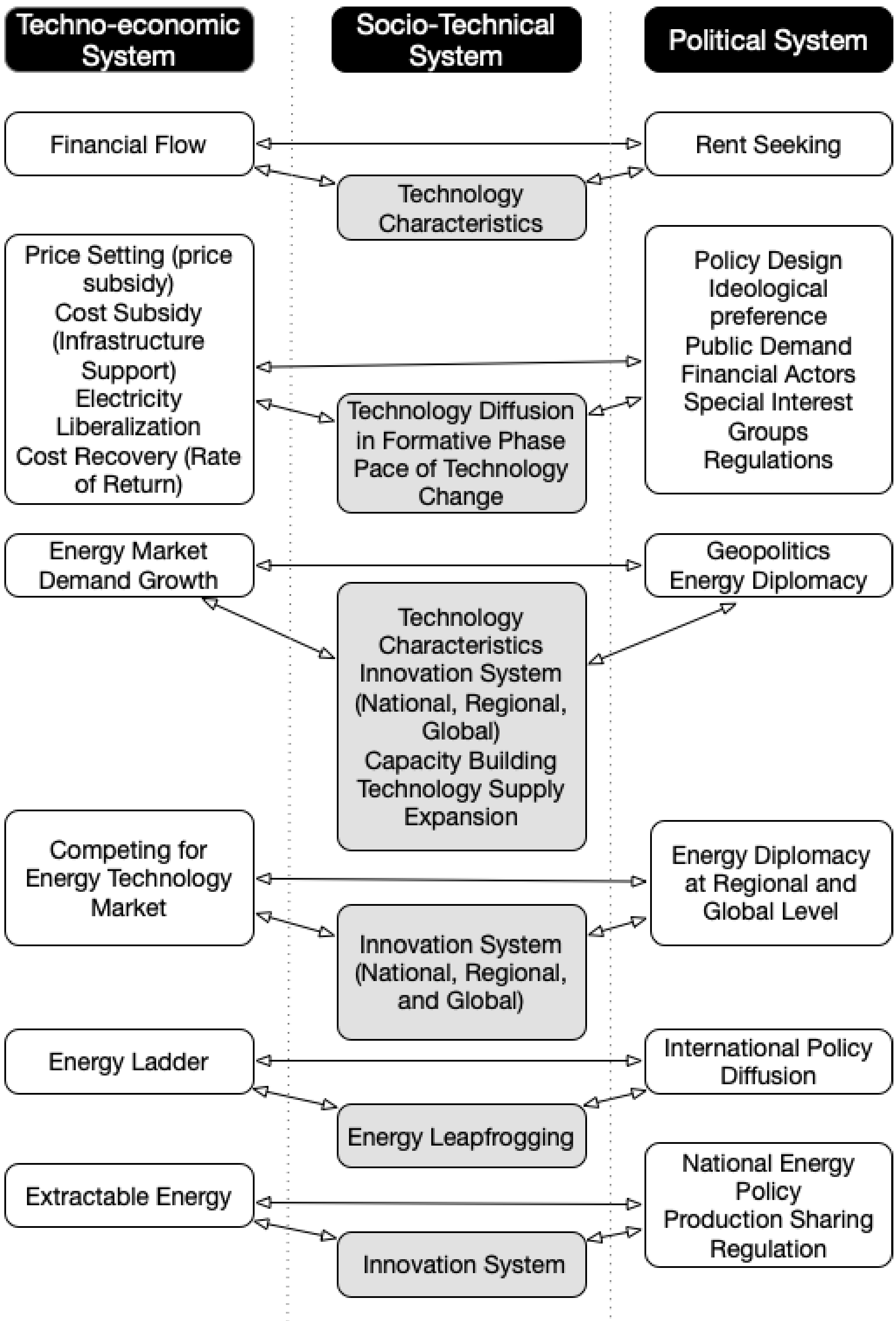
In this co-evolving system, capacity is not a static indicator, rather an evolving process where national, regional, and international actors are involved. Capacity is defined as technical, human resource, regulatory, and institutional capacity. These capacities vary across countries and involve multiple mechanisms to develop. In this dissertation, I treat capacity as an evolving phenomenon.

The variables in three systems are interconnected and this interconnectedness creates a ground for an explanation beyond the human perceptions. This interconnection also allows conceptually define the multiplicity of causal mechanisms and their interactions. In figure 3-1 I outline the variables and concepts in three systems. I figure 3-2, I depict the interconnectedness of the variables of each system.

Table 3-1 Variables and Concepts in Three Systems

Techno-economics System	Socio-technical System	Political System
Techno-economics	Technology Diffusion	National Energy Policy
System	Learning	Ideological preference of a state
Extractable Energy	Experience	Energy security
Energy Ladder	Global, Regional, and National	State imperatives
Energy Demand	Innovation System	Policy actor
Energy Supply	Resource Mobilization in	Technology actor
Market Price	Formative Phase, Take off Phase,	Financial actor
Cost	Saturation Phase.	Policy Design
Price Setting	Spillover of Knowledge in Regional	State's Control Over Market
Infrastructure	Technology Cluster	Regulations
Incentives	Regime Destabilization	Regulatory bodies
Investment	Strategic Niche Management	Interest Groups
Capital Demand	Technology Characteristics incl.	Energy trader
Rate of Return	Scale, Complexity, Riskiness etc.	Institutional Lock-in
Profitability	Technology lock-in	Policy Diffusion
Economies of Scale	Technical, Institutional, and	Geopolitics
Capacity Charge	Human Resource Capacity	Energy diplomacy
Feed in Tariff	Leapfrogging	Balancing Act
Gross Metering	Trust to Society	Financing
Net Metering	Social Acceptability	Strategic Cooperation
Electricity Liberalization		Bilateral Economic Co-operation
Efficiency		
Cost Recovery		
External Debt		
Import Dependence		

Figure 3-1 Interconnectedness of Variables from Three Systems



3.6 Differences between mechanisms of developed and developing countries

In this dissertation, one of the main contributions to the existing conceptualization of energy transition is the distinction made between developed and developing countries and how this distinction impacts the energy transition mechanisms. In doing so, I do not compare a developed country with a developing country to draw the distinction. Rather, I conceptualize this distinction from the previous scholarly works on historical causes of underdevelopment, and the literature on development theories.

I distinguish between developed and developing countries in terms of their underlying characteristics of the interactions between them that make developing countries different from developed countries. To do that I specifically focus on the relationship of interdependence between two types of countries. The dependency school scholars (Prebisch 1950, Singer 2012, Frank 1963, 1967, 1978, Amin 1974) argued that the causes of underdevelopment are historical dependence of colonizers on colonies for extraction of resources, surplus value transfer, benefits from unequal terms of trade. Although some scholars (Frank 1978, Sweezy 1968, Amin 1974, Amsden 2003) argued that development is still possible by taking some measures, the basic premise of both dependency school and their critics is that there is a relation of dependency between these two categories of countries not only because of the differences in income level, but also for their history of capital formation and exploitation. While the developing countries depend on developed countries for capital inflow, technology, and institutional resources, developed countries depend on developing countries because developing countries are market for technologies, financial loan, and institutional knowledge of developed countries. In this framework I use dependency as a premise to distinguish between developed and developing countries.

The following table summarizes the differences in the characteristics of developed and developing countries and their implications in differentiating the mechanisms of developing countries from the developed ones.

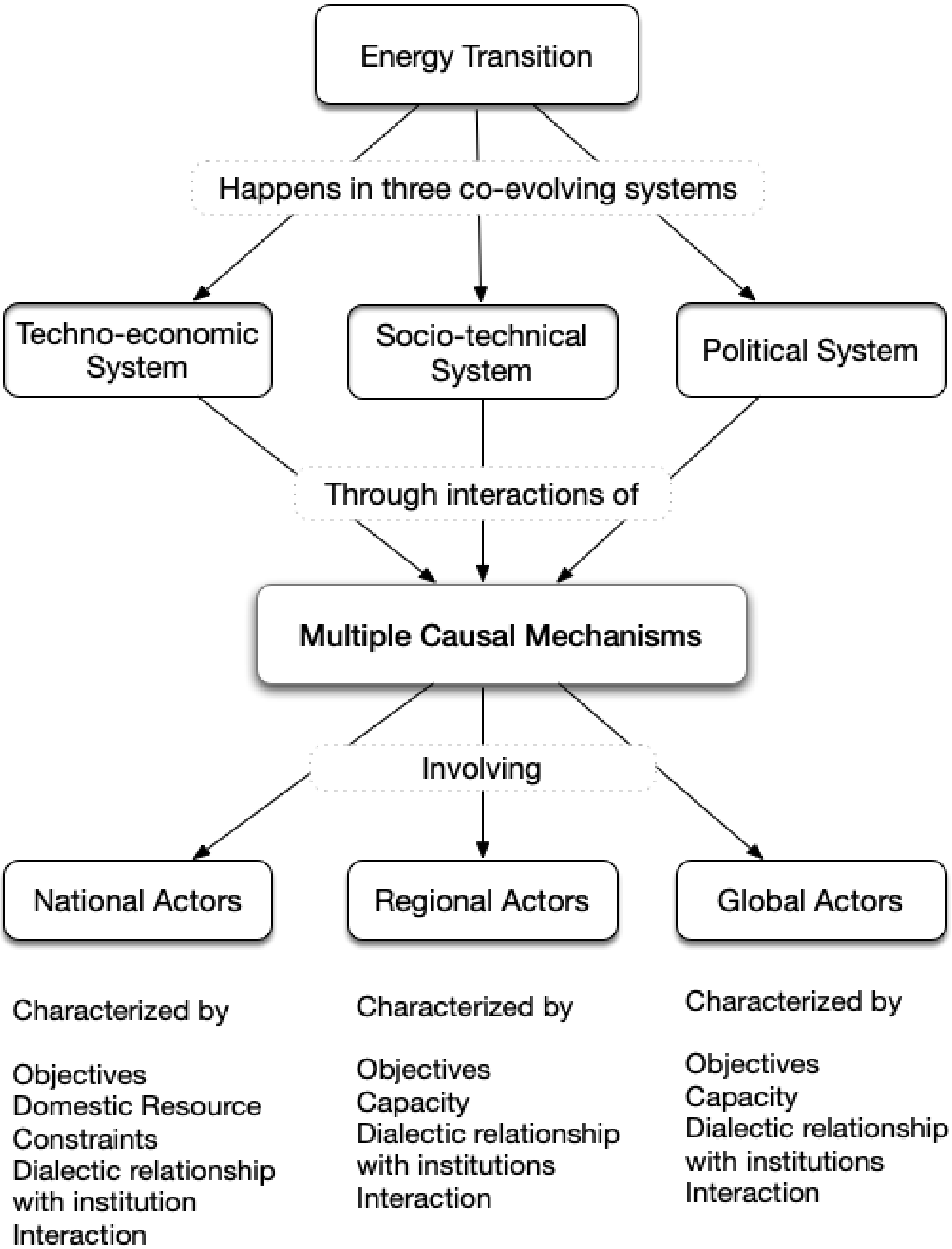
Table 3-2 Difference Between Developed and Developing Countries and its Implications to Energy Transition Mechanisms

Characteristics	Developed Countries	Developing Countries	Implication of the Differences in Energy Transition Mechanisms
Technical Resources	Technology innovated in the core	Technology diffuses to the periphery	Technology Diffusion from core (developed) to periphery (developing)
Capital Resources	State's ideological preference: development	Techno-economic mechanisms	Developing countries are usually more dependent on external actors for capital resources
Institutional Resources	Domestic mostly	Domestically low	Developing countries are usually more dependent on external actors for institutional resources
Policy Making	More control over national policy making	Less control over national policy making	Policy making in developing countries is more constrained by resource access than that of developed countries
Geopolitical Position	Strong	Weak	Developing countries tend to be more susceptible to geopolitical constraints.

While the "three-perspectives" framework is useful in analyzing energy transition, there are some limitations in defining the variables associated with each system. After distinguishing between the co-evolving systems of developed and developing countries, I introduce some concepts differently to apply it in the context of developing countries.

In figure 3-3, I introduce a conceptual framework for energy transition of developing countries. I distinguish between different group of actors involved in shaping the causal mechanisms. Since this framework is relevant to developing and emerging economies, I make distinction among different types of actors. I assume that national actors make decisions under constrained technical, financial, and institutional resources. The constrained resources make them dependent on external actors, including regional and global actors. While I characterized the national actors for their interaction constrained by financial, technical, and institutional resources, other actors, including regional and international ones, are characterized by their motivation, capacity, and interaction.

Figure 3-2 Conceptual Framework



3.7 Ontological and epistemological position of energy transition research

While the three perspectives framework is a comprehensive framework, it poses ontological and epistemological challenges for holistic research of energy transitions. In this section, first I discuss the ontological and epistemological challenges in interdisciplinary research of energy transition. By identifying the challenges and incompatibility between different perspectives, this section shows why an interdisciplinary energy transition research can best find its ground in the philosophical tradition of critical realism in order to accommodate theories in three disciplines and deductively draw the causal mechanisms behind an energy outcome.

3.7.1.1 Ontological and epistemological challenges in interdisciplinary research of energy transitions

The ontological and epistemological positions differ across disciplines based on research needs, making it extremely complicated to define the ontological and epistemological positions in interdisciplinary research. In this section I discuss some challenges faced by the interdisciplinary approach when accommodating three perspectives.

3.7.1.1.1 Techno-economic perspective

The mainstream economics research dominantly follows the positivist philosophy of science. For example, the focus on individual decision-making in neoclassical economics can be interpreted as a positivist viewpoint, since it highlights the significance of empirically evaluating theoretical predictions using real-world data to evaluate their explanatory capacity and pertinence. According to Meyer (2023) the unrealistic built-in assumptions of neo-classical economic models fail to consider open-endedness of choices and therefore make it ineffective.

While framing the research question based purely on empirical observations ignores external realities, framing questions based on certain assumptions may allow neoclassical economic theory to overcome some of the limitations of over simplicity based on pure empiricism. Verification of unrealistic assumptions using empirical data often justifies the effectiveness of models. the Neoclassical economics often aims to uncover the causal mechanisms that drive economic behavior and results. For example, the law of demand states that when the price of a good rises, the demand falls assuming that all other things remaining the same and that consumers behave rationally and that the satisfaction they derive from consuming additional units of a good diminishes over time. These causal processes are observed to be valid in the actual world, influencing economic interactions and results. However, what happens when the suppliers have the ability to create demand by making the consumers dependent on certain goods and services? The assumption of rational choices is often violated within the system and this makes it difficult to explain the irrational choices made by actors. This is a question about an agent that influences the decision of consumers even when the price of good is high compared to other alternatives. This is an example of how neoclassical economic theories fail to recognize the external realities in certain situations making it difficult to align the theory with realist and critical realist philosophy.

3.7.1.1.2 Socio-technical perspective

The expanding body of research on energy transition in sociotechnical system, often known as 'sociotechnical transitions', has several origins and manifestations. However, it has progressively centered around a specific theoretical framework of multilevel perspective (MLP) on sociotechnical transitions (Geels, 2002). The multi-level perspective seeks to combine insights from several bodies of literature as an "appreciative theory" (Nelson and Winter, 1982). Appreciative inquiry mainly deals with recognizing strength in the system rather than overcoming weaknesses and emphasizes on following best practices. In MLP many levels do not serve as ontological representations of reality, but rather as analytical and heuristic constructs to comprehend the intricate dynamics of sociotechnical transformation.

Sorell (2018) identified a number of potential weaknesses of MLP by assessing the consistency of these assumptions with the philosophical tradition of critical realism. Sorell (2018 p. 1267)) specifically wrote “*These include: the problematic conception of social structure and the misleading priority given to intangible rules; the tendency to use theory as a heuristic device rather than causal explanation; the ambition to develop an extremely versatile framework rather than testing competing explanations; the relative neglect of the* *necessity or contingency of particular causal mechanisms; and the reliance upon single, historical case studies with insufficient use of comparative methods*." To avoid misinterpretation of social structure and make sociotechnical theory consistent with critical realism philosophy, Sorell proposed to drop the distinction between systems and regimes and explain regimes as a distinct social entity with emergent causal property.

Sorell (2018, P. 1280) pointed out that "*the application of the MLP creates a number of epistemic difficulties, including: a) the tendency to use the framework as a heuristic device rather than the basis of causal explanation; b) the priority given to this overarching theoretical framework, as compared to testing competing theories or assessing the relative importance of different causal mechanisms; c) the lack of attention to the necessity or contingency of particular mechanisms or events; d) the reliance upon single, historical case studies with limited use of comparative case studies or other research methods; e) the influence of 'process theory' that emphasizes empirical events rather than underlying structures and mechanisms; and f) the skepticism towards more 'reductionist' methodologies such as agent-based and systems dynamics modelling that could potentially offer useful insights into specific transition processes*." Sorell (2018, P.1280) proposed to shift the attention away from the framework itself and towards identifying the specific causal mechanisms that drive particular transitions. He recommended that the main focus should be on proving the need or contingency of certain mechanisms and events, rather than assuming that a combination of these is necessary for a transition to happen.

3.7.1.1.3 Political perspective

The discipline of political science adheres to a wide spectrum of philosophical position, ranging from positivist epistemological paradigm to interpretivist paradigm. However, the recent trend of contemporary mainstream political science research shows a tendency to situate their epistemological position within the positivist paradigm that emphasizes the pursuit of objective knowledge about the world. (Grass 2024)

In the political economy research, actors, objectives, institutions, ideologies are the focal points of analysis. Researchers use various suitable conceptual frameworks and methodologies based on their research objectives. The eclectic choices of epistemological and ontological positions in political economy makes it even more complicated to adhere to any specific paradigm. Often, the difference between variables and mechanisms are blurred and make deductive reasoning complicated, especially when the causally linked variables are greater in number. This poses a serious challenge to create link among different disciplines and consequently adhere to original theoretical framework within which mechanisms were theorized.

3.7.1.2 Critical realism in interdisciplinary research

The underlying assumption of this research aligns with philosophical assumption of critical realism. While the philosophical prerequisites and assumptions behind theories of each discipline often contradicts with each other, critical realism, as a branch of philosophy, can link the disciplines by distinguishing between observed and unobserved reality, rather than relying solely on observed realities or solely on the sense data or perceptions. Critical realism allows navigates across disciplines and at the same time uses mechanism-based analysis to explain the unobserved evidence. Scholars (Danermark 2002, 2018, 2019; Bhaskar and Danermark 2006; and, Price 2014) argued that critical realism, as a philosophical tradition, can sustain and strengthen interdisciplinary research. In this section, I discuss how the ontological and epistemological position of the study of energy transition align with assumption of critical realism.

3.7.1.2.1 Ontology of critical realism

According to critical realism there exists reality, which is objective, and independent of perception of human. The reality is stratified, meaning that it consists of surface-level events and real entities with particular structures and causal properties. According to Bhaskar (2010, P. 2) Critical realism emphasizes the importance of understanding reality in terms of three distinct domains: the real, the actual, and the empirical. The real domain encompasses both the actual and the empirical, and also includes potentialities or abilities that have not yet been realized or manifested. These potentialities may exist in an un-manifested state or may be exercised without being actualized in a specific sequence of events. The actual domain includes the empirical, as well as things and events that exist or occur without being perceived or experienced by humans in general.

The open-endedness across the domains allows navigation across disciplines, rather than limiting the explanations to inferences based on surface-level events. In the research of energy transition, this openness facilitates deductive reasoning by navigating beyond perceived realities in a specific discipline and seeking explanations across disciplines.

3.7.1.2.2 Epistemology of critical realism

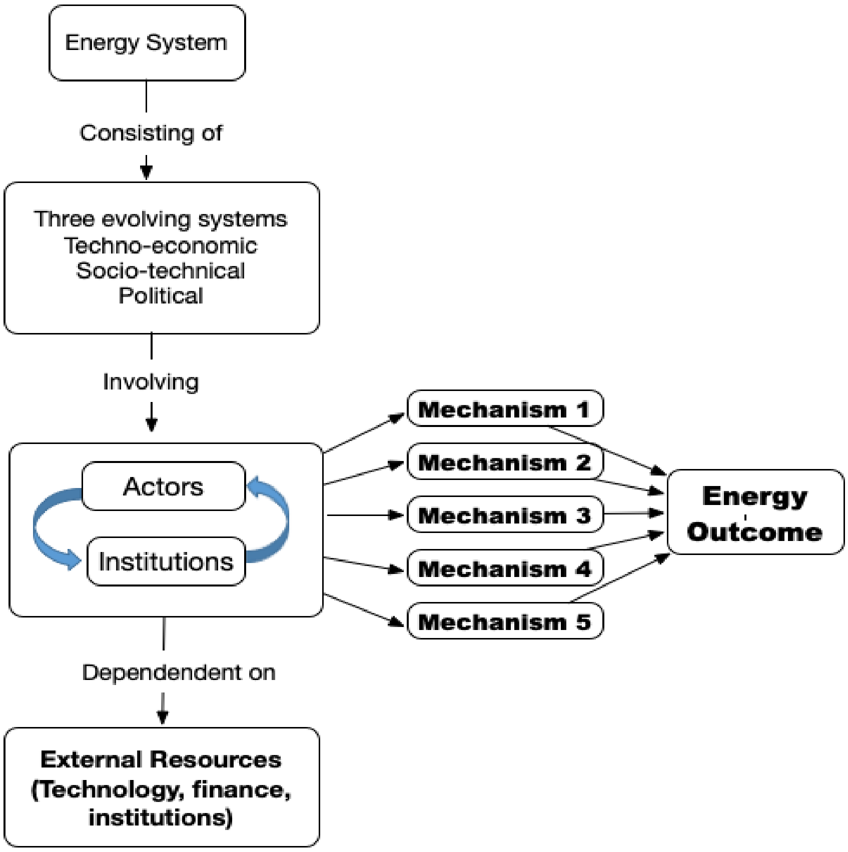
Critical realism posits the presence of an objective reality that exists autonomously from human observation and understanding. Nevertheless, it recognizes that our understanding of this existence is influenced by our sensory perceptions, personal encounters, and societal frameworks. Transcendental realism posits that although direct access to reality may be unattainable, scientific investigation allows us to acquire understanding of its fundamental structures and dynamics. In order to do that critical realism employs retroduction as a method to identify the presence of underlying causal mechanisms and structures that may not be readily evident. Retroduction is a process of using deductive reasoning to infer the presence of underlying causes that can provide an explanation for observed occurrences. Abduction entails formulating hypotheses or explanations that align with observed facts yet surpass what is readily apparent.

In this research I use retroduction for reasoning about the entities, structures and causal mechanisms to explain the unobserved reality. The epistemological position aligns with the interdisciplinary research field like energy transition because the analysis encompasses wide range of observed occurrences and needs a scientific retroduction to find underlying causal mechanisms.

3.8 Conceptual framework for developing countries

The co-evolving energy system consists of techno-economic, socio-technical, and political systems. Unlike structuralist approach of historical institutionalism, where actors’ actions are motivated by the institutions and socio-economic conditions, this framework recognizes the dialectical relationship of institutions and actors, and their synthesis through complex mechanisms emanating from three systems in which actors and institutional structure play the key role in the functioning of the mechanisms.

Figure 3-3 Causal mechanisms of energy transition in developing countries



In mechanism-based approach, a highly debated question is how mechanisms unfold and what their key "entities" and "activities" are (Machamer et al. 2000). Kuhlman consider policy actors, their actions, and interaction as key drivers of social policy. Rather than following the structuralist approach, in which socio-economic conditions, institutionalized rules, or other factors determine policy developments, Kuhlman focused on entities, activities, and their interactions. In my research, although I consider actors, actions, and interaction as key drivers of energy outcome, I consider institutional character as a potentially path dependent reality in which actors interact with other actors, and institutions and act at various capacities based on their objectives. In this framework, institutions and actors are in continuous dialectic relationship with each other and at the same time are constrained by the institutional lock-in created historically in a path dependent process.

The causal mechanisms approach makes an ontological assumption regarding the existence of mechanisms with "real causal powers" that link consequences to causes. (Little 2011). The causal mechanisms approach is realist in the most fundamental sense: it maintains that the mechanisms proposed in social explanations are concretely realized in the social reality through the acts of persons placed within institutions and norms. Mechanisms are more than just hypothetical models. Mechanisms are regarded to represent real underlying processes with properties that can be identified using a number of empirical methods. Little (2015).

The causal mechanism approach allows for the integration of various types of knowledge by linking them with different processes, which are then brought together to explain a specific phenomenon. It is especially well-suited for analyzing complex social phenomena like energy transitions since it allows for some regularity at the level of underlying mechanisms as well as context-dependence due to unique combinations of mechanisms.

4 Research Design

4.1 Introduction

The selection of methodology of my research is influenced by the presumed ontology and epistemology of energy transitions, which is grounded in causal mechanisms. Little (2015) defines a methodology as a collection of guidelines for gathering and validating knowledge on a particular subject. Hall (2003) highlights that qualitative methodologists hold the belief that the social world is intricate because of path dependence, tipping points, interaction of multiple mechanisms, two-directional causality and may lead to equifinality (multiple paths leading to the same outcome) or multifinality (multiple outcomes resulting from the same value of an independent variable, depending on the context). The potential existence of these intricacies in the real world pose challenges to the optimal construction and validation of any knowledge claims.

A theory generally aims to generalize logically related explanatory statements that establish a causal relationship between two or more individual observations. However, theoretical assertions in the behavioral and social sciences are limited in their range of generalization due to at least two causes. Establishing causation is challenging due to the probabilistic character of most associations being investigated. Furthermore, human conduct and human civilizations exhibit intricate, diverse, and dynamic characteristics, hence preventing any straightforward simplification into universal assertions.

In this intricate social world, where generalization and validation of knowledge claims are continuously being challenged for both temporal and spatial dimension in the process of new knowledge creation, there is a need to maintain a consistency in selecting ontological, epistemological, and methodological position in research. According to Little (2015), the study of causal mechanisms has methodological implications and emphasizes specific research methodologies that are particularly suitable for this approach as they contribute in the identification of causal mechanisms.

Critical realism points out to the existence of a subjective element, which is mind-dependent, in the world that seeks to comprehend and gain knowledge about the objective world. However, it is possible to infer mind-independent explanation. Thus, critical realism emphasizes that to be able to have a mind-independent explanation it is important to understand the underlying structure and real causes behind the observable evidence. A method that enables various perspectives to deeply analyze empirical evidence and establish causal links align well with the philosophical position of critical realism.

While the first analytical chapter (chapter 4) sets the context by identifying the institutional characters of Bangladesh, second analytical chapter (chapter 6) explains why Bangladesh adopted solar and why the growth of solar has been low despite declining cost. The third analytical chapter (chapter 7) reveals the mechanisms of nuclear adoption in Bangladesh. The fourth analytical chapter (chapter8) deals with the adoption of LNG and coal throughout the last decade in Bangladesh.

4.2 Method

4.2.1 Case Study

One of the most important strengths of a case study method is that it can reveal a holistic view of the story and a detailed view of events as it can identify the path dependence and causal mechanisms and distinguish between different parts of the causal chain. A detailed in-depth case can reveal how the events can shift a sequence of path or stay in the same path. Theorists often differentiate between accounts of how institutions are created and those of how they are sustained, and case studies can help to identify and explain the mechanisms involved in both periods (Mahoney 2000, 511-2).

In alignment with critical realism and to pursue mind-independent unobservable reality using the observable evidences, in this thesis, I use three complementary methods

1. A longitudinal national case study
2. Within-unit case studies
3. Comparative national case study

Chapter 5 is a longitudinal case study that sets the historical context of the within-case study, with analysis of empirical evidence of fifty years. This chapter investigates the actors and institutions involved in energy transitions and whether there is existence of a path dependence that leads to institutional or technological lock-in. Chapter 6, 7, 8 are case studies of individual technologies within a single national case (within-unit case-studies of different phenomena in the same context). While chapter 6 and 7 focus on the adoption of new low-carbon energy technologies, chapter 8 focuses on adoption of two new hydrocarbon energy technologies. Chapter 9 is a comparative case study between two developing countries observing deviating energy outcome in terms of their energy technology adoption.

4.2.2 Process Tracing

Process Tracing refers to the methodical investigation of diagnostic evidence that is carefully chosen and studied in relation to the research questions and hypotheses put out by the investigator. Process tracing plays a crucial role in both describing political and social phenomena and evaluating causal claims. (Collier 2011)

Within mainstream qualitative methods, the primary objective of within-case approaches is to identify and confirm causal mechanisms. George & Bennett (2005) utilized process tracing in single case study to identify the most significant causal mechanisms. Process tracing enables the deduction of causal processes within the limitations of a single case or a small number of cases. Following the mainstream qualitative methods, I use in-depth within-case study to identify and assess energy transition mechanisms in developing countries. To do that, I use process tracing, the process of identifying the intervening causal process or the causal chain between independent variable and the dependent variable.

4.3 The Longitudinal National Case Study

The longitudinal national case study helps to identify the institutional structure, whether there is path dependency leading to institutional lock-in that relates to the functioning of causal mechanisms.

4.3.1 Case Selection

For longitudinal national case study, I choose Bangladesh as case because Bangladesh is one of the developing countries adopting new energy technologies. Bangladesh is a suitable case not only because it is a rather typical lower middle-income country, but also because of the diversity of its energy options and choices. Bangladesh uses coal, oil and gas for electricity production with increasing contribution from solar and planned nuclear power. Moreover, the case of Bangladesh presents an interesting scientific puzzle: with respect to its energy choices. While the cost of renewable energy has been declining throughout the last decade, Bangladesh adopted nuclear, LNG, and coal which seems to contradict both economic considerations and energy security goals. In order to understand whether the historical development of institutional structure of developing countries has any implication in explaining the mechanisms of energy transition, I selected the case of Bangladesh with historical evidence of fifty years: from 1970 to 2020.

4.3.2 Focus of Analysis

The focus of the longitudinal case study is to analyze the historical evidences since Bangladesh's independence. As a developing country dependent on foreign technology, innovation, and capital for developing its national innovation system to ensure energy security, Bangladesh lags behind in terms of developing its own capacity. The quantitative studies find correlation between income and capacity of a country to explain why developing countries lag behind in terms of increasing clean energy use. The case study shifts away from this correlation based on large N study and instead focus on an in-depth longitudinal case study to check whether the historical evidence shows any recurring pattern based on which a path dependence may have occurred and as a result it becomes irreversible to develop its own technology and break the institutional inertia in which the energy system evolved.

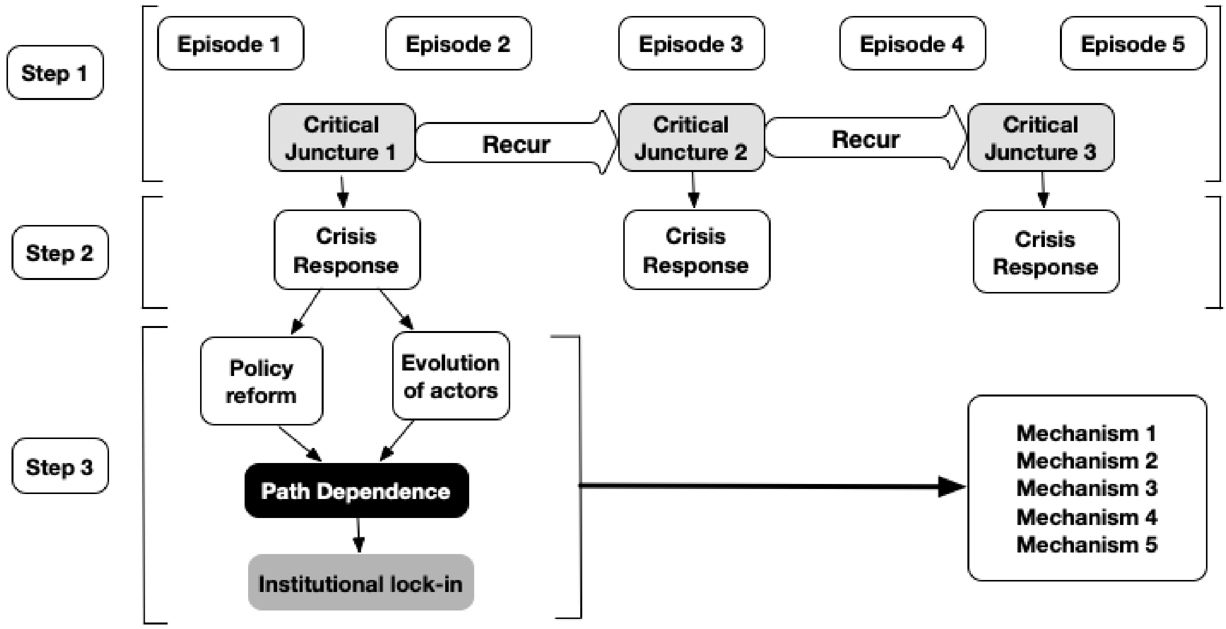
4.3.3 Structure of Analysis

This case analysis divides fifty years into five episodes: 1970s, 1980s, 1990s, 2000s, 2010s. I identify the critical juncture in the history of Bangladesh based on the major crises period in which Bangladesh took major reform decisions about solving the crises. By analyzing the reform measures and their consequences, recurrence of crisis, evolution of actors, structure of institutions, regulations determining the actors' responses to crises, states ideological preferences, and the beneficiaries from reform measures over the long period of time, I infer causal relationship between the variables and the energy outcome.

In this analysis, adoption of more complex and expensive technology is the energy outcome. The research is designed to go fifty years back to understand why Bangladesh has adopted certain policies in the past, what drove Bangladesh to solve the crisis and how, and whether the institutions are locked-in, characterized by dependency on some actors.

The structure of the analysis follows three steps. In the first step, I identify two critical junctures based on the empirical data. In the second step, I try to find out the commonalities in the crises and how they recurred. In the third step, I analyze why Bangladesh adopted similar policies in two consecutive crises, and whether a similar approach has been repeated in the latest crisis. Through the evidences in each episode, I show whether there is a path dependence causing institutional lock-in.

Figure 4-1 Longitudinal case study: structure of analysis



4.3.4 Data Collection

In national case study I predominantly use secondary quantitative and qualitative data to analyze and validate my findings. Since, this case study deals with a long period of time, I use quantitative data to follow the trends of some of the dependent and independent variables. The data are collected from International Energy Agency (IEA), publications and data of state-owned utility companies, government bodies, and annual reports, and international financial institutes like World Bank. To analyze the qualitative data on policy variables, I use secondary literature like policies, acts, strategies, laws over the fifty years.

4.4 Within-unit case studies

Generally, the rationale for a within-unit comparison is that cases belonging to the same unit are likely to be more comparable than cases from different units (George and Bennett 2005, 166). Within a single country (same unit) four different sectors represent four comparable units because they share a similar economic and political context. However, the four units differ in their substantive character like technology, institutional set up, scale of production, social acceptability, environmental implication etc.

4.4.1 Case selection

I select four energy technologies and their associated sectors as cases. All of these sectors: solar, nuclear, LNG and coal power have emerged during the last decade in Bangladesh. To do a more in-depth analysis of each technology I categorize the technologies based on their cost, environmental implications, and complexity. For example, solar is a simpler and readily available technology, nuclear is a complex, risky, and highly customized technology, and coal and LNG are two hydrocarbon technologies that are responsible for high carbon footprint.

4.4.2 Focus of analysis

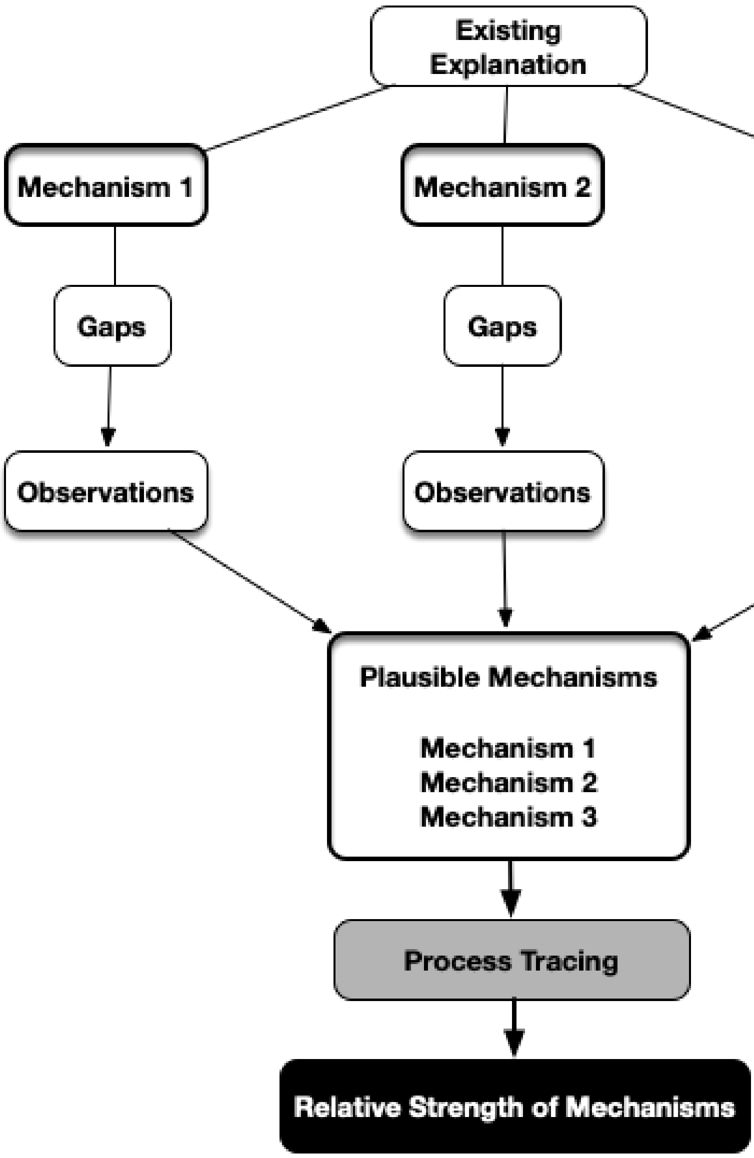
In four within-unit case studies for four technologies, I use process tracing to identify the causal mechanisms behind the energy outcome. Here, in different cases, I use different relevant variables pertinent to each technology. Some variables are common, while others are mutually exclusive because the technology characteristics are not same and there are variations in the actors and institutions involved in the process. The objective of the analysis is not to compare the technologies to find differences and similarities across energy technologies. Rather, the objective is to find the more dominant and weaker mechanisms in adopting each of those technologies.

4.4.3 Structure of within-case analyses

The structure of analysis of chapter 6,7, and 8 is built upon the findings of chapter 5. Chapter 5 sets the common context for the four sectors. The longitudinal case analysis of Bangladesh for first four decades, from 1970s to the 2000s provides an understanding of the evolving dialectic relationship between actors and institutions in the country. And the case-studies show how the outcome of these four decades created actors and institutions that shaped the adoption of the four new technologies in the 2010s.

The analyses in each of these four cases followed three steps. In the first step, I identify the existing dominant explanations of the adoption of new technologies and point out why such explanations are insufficient. In the second step, I introduce the plausible mechanisms and why actors and institutions, being at the focal point of analysis, can explain the mechanisms in light of the empirical evidences. In this step I focus on the actions of actors and institutions and develop a causal chain or causal process that forms the basis for explaining the mechanisms. In the third step, in the discussion section of each chapter, I present comprehensive analyses of the strength of mechanisms using the method of process tracing.

Figure 4-2 Within-case Study: Structure of Analysis



4.4.4 Data collection

Although the structure of analysis in chapter 6, 7, and 8 are similar, the methods of data collection differ across these cases. While nuclear, LNG, and coal technology involve a more centralized authority, solar technology is more decentralized. For nuclear, coal, and LNG technology one needs to depend on the secondary data to be able to analyze causal relationship. The secondary data available in grey literature and newspapers typically represent the main sources of current policy updates and impacts. On the other hand, the solar technology itself is diverse, ranging from solar home system, rooftop solar, utility scale, solar irrigation, street light etc. The secondary sources of updated information are incomplete and requires primary data collection for getting a comprehensive understanding. Besides, in order to validate some findings, there is a need to do a cross country statistical comparison. In case of solar technology, I use both statistical analysis and interviews to explain the causal mechanisms. In chapter 7 and 8, I rely on secondary data for process tracing.

4.5 The comparative national case study

Chapter 5,6,7, and 8 are in-depth within case analysis of Bangladesh. The findings are applicable to a developing country like Bangladesh. However, this needs to be validated by comparing with a similar country where initial characteristics are suitable for a systematic comparison. The objective of the comparative case study is to compare the causal mechanisms of the two countries that led to divergent energy outcomes. These chapters explain why the existing explanations are not sufficient for understanding the energy transition mechanisms. However, what happens in other developing countries having similar character and historical crises and dependency need. Using process tracing as a method, I introduce the comparison of national case study to validate findings found in other chapters. While I observe the outcomes of causal mechanisms in Bangladesh, often one and the same outcome can be explained by several different mechanisms. But we don’t know which of these are dominant or weak. The second comparative case allows me to vary the context so that the combination of mechanisms is slightly different, leading to different outcomes. By comparing the two different configurations of mechanisms and contrasting two different outcomes we are able to infer the relative strengths of different mechanisms.

4.5.1 Case selection

I select Vietnam and Bangladesh as two cases because both of these countries are lower middle-income countries of similar size with rapidly increasing demand for electricity. These two countries have gone through similar crises in 1970s and 1990s and adopted reform measures to solve the crises. At the same time there are some dissimilarities in the geographical location, political ideologies, and regional priorities which result in different energy choices and provide for potentially interesting comparison.

Table 4-1 Case Selection Criteria

Energy Outcome			
		Bangladesh	Vietnam
Divergence	New Energy	Nuclear Slow growth of solar	No nuclear Faster growth of solar
Similarities and Dissimilarities			
		Bangladesh	Vietnam
Mostly similar	Third new energy as transition fuel	LNG import since 2018	LNG import planned from 2025
Similar	Potential for solar	High	High
Similar	Potential for wind	High	High
Different	Domestic coal	Bangladesh cannot use sufficient domestic coal because social and environmental cost is too high. There is social movement against open pit coal mining	Vietnam relied mostly on domestic coal until 2015 when coal resource could not meet domestic demand any longer.
Similar	Coal import	Increased from 2015	Increased from 2015
Similar	Power import	From India	From China and Laos
Mostly similar	Dependence on domestic energy resources	Highly dependent on gas Coal dependency is low There are both unutilized gas and coal resources.	Coal dependency is high Oil, and hydro power dependency is moderate

Similar	External influence in policy making	Japan, Denmark	Japan, some EU countries, China, and US
Similar	Demand for electricity	High	High
Similar	Foreign investment interest in power and energy	High	High
Similar	Industrial use of electricity	Percentage of Electricity used for industrial sector 47.7%	Percentage of Electricity used for industrial sector 46.3%
Similar	Established regime	Gas regime	Coal regime
Similar	Potential niche	Imported LNG, coal, solar, nuclear	Imported LNG, solar, nuclear
Dissimilar	Solar manufacturing	Very limited (mostly for domestic use)	Strong (mostly for exporting to the US)
Dissimilar	Electricity liberalization	More liberalized (started in 1990s)	Less liberalized (government-controlled liberalization started in 1990s
Similar	Economy by sector	Agriculture: 14.23% industry: 35.66% services: 50.11%	Agriculture: 15.3% Industry: 33.3% Service: 51%
Similar	Electricity for industrial use	47.7%	46.3%
Similar	War	Impacted by cold war. Supported by Russia. Not supported by US.	Impacted by cold war Supported by Russia and China In a war with the US
Similar	Post war reconstruction	After 1972	After 1973
Dissimilar	Political Orientation	A parliamentary representative democratic republic framework, whereby the Prime Minister of Bangladesh is the head of government, and of a multi-party system. Executive power is exercised by the government.	A single-party socialist republic framework, where the General Secretary of the Communist Party of Vietnam is the Party leader and head of the Politburo, holding the highest position in the one-party system

4.5.2 Focus of analysis

The focus of the comparative analysis is on identifying the strength of mechanisms for which the energy outcomes diverge in two countries. The goal is to find both common and dissimilar causal processes, and then deductively reject the weaker mechanisms to isolate the most significant ones. By using process tracing I reject any existing explanation when despite the same causal mechanism applied to both countries, one country adopts nuclear and the other country adopts solar. The gradual elimination of weaker explanations leads to identification of the strongest mechanisms.

4.5.3 Structure of analysis

The case study uses process tracing as a method to compare the mechanisms of energy technology adoption in two similar countries. To do the process tracing the analysis follows three steps to systematically eliminate some existing explanations and juxtapose the plausible explanation to identify relative strength of the mechanisms.

In the first step, I outline the plausible explanation of new technology adoption in two countries and then identify the gaps by looking at other equally compelling observations that challenge those explanations. After identifying the gaps in the explanations, in the second step, I focus on the actors and institutions and the consequences of certain policy adoption to facilitate certain technology developments. In doing so, I analyse the policies, their limitations in meeting the objectives, and other unobserved plausible mechanisms that may have contributed to the change in the energy outcome in these two countries. Then, in the third step, I go back to the initial phase of decision making of each country, the relative strength of actors in influencing policies, public demand, ideological preferences of the state, and the resources available for an energy technology to grow. By comparing the mechanisms used in two countries I eliminate the least probable mechanisms based on their explanatory power. To eliminate the weakest mechanisms, I use process tracing as a method. With the gradual elimination of the weak mechanisms, I identify the mechanisms with the strongest explanatory power.

For the convenience of moving from one step to another and describe the causal story in a systematic way I describe the causal links in the process of answering two questions. This story telling helps to describe the process of eliminating the weaker mechanisms and reveal the strongest ones. These two questions are:

1. Why nuclear was cancelled in Vietnam and adopted in Bangladesh?

2. What drove Vietnam to rapidly increase its solar share and why Bangladesh could not do it?

The analysis uses the existing explanations as a basis to identify the challenges faced by the explanations. The scepticism about the initial explanation leads to further analysis of the evidences and logically deduct why certain mechanisms worked and others did not completely work to have a significant impact on the energy outcome.

4.6 Summary

Table 4-2 Research design and method

	Chapter 5	Chapter 6	Chapter 7	Chapter 8	Chapter 9
	The History and the Context of Energy Transition in Bangladesh	Solar Power in Bangladesh	Geopolitics and Nuclear Power in Bangladesh	New Fossil Fuels: LNG, and Coal	Comparing electricity transition of Bangladesh and Vietnam
Countries	Bangladesh	Bangladesh	Bangladesh	Bangladesh	Bangladesh and Vietnam
Technologies	Gas, oil, coal, LNG, nuclear, solar	Solar	Nuclear	Coal and LNG	Nuclear, Solar
Periods	1971-2020 (5 episodes)	1980-2023	2010-2023	2010-2023	2010-2023
Methods	Qualitative Longitudinal case study	Mixed method (Individual case study based on Interview and statistical Analysis)	Qualitative (Individual case study with elements of process tracing)	Qualitative (Individual case study with elements of process tracing)	Qualitative (Comparative case study with process tracing, and using findings from chapter 5,6,7)
Case Selection	Individual emerging country case of energy transition	Individual emerging country using new low carbon granular technology	Individual emerging country using low carbon lumpy technology	Individual emerging country using new fossil fuel technology	Most similar cases with well documented similar history of electricity liberalization and development phases.
Objective	Identify historical precedence of solving past energy crisis of a developing country, evolution of actors leading to path dependence and institutional lock-in.	Identify the techno-economic, socio-technical, and political mechanism of diffusion of a new granular technology	Identify the techno-economic, socio-technical, and political mechanism of diffusion of a new lumpy technology	Identify the techno-economic, socio-technical, and political mechanism of diffusion of new fossil fuel-based electricity technology	Validate the findings from the first four chapters by comparing with a similar case

5 The Structure and Evolution of Energy System in Bangladesh

5.1 Introduction

In my quest to understand the energy transition mechanisms of developing countries, particularly Bangladesh, I began by analyzing recent developments in Bangladesh's power and energy sector. This process necessitated a historical analysis of the past policies and measures implemented. I realized that there is no historical account of the transformation of the power and energy sectors since its independence. The existing literature was written either by scientists and engineers, or the literature (reports, project evaluations, policies, memos, plans, guidelines, and strategies) was prepared mostly with the support of international and bilateral development agencies. No comprehensive analysis was available on how Bangladesh handled previous crises, the policies implemented, or the responses adopted. In an attempt to gather long-term data, I initially wrote this chapter to give an introduction to the context in which the energy transition mechanisms evolved. As I progressed through my PhD journey, I realized that, without understanding the actors and institutions and their historical evolution, the quantitative data did not explain much of what was necessary to understand the mechanisms. This realization drove me to analyze the historical data and find out how the power and energy sectors have transformed over the decades.

The historical evolution of actors and institutions, and their roles in the current scenario are inextricably linked to the causal mechanisms discussed in other chapters. This chapter explains the institutions and actors involved in the causal mechanisms, sheds light on why certain actors and institutions adopts inefficient policies despite knowing the consequences, and explores whether these institutions have developed any inertia that is difficult to change.

Since gaining independence in 1971, Bangladesh has witnessed significant transformations in its power and energy sectors over the span of five decades. During this time, the realms of politics, economy, institutions, and society have undergone various stages of evolution. The structural changes in the economy, the growth in electricity demand, and technological changes made new policy options available to different types of actors. When each phase of global and national crises created new opportunities, both external and internal actors evolved and influenced policies to take advantage of them. Bangladesh has adopted numerous policies and plans, as well as developed financing mechanisms, institutions, and regulations in order to increase commercial production of power and energy.

This chapter uses an institutional analysis framework to analyze five decades of historical power and energy development (from 1971 to 2020) and how historical episodes shaped the recent phase of transition from 2021 to 2024. It explores the evolution of actors and institutions that shape the energy transition mechanisms. Through analyzing the crises of the last five decades and the responses to crises, it reveals how a pattern has developed historically in the politics and culture of power and energy planning.

In the last 50 years, demand for power increased seventy-fold (from 183 MW maximum in 1971 to 12738 MW maximum in 2020), while population increased 2.5 times (from 66 million in 1971 to 168 million in 2020). Per capita consumption of electricity increased 36 times (from 10.46 kwh in 1971 to 378.16 kwh in 2020). To meet the growing demand for electricity, installed capacity increased 37 times (from 547 MW in 1971 to 20,383 MW in 2020). This chapter sets the context of the dissertation by revealing the long-term changes in the indicators of the energy system, identifying the character of the institutions and actors, and introducing the evolutionary process through which the energy system developed with the interaction of three systems: the techno-economic system, the socio-technical system, and the political system.

This chapter begins with an analysis of the power and energy indicators from the time of independence. I provide a detailed explanation of the method in Section 5.2. In sections 5.3 I show the changes in indicators in Fifty years. Section 5.4 uses the empirical observations to explain the evolution of actors and institutions. In Section 5.5, I utilize the analysis from previous sections to discuss the mechanism of path dependence. Section 5.5 summarizes the findings.

5.2 Method of longitudinal case study

5.2.1 Longitudinal case study

The research design outlined in Chapter 3 describes the reason for selecting Bangladesh as a longitudinal national case representing developing countries. In this section, I provide an in-depth explanation of process tracing. The longitudinal case study is necessary in the analysis of energy transition because one of the objectives of the thesis is to analyze the historical evolution of institutions and actors and explore their role in energy transition mechanisms. The longitudinal case study on Bangladesh's power and energy sector over the period of 50 years analyzes both qualitative and quantitative data for process tracing. The case study considers fifty years (from the 1970s to the 2000s) for longitudinal analysis because Bangladesh became independent in 1971, when the birth of a new nation marked the formation of a state free from external domination.

In order to explain the causal process linking the chronological developments, I divide the time into five episodes. Each episode consists of a decade, starting from the 1970s to the 2010s. Dividing the episodes is useful for a deeper understanding of crises, policy responses, reform measures, changes in political power, and the level of development in the country.

5.2.2 Process tracing

The objective of process tracing is to find the most relevant mechanisms of evolution among actors and institutions that shaped the energy transition in Bangladesh. The process tracing intends to accept or reject the hypothesis formulated in the first step. It uses deductive reasoning to systematically find out if there is any common pattern that may lead to path dependence, that cannot be reversed.

I outline the detailed steps of the process and the objectives of each step. I use seven steps to process trace the existence of path dependence.

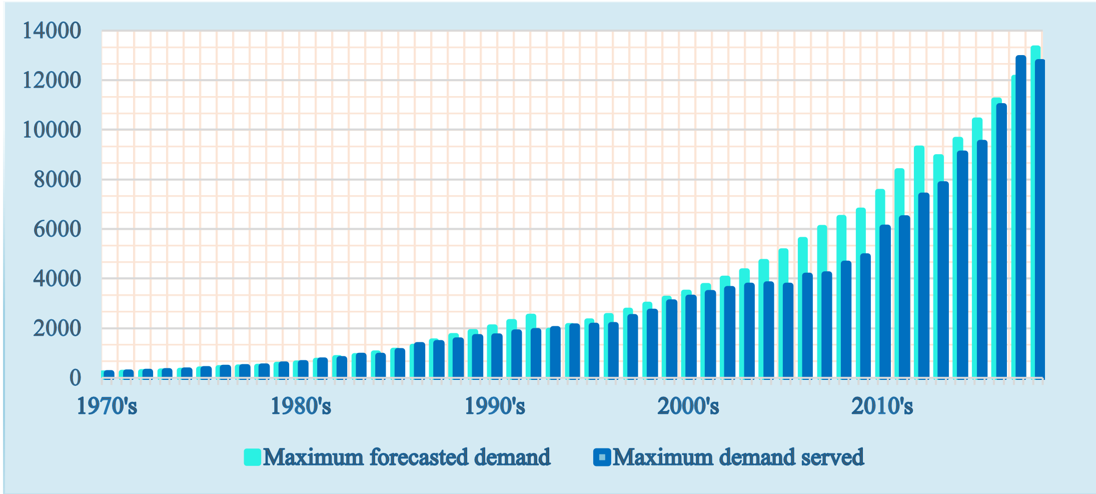
Table 5-1 Steps of process tracing

	Objectives	Steps of Process Tracing
1.	Hypotheses formulation	(i) There is an institutional lock-in.
		(ii) The root cause of the institutional lock-in is path dependence.
2.	Identify common institutional pattern	Find the early crisis period and the following crisis periods in Bangladesh's history of power and energy development.
		Examine the state's crisis responses and determine whether they follow any common pattern.
		Analyze the crisis responses and determine what drove the country to take repeated actions that relied on external resources.
3.	Identify critical juncture	In order to confirm the hypotheses, first identify the critical juncture based on the observations.
		Identify similarities in the policies in critical juncture.
4.	Identify source of path dependence	Identify alternative paths that could be taken.
		Explain under what kind of circumstances the paths were taken and whether the circumstances were created exogenously.
		Explain the characteristics of the actors and institutions that evolved after the first crisis.
5.	Identify if path dependence persists	Use empirical observations to explore how the path taken in the first crisis created an increasing return from dependency.
		Examine the reasons behind the adoption of a similar strategy during the second crisis. What were the roles of actors and institutions in adopting a similar approach?
6.	Find the reason of Irreversibility of path dependence	Identify the constraints that prevented the country from taking an alternative path again.
		Determine why it is challenging to remove the constraints and the extent to which the institutional structure has incorporated them.
7.	Hypotheses rejection or acceptance	(i) There is an institutional lock-in.
		(ii) The root cause of the institutional lock-in is path dependence.

5.3 Changes in the power and energy indicators (1970 - 2020)

Bangladesh has gone through a persistent energy crisis since independence. The crisis in the 1970s was mainly caused by rising oil prices and a lack of capacity to meet electricity demand. From the mid-1980s on, the gap between forecasted demand and demand served started to increase rapidly. The gap between demand and supply started to increase further in the 1990s and 2000s, and from 2005 until mid-2015, it was the highest.

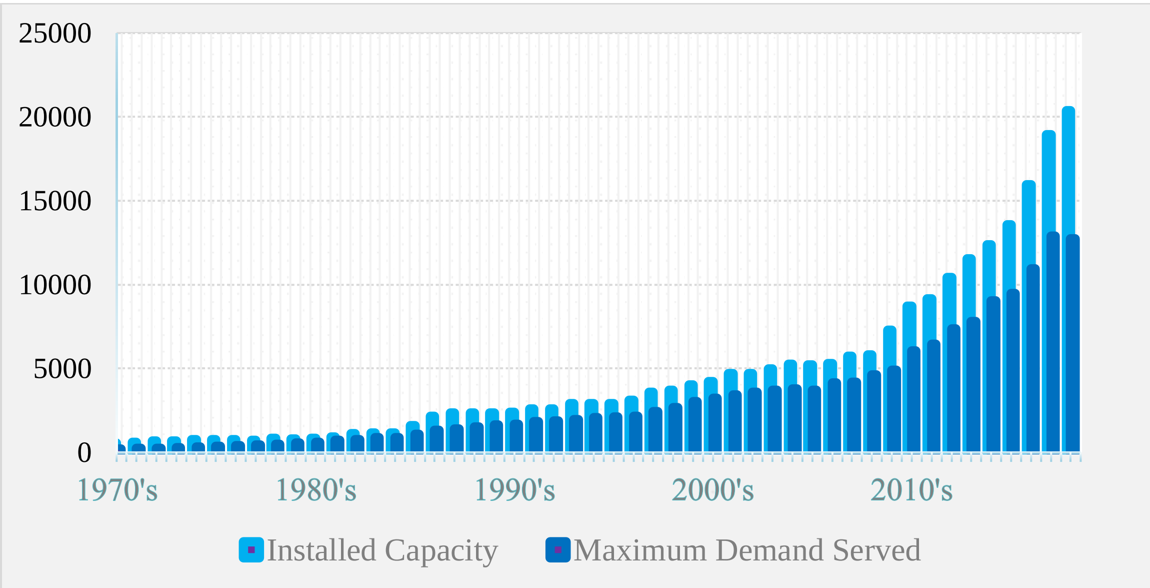
Figure 5-1 Maximum forecasted demand and maximum supply in MW (1970's-2010's)



Source: BPDB Annual Report, 2020

Every decade, Bangladesh's installed capacity has increased. From the mid-1980s onwards, the growth of the service sector and increasing urbanization led to a faster growth in demand compared to the 1970s and early 1980s. From 2010 onward, the increase was sharper. Installed capacity also experienced the highest growth from 2010 onwards.

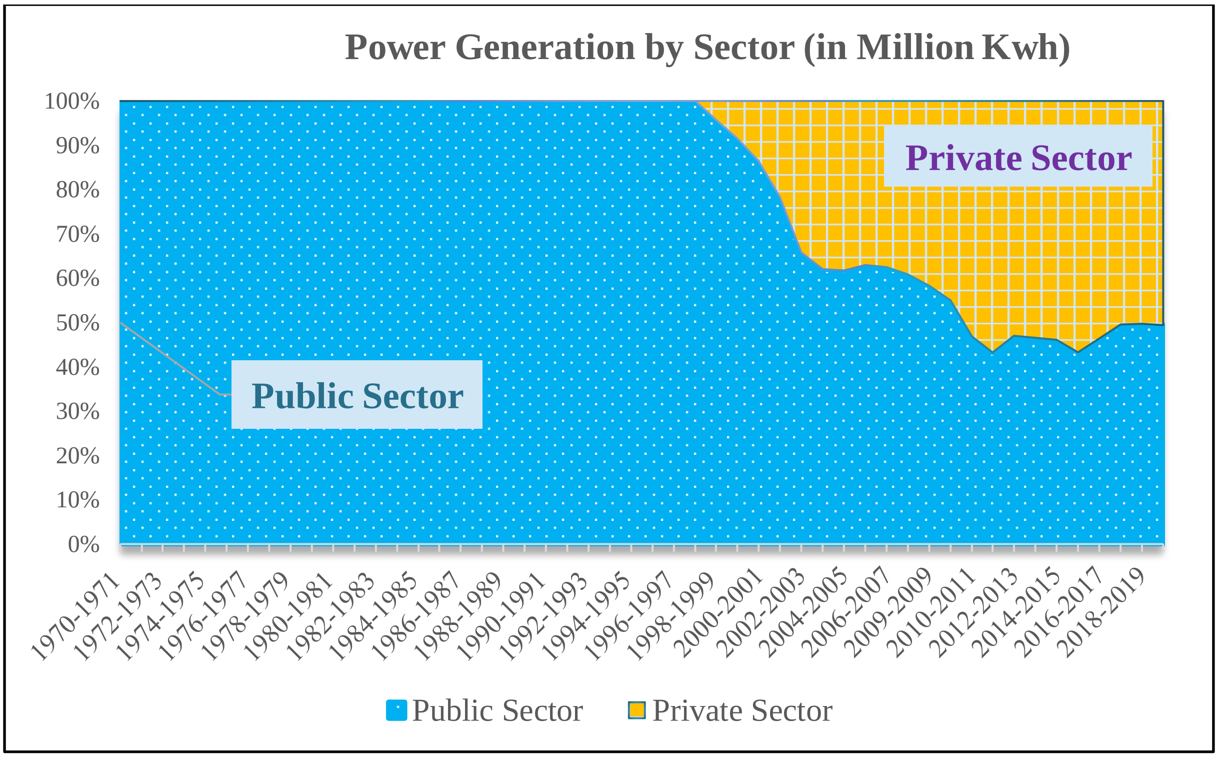
Figure 5-2 Installed capacity against maximum demand in MW (1971-2020)



Source: BPDB Annual Report 2020

After independence, the public sector had the sole responsibility of generating power. Since the power sector reform started to encourage private sector participation in the late 1990s, the scenario has changed. Since 1997–98, when the private sector started to produce electricity, the share of electricity generation by the private sector has gradually increased to 50% in 23 years (1998–2020). This section illustrates the trend of various indicators, highlighting Bangladesh's gradual transition to an import-dependent economy and the significant impact of private sector participation on the electricity sector.

Figure 5-3 Power generation by public and private sector (1970-2019)

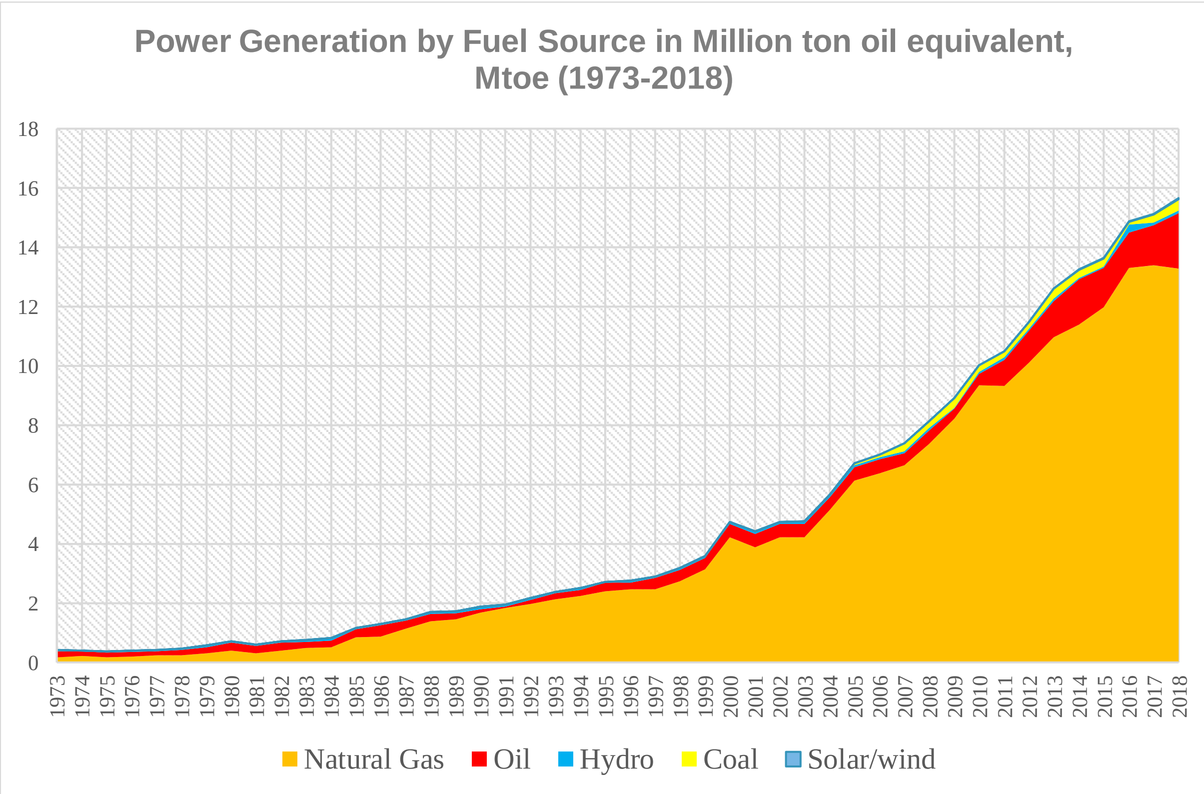


Source: IEA, 2020

With the growing participation of the private sector in power generation, both generation costs and prices have increased. The minimum retail tariff increased from 2.60 Tk/kwh in 2010 to 3.75 Tk/kwh in 2020. Additionally, the maximum retail tariff increased from 8.45 Tk/kwh in 2010 to 12 Tk/kwh in 2020. (GoB, 2020) Per unit generation cost increased from 3.95 Tk/kwh in 2010 to 5.91 Tk/kwh in 2020. (GoB, 2020)

Since 1971, the fuel mix in power generation has changed significantly. In 1973, import oil accounted for around 50% of the power production. Bangladesh has reduced its dependence on imported oil by gradually developing the gas sector and using indigenous gas in power generation (IEA, 2020). In 2018, indigenous natural gas generated 63.51% of the power. In 2018–19, Bangladesh began importing LNG, and by 2020, natural gas and imported LNG accounted for 71.8% of electricity generation. LNG imports grew so fast that by 2020, approximately 30% of the gas would consist of imported LNG. Furthermore, Bangladesh has begun to use less oil and more coal for power generation. It has also started to import more electricity from India. While the share of coal has increased from 2.7% in 2018 to 4.16% in 2020 and imports have increased from 7.63% in 2018 to 9.34% in 2020, In last two years, the use of oil has decreased from 24.52% in 2018 to 13.45% in 2020.

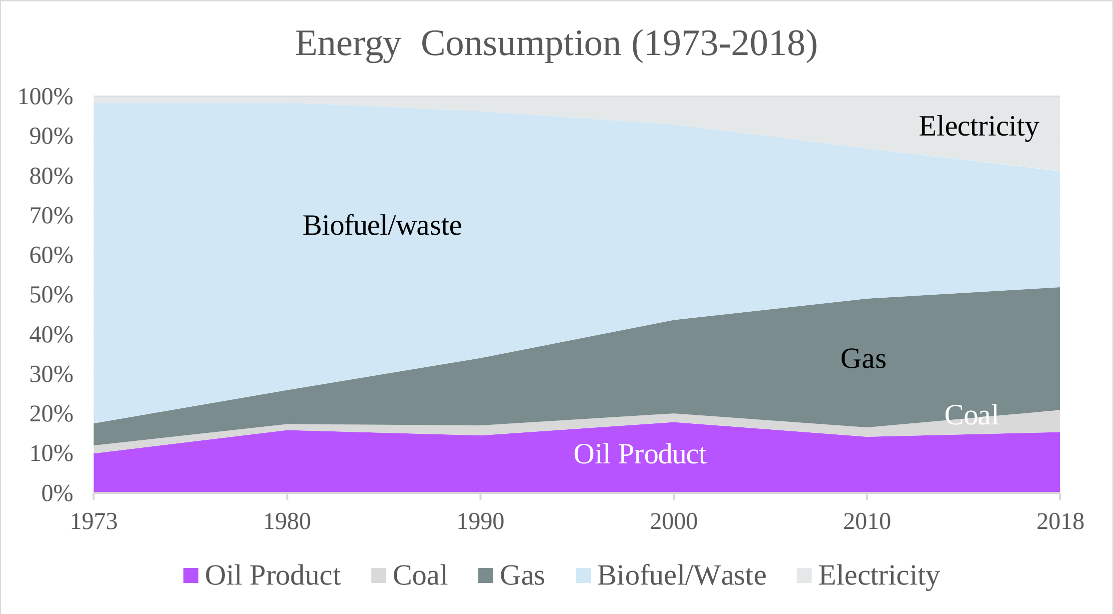
Figure 5-4 Power generation by fuel source



Source: IEA, 2020

Total energy consumption has changed since 1970s. All types of energy consumption have increased. However, the share of energy use did not change equally. While the share of electricity, gas, coal, and oil increased, the share of biofuel/waste decreased in the total energy consumption.

Figure 5-5 Energy consumption in Bangladesh (1973-2018)

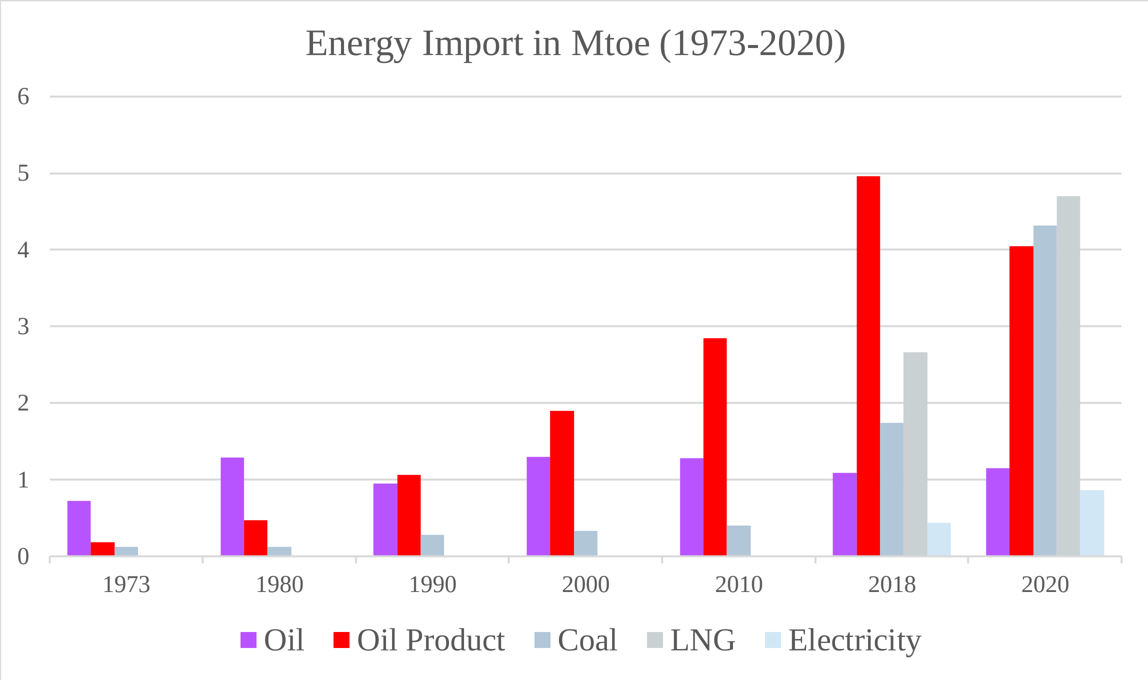


Source: IEA, 2020

Energy imports have changed significantly since the 1970s. While oil imports have increased slightly, there has been a significant increase in oil products. Although coal imports increased gradually from the 1970s to 2010, after 2010, they increased fourfold in the following eight years (from 2010 to 2018). From 2018-2020, coal imports have more than doubled. In 2018, Bangladesh also began to import LNG. LNG imports also doubled from August 2018 to June 2020. **(**Hydrocarbon Unit 2021)

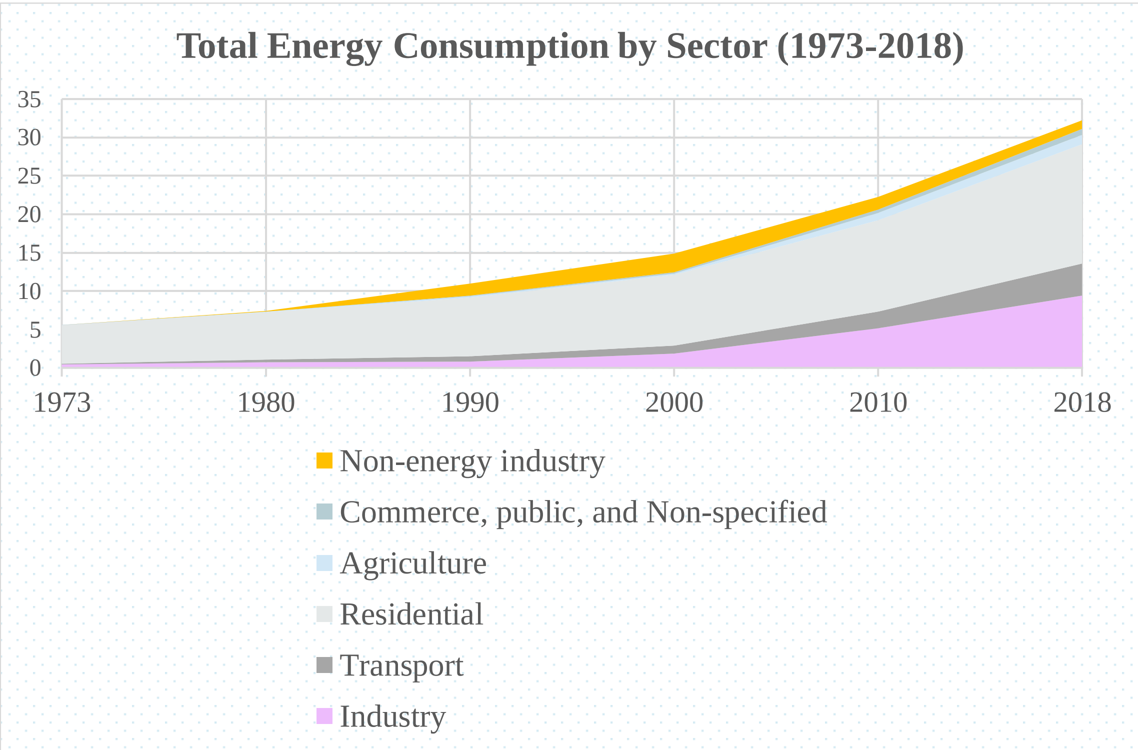
The share of residential energy use was the highest (89%) and industrial energy use was low (8.6%) in the 1970s, when the economy was mostly agriculture-based. With structural change in the economy from predominantly agriculture-based to growing service- and manufacturing-based, the use of energy in industry (29%), transport (13%), commerce, and the non-energy industry (2%) increased both in absolute and relative terms. However, residential energy consumption remained the highest after 45 years (48%). With increased use of energy in irrigation agriculture, energy use started to increase in the late 1990s, and by 2018, the share of energy use in agriculture had become 3.7%.

Figure 5-6 Energy import (1973-2020)



Source: IEA, 2020

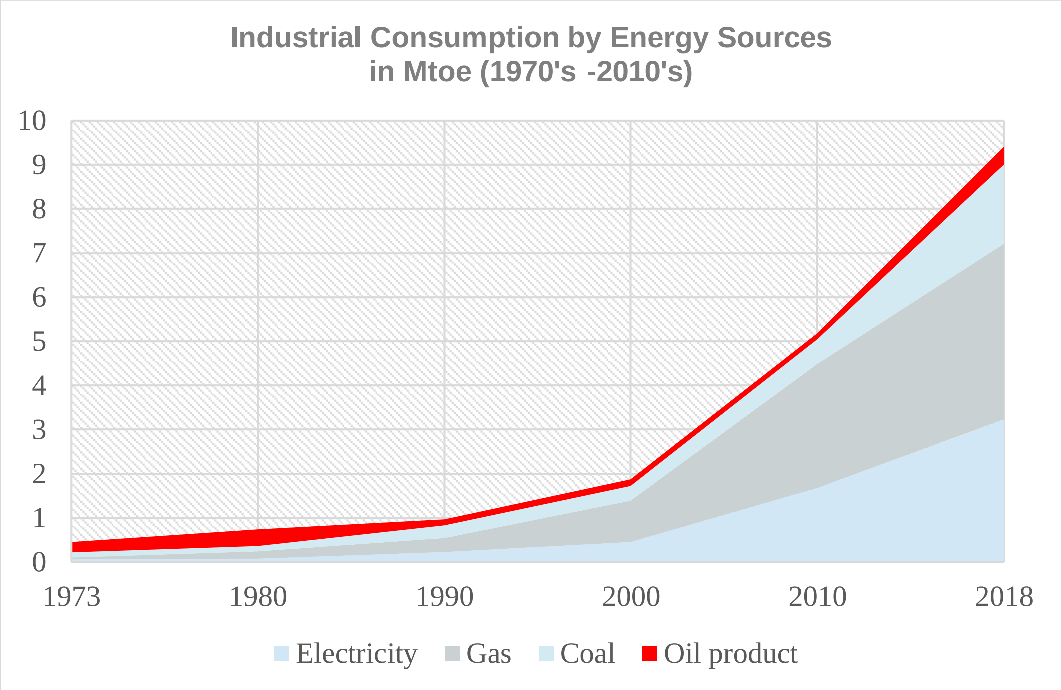
Figure 5-7 Total energy consumption by sector (1973-2018)



Source: IEA, 2020

Over the five decades, the contribution of industry and the service sector to GDP has increased. While the share of industry increased from as low as 7 percent to 28 percent and the share of the service sector increased from as low as 35 percent to more than 50 percent, the share of agriculture in GDP declined from as high as over 60 percent to less than 15 percent. The change in industrial energy consumption reflects this structural change. The following diagram shows the use of different types of energy by the industrial sector. It shows that although use of all types of energy increased in five decades, gas, electricity, and coal started to increase more sharply after 2000. In the last 20 years, electricity use has increased seven times, gas use has increased more than four times, and coal use has increased more than five times.

Figure 5-8 Industrial consumption by energy sources (1970s-2010s)



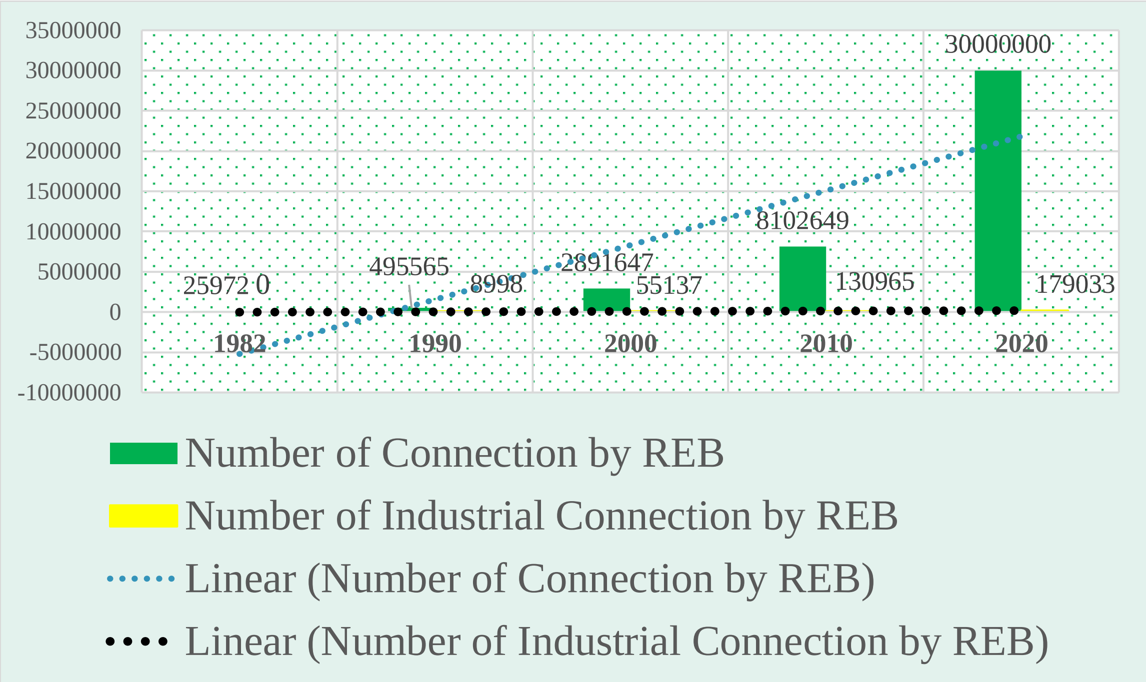
Source: IEA, 2020

Immediately after independence, the contribution of the industrial sector was insignificant. In the 1980s, manufacturing was between 13% and 17%, and it reached 20% in 2019. In Bangladesh, the service sector is the most dominant economic sector in terms of output. The service sector accounted for 66.8% of GDP in 2019. The expansion of banking, insurance, micro-credit, transportation, and telecommunications has contributed to this sector's growth.

In the four decades since Bangladesh began rural electrification, the number of connections increased significantly after 2010. The expansion of the grid brought many remote areas under grid connection, which in turn led to an increase in the number of new connections.

The following diagram illustrates the rise of new connections from 1980s to 2020s. Among the new connections, industrial connections rose from 55,137 in the 1990s to 179,033 in 2020. This increase shows that industrial activities have risen over the last four decades as grid expansion occurred.

Figure 5-9 Rural electrification (1980 -2020)



Source: Rural Electrification Board (REB), 2020

5.4 Empirical Analysis

5.4.1 Episode 1: 1970s

Oil Shock, Petroleum Act, Nationalization, International Participation in Domestic Resource Extraction, and US Model in Rural Electrification (1971-1980)

When Bangladesh gained independence in 1971, the war-torn country's economy suffered not only from bad harvests, flooding, and the food crisis, but also from the rise in international oil prices in the early 1970s. At that time, faced with the oil crisis, the whole world started to explore the possibilities of extracting indigenous energy resources to ensure energy security.

Bangladesh also needed to explore its own oil and gas resources to reduce its dependency on imported oil.

5.4.1.1 Response to the international oil crisis

At the onset of the oil crisis, the consumption of petroleum products in Bangladesh remained stagnant between 1971 and 1980. At that time, 60% of the energy used came from traditional fuels such as animal and vegetable waste. The fuelwood resources, both in government forests and private woodlots, were being overexploited. Between 1971 and 1978, fuelwood prices increased by an average annual rate of 40%. The entire domestic demand for oil and petroleum products was met through imports from Iran, Saudi Arabia, Iraq, and the U.A.E. In the 1980s, the import bill stood at about 80% of the export earnings. (World Bank, 1983) While motor spirit and kerosene consumption decreased, diesel oil consumption increased. Diesel oil was mostly used in transport, power generation, and agriculture. The oil crisis pushed Bangladesh to become more dependent on domestic resources. Consumption of natural gas increased sharply, and by 1979, it was equivalent to 1.1 million tons of oil. (World Bank, 1982a) While coal, petroleum, and hydro remained stable, the commercial use of natural gas almost doubled from 1975–76 to 1980–81. (World Bank, 1982b) In 1973, Bangladesh's electricity came from three sources: hydroelectric: 23.6%, natural gas: 34.7%, and oil: 41.7%. By 1979, the same distribution had changed to hydroelectric: 24.4%, natural gas: 45.6%, and oil: 29.9%. (World Bank, 2019)

5.4.1.2 National institutional capacity development and state ownership

Throughout the 1970s, when nationalization of oil companies was a trend across the Middle East. Influenced by the policies adopted at that time, Bangladesh also decided to establish its own national institution to facilitate the development of oil, gas, and mineral resources. In 1972, Bangladesh Minerals, Oil, and Gas Corporation (BMOGC) was established to deal with the exploration and development of oil, gas, and mineral resources. Later, when mineral exploration was segregated and placed under a new organization named Bangladesh Mineral Exploration and Development Corporation (BMEDC), BMOGC became Bangladesh Oil and Gas Corporation (BOGC) and was short-named "Petrobangla" by Ordinance on August 22, 1974. On August 9, 1975, the government purchased five gas fields—Titas, Habiganj, Rashidpur, Kailashtila, and Bakhrabad—from a British company, Shell Petroleum Company

Limited, for a nominal amount of 4.5 million- pounds sterling. This landmark decision taken by the then-government laid the foundation for the energy security of the country by introducing sole ownership of the state over these major gas fields. According to Imam (2013), this may be considered the most successful negotiation between Bangladesh and the IOC.

With the objective of having state control over the import, export, refinery, and market of crude oil, Bangladesh established Bangladesh Petroleum Corporation (BPC) in 1977. It discharged its functions to nationally acquired foreign-owned subsidiaries like Burmah Eastern (a successor to Burmah oil company with 40% share), Jamuna (a successor to Pakistan oil company with 32% share), and Meghna (a successor to ESSO Eastern Inc. of the United States with 27% share).

5.4.1.3 International participation in domestic energy resource extraction

The Bangladesh Petroleum Act was enacted in 1974 to facilitate international participation under a production sharing contract (PSC). The first PSC round was held in 1974. The Bay of Bengal was divided into six blocks and awarded to six international oil companies. (Appendix I) These blocks were in the shallow sea up to a water depth of about 200 meters. (Imam 2013) The companies that signed PSCs were: ARCO, Ashland, Canadian Superior Oil (CSO), Bengal ODC (Japex), Ina Nampthaplin, and Union Oil. "Following the seismic surveys, the companies drilled a total of seven wells during the period of 1974–1977. All of these contracts were relinquished by 1978, following a combination of unsuccessful drilling, poor incentives, and political uncertainty. The only success was the discovery of the offshore Kutubdia gas field by Union Oil (later named Unocal, now Chevron)." (Imam, B. 2013)

5.4.1.4 Oil exploration

In an effort to find oil during the oil crisis, Bangladesh received assistance from the USSR for drilling exploration wells. Despite considerable efforts, no significant oil or gas discoveries were made in the 1970s. In 974, exploration activities by the IOCs started. This round of activities also became unsuccessful, except for the discovery of gas in Kutubdia. By 1978, the IOCs had finally withdrawn from the offshore areas after conducting extensive seismic surveys and drilling seven offshore exploration wells. (Imam 2013)

5.4.1.5 Gas sector development

Before independence, Bangladesh's gas sector started its journey in the 1960s. According to Imam (2013), the decade of the 1960s was a golden era for gas discovery because in 1961, Oil and Gas Development Corporation (OGDC) was established, and Shell Company discovered five large gas fields: Rashidpur, Kailashtila, Titas, Habiganj, and Bakhrabad. These fields were nationalized in 1972 by the new Government of Bangladesh (GOB), and the part of OGDC was reorganized and named Bangladesh Mineral Oil and Gas Corporation (Petrobangla). Initially, the use of natural gas was confined to fertilizer and cement plants. After Titas Field was discovered in 1962, transmission and distribution facilities were built to connect users in and around the greater Dhaka area. Gas utilization grew at a compound rate of 11.8% between 1976 and 1980. This high rate of growth reflects the low cost of natural gas relative to other commercially imported energy sources. In 1980/81, 38% of the gas was used in the power sector, 36% by the fertilizer industry, 16% by other industries, and 10% by the domestic and commercial sectors.

According to a joint UNDP/World Bank Report (World Bank 1982), Bangladesh has very large gas reserves relative to domestic demand for at least till 2000, and fuel oil could be substituted by gas. Without massive gas exports (a prospect that can only be considered very modest over the next several years), the opportunity cost of gas will fall to its long-run supply cost." According to the 1983 World Bank Report, Bangladesh had a natural gas reserve of 12.3 to 13.4 trillion TCF, of which 75% was recoverable. Initially, technical and financial assistance from the Soviet Union, West Germany, and Great Britain supported Petrobangla's exploration activities, like geological, geophysical, and drilling activities. Petrobangla started its exploration drilling in the Muladi-Begumganj area of southern Bangladesh in the mid-70s and discovered the Begumganj gas field in 1977. During the 1970s, 10 exploratory wells were drilled and two gas fields were discovered.

5.4.1.6 Rural electrification

The Rural Electricity Board was established in 1977 with funding from USAID. The model of community-based rural electrification originally stemmed from the 1930s US model, in which consumers form cooperatives and operate the board based on democratic principles. Membership is open and voluntary, and members have the right to elect representatives, which form the board of the cooperative. These representatives then have the right to appoint a manager of the cooperative. 7–20 staff members manage the day-to-day business. This model was successful in the US, as 99% of rural areas were under complete electrification. It was later replicated in countries like Bangladesh. In Bangladesh, the cooperatives are known as Palli Bidut Samities (PBS), through which local personnel carry out their primary duties. By 2020, REB reached 3 crore consumers in both on-grid and off-grid areas. From 1978 until 2020, a 5.3 lac KM distribution line was created. Beside residential consumers, in 42 years REB reached 180,000 small industries, 15,000 medium industries, 374 large industries, 8 EPZ, and 360,000 irrigation pumps by 2020. (Rural Electrification Board, 2020)

5.4.2 Episode 2: 1980s

External Influence in Exploration, Gas Regime Formation, and Capacity Building, Formation of BAPEX, and Bangladesh Petroleum Institute (1981-1990)

The 1980s were the decade of electricity reform in the USA and the electricity liberalization experiment in Chile. Since the oil crisis started, the electricity sector has suffered losses, and dependency on subsidies is increasing. As a solution, many developed countries started to go through gradual liberalization. At that time, the demand for electricity was increasing in Bangladesh. With increasing migration from rural to urban areas and growing service sector were pushing upward pressure on the demand for electricity. In the beginning of the 1980s, two-thirds of all energy consumed used to come from noncommercial energy sources such as crop residues and animal waste. The third major source of energy was oil and gas. During this decade, dependency on domestic gas increased while the share of oil in electricity production decreased. Bapex was formed to explore more indigenous gas resources to meet the rising demand.

5.4.2.1 Petroleum exploration led by the World Bank

During the 1970s, the world oil price increased fivefold in real terms, which had a profound impact on the economies of developing countries like Bangladesh. However, until the 1980s, there had not been much progress in exploration in many developing countries like Bangladesh. The state-run oil companies in countries such as Colombia and Mexico were successful in finding and developing oil fields. (World Bank, 1992) But many countries remained dependent on imported oil. In fiscal year 1982, net oil imports accounted for about 87% of the country's total foreign exchange earnings. It was a huge burden for the economy.

One of the World Bank reports (1992) acknowledged that due to limited financial resources and a lack of interest by international companies, poorer countries were unable to explore their indigenous resources of oil and gas with their own means. They remain import-dependent, and their economies generally suffer from increased energy import costs, thereby exacerbating their balance of payments deficit. At that time, the World Bank started to assist developing countries in mobilizing capital and attracting international oil companies to accelerate the exploration and development of domestic petroleum sources.

The World Bank started a petroleum exploration and promotion program in the 1980s. It provided assistance for the development of energy legislation and policies for acquiring and organizing geological and geophysical (seismic) data to facilitate the evaluation of hydrocarbon potential. As part of the institution building for upgrading the capability of BOGMC, a seismic data processing center was established in Dhaka in 1985 with contractor personnel and counterpart BOGMC staff. All the data from the seismic surveys was processed at the center. The local personnel were trained to the point where they were able to run the center themselves. New equipment was provided to upgrade BOGMC petrophysical and geochemical laboratories, and BOGMC personnel were trained to use the new equipment.

Petrobangla discovered the first commercial oil pool in Haripur in December 1986. In 1987, Scimitar Exploration was awarded the block under an unsolicited and controversial PSC deal. Under the deal, the block was leased out for exploration and development of the Haripur oil field. A people's inquiry commission found that the PSC deal was against the national interest. Scimitar drilled two wells and discovered the Jalalabad gas field, but failed in the Haripur oilfield. Later, due to being unable to fulfill contractual obligations and alleged fraud, the contract with Scimitar was canceled.

5.4.2.2 Gas exploration and failed PSC

BOMGC drilled nine wells in some of the best acreage with identified structures and discovered commercial quantities of gas. Some IOCs were interested in that same acreage. On the other hand, according to the 1992 World Bank Report, although BOMGC approved the conditions of the promotion, it took a year to receive GOB's approval. This delay in decision-making, coupled with the absence of an attractive gas utilization policy, is considered one of the main contributing factors to the failure to attract and sustain the IOC's interest in Bangladesh, as these were perceived as lack of interest by the government in the promotional initiatives. However, in this decade of 1980s, the average daily gas production of Petrobangla increased almost four times, from 126 mmcf in 1979–80 to 460 mmcf in 1989–90.

During the 1980s, there was infrequent activities within the oil industry, with an average of one or two wells being dug annually. In the 1980s, Production Sharing Contracts (PSC) were introduced, with Shell signing the first one in 1981 and Scimitar signing the second one in 1987. In 1988, a new version of the PSC was established, which was then followed by a licensing round. During this round, the country was divided into twenty-three blocks. The round yielded no success, as only Texaco and Unocal JV showed genuine interest. During the second Production Sharing Contract (PSC) round in 1986/87, Shell Oil Company received the rights to explore and develop two onshore blocks: Block 22 located in the Chittagong Hill Tracts, and Block 23, which is the northernmost onshore block. Shell conducted drilling operations at a single well in Sitapahar, located in the Chittagong Hill Tract. However, their activity was halted because resistance from the local inhabitants of the Chittagong Hill Tract. Shell employees were once abducted and subsequently freed upon payment of the ransom. Shell has recently completed the drilling of a new well in the northern region but later relinquished it and left the country as it was dry. (Imam, 2013)

During this decade, gas dependency gradually increased, and by the end of the decade, natural gas became the predominant source of energy after traditional sources (52%). By the year 1990, 30% of the energy came from gas, 16% came from oil, and 3% came from hydro.

5.4.2.3 National capacity building effort

In 1989, Bangladesh Petroleum Exploration Company (BAPEX) was formed to work as an exploration company under Petrobangla. Later, Bapex became an exploration and production company. Since its inception, Bapex has continued its exploration, with several successes in the 1990s. The Bangladesh government understood the need for establishing an institution for building human resources in the hydrocarbon sector. In 1981, the Bangladesh Petroleum Institute was established by the government of Bangladesh under the Ministry of Energy and Mineral Resources. The main objective of BPI was to train professionals and technicians engaged in the petroleum sector.

5.4.3 Episode 3: 1990s

Electricity Reform, Petroleum Policy, Production Sharing Contract, Negligence of International Companies (1991-2000)

The decade of 1990 can be marked as the beginning of electricity reform in Bangladesh, an increase in gas production by national companies (BGFCL, SGFCL, and Bapex), an increase in gas reserve discovery, and the signing of Production Sharing Contracts (PSCs) with IOCs. The government of Bangladesh has initiated the vertical unbundling of the electricity sector by creating separate publicly owned entities for generation, transmission, and distribution and by developing a single buyer market model. In 1996, independent power producers (IPP) entered the electricity market. The new IPPs were supported by the attractive policies of the government. The national companies were the main source of cheap gas for electricity production. Seven gas fields of 7.77 tcf were discovered in this decade. The annual gas production of national companies rose from 172.7 bcf in 1990–91 to 307.8 bcf in 1998–1999. (Imam, B. 2013) In 1991, the share of gas in producing electricity reached 93%, the share of oil decreased to 2.56%, and hydro became 3.5%. The use of gas in power production increased from 1.83 mtoe to 3.28 mtoe in 2000. By 2000, gas was still a major source of energy for electricity. During this time, the use of oil in electricity increased seven times, from 0.05 mtoe in 1991 to 0.35 mtoe in 2000. (IEA. 2020)

5.4.3.1 Policy reform

After 15 years of military dictatorship (1975–1990), the first BNP-led democratically elected government began crafting new policies. In mid-1993, the government published a new petroleum strategy to guide hydrocarbon development after the World Bank advised it to strengthen oil and gas incentive and contractual terms. Afterwards, Petrobangla conducted an investment promotion roundtable conference for foreign oil corporations in late 1993. This meeting, arranged by expert consultants and supported by the World Bank, spurred gas exploration by foreign private capital. (2004) World Bank

In 1996, the first National Energy Policy was passed. In addition to ensuring proper exploration, production, distribution, and rational use of energy sources to meet growing energy demand, the 1996 National Energy Policy encouraged public and private sector participation in energy sector development and management. That energy policy was heavily influenced by foreign financial institutions like the World Bank Group and ADB. M. Sultana (2016), 254.

When the Awami League ruled from 1996 to 2001, the first model PSC was created in 1997. Four joint venture PSCs were awarded to IOCs and Petrobangla. (Appendix I has more.) Before the election, the Awami-led administration outlined long-term goals in the “Vision and Policy Reforms for Power Sector Reforms 2000,” which called for foreign direct investment to expand the sector.

Since 1994, the ADB has helped prepare the "Power Sector Reforms in Bangladesh" (PSRB) document and the World Bank has helped form power cells. PSRB suggested unbundling the electricity sector, corporatizing sector entities, and creating an independent regulatory commission. Power Cell was developed to enable these changes. ADB helped the government with all PSRB aspects, including vertical electricity unbundling and private sector investment promotion and finance. Asian Development Bank (2009) The 1996 Private Sector Power Generation Policy outlined standards for local and foreign private firms. Foreign investors, consultants, and private power producers received tax and income tax breaks under this strategy. For technical support, this approach favored international financial institution funding.

In 1998, a private sector small power plant (SPP) policy guideline was produced and later it was modified in 2008. Private investors could fast-track, build-own-operate small power plants (SPP) to generate electricity for private use and sell the surplus to other consumers under this proposal. IPP contracts were issued for Meghnaghat and Haripur in 1998. Sultana (2016)

The planning process of establishing cross-border electricity interconnections also started in this decade, when USAID first completed the pre-feasibility study on four border electricity interconnections conducted in 2000. Throughout the 1990s, the policy focus was on finding a quick solution to the problem of emerging power shortages. The government dealt with energy shortages in a number of ways. A captive power solution has been used to solve the immediate crisis in some industries since 1996. According to Islam (2008), captive power failed to achieve economic scale and inflated energy demand. (Islam 2014) Gas rationing has become common for fertilizer production, businesses, households, and several industrial plants. Natural gas made a tremendous contribution to industrial growth in the country as a fuel for heating and captive power generation at a very favorable price. Later, by 2019, captive electricity generation used 15 percent of the gas. However, later it has become difficult to move away from this captive power dependency.

5.4.3.2 IOC's interest in gas exploration

Beginning in the 1990s, IOC delegates expressed interest in Bangladesh exploration. Countries were divided into 23 blocks for IOC bidding. Four companies—Occidental, Cairn, Okland/Rexwood, and United Meridian—signed PSCs for eight blocks in the third phase. Occidental discovered Moulavibazar and Bibiana gas reserves in 1997 and 1998. Cairn Energy discovered the offshore Sangu gas field in 1996 and began production in 1998. Four blocks were awarded to Shell Oil/Cairn Energy, Unocal, Tullow, and Chevron Texaco in the 1997 fourth PSC round. Bapex received 10% of each block. Chevron Texaco sold its stake to Niko Resources. (See Appendix I)

When Occidental was drilling in Magurchhara in 1997, a gas blowout squandered 200 billion cubic feet of gas worth 500 million USD. Explosion losses are estimated between Tk 90 billion to Tk 140 billion. Over Tk 98.58 billion was lost in the forest. Damage to a 2,000-foot railway track cost approximately Tk 8.1 million. Losses included Tk 210 million for the road and Tk 1.3 million for the gas pipeline. Lost money was not compensated by Occidental. The government failed to take thorough action against multinational businesses and defend national interests and local populations affected by the blowout. According to international experts, this failure caused another $1 billion failure to compensate for the 2005 Tengratila blowout. Muhammad (2017) noted that the gas loss costs about $5 billion, roughly eight times the energy sector's annual budget. No government has attempted to recover the funds since 1997. It is not unexpected that the WB, ADB, and other IFIs, who were formerly vociferous, have been silent on compensation." (Muhammad 2014, p. 64)

5.4.3.3 National capacity building initiative

In 1999, a Hydrocarbon Unit (HCU) was formed under the Energy and Mineral Resource Division for technology transfer in the hydrocarbon sector. It was developed as a project financed by the Norwegian Government and later administered by ADB with a view to strengthening the hydrocarbon sector.

5.4.4 Episode 4: 2000s

Energy Policy and Planning, Gas Sector Reform, Coal Politics, Regulatory Reforms, Accelerated Private Sector Participation (2001-2010)

The electricity crisis that originated in the 1990s escalated significantly in the early 2000s. Based on a 2003 survey conducted by the World Bank, 73 percent of companies identified electric power as a significant constraint. A study revealed that the power shortfall incurred an annual cost of 2% for Bangladesh. At the point of highest demand, which was 6500 MW, the amount of electricity being generated ranged from 4,600 to 5,200 megawatts. The 2000s witnessed significant regulatory reforms in pricing mechanisms, the adoption of Compressed Natural Gas (CNG) in vehicles to mitigate air pollution, the initiation of coal-based electricity generation, the introduction of Liquefied Petroleum Gas (LPG) for household consumption, the formulation of the Model Production Sharing Contract (PSC) in 2008, the expansion of private power generation, and the triumph of two prominent movements: one opposing gas exports and the other advocating against open pit coal mining.

5.4.4.1 Policy, roadmap, and master plan

The year 2004 witnessed six important developments: (i) National Energy Policy 2004 was approved; (ii) Gas Sector Reform Roadmap (GSRR) 2004 was approved; (iii) PGCB's corporate bond issuance was approved for raising funds; (iv) Power Pricing Framework 2004 was formulated; and (v) renewable energy policy was drafted.

In 2005, a Power System Master Plan (PSMP) was prepared with technical assistance provided by ADB. The study covered power sector planning for twenty years, covering the period 1995–2015, and recommended a generation and transmission expansion plan up to 2025. The master plan established the fact that the Phulbari Coal Project may be able to supply its coal for less than the estimated forecast cost of imported coal, whereas the cost of coal from the Barapukuria Coal Mine may be higher. Thus, this master plan emphasized the extraction of coal from the Phulbari coal mine. This plan used the forecast data from Asia Energy to justify the idea that Bangladesh needs to develop domestic primary energy resources to supply energy for power generation." (Sultana 2016, p. 255)

Between 2006 and 2008, the caretaker government prepared three policy guidelines: (i) Policy Guideline for Power Purchase from Captive Power 2007; (ii) Remote Area Power Supply Guideline 2007; (iii) Policy Guideline for Enhancement for Private Participation in the Power Sector 2008. At this time, a 3-year plan for reforming the electricity sector from 2008 to 2010 was released.

In COP13, for the first time, mitigation for developing countries was emphasized more than ever before. Beside the Bali Action Plan, pressure from the international community played an important role in encouraging Bangladesh to have a plan for a clean energy transition. As a result, Bangladesh developed interrelated plans and actions, namely the Climate Change Strategy and Action Plan, the National Disaster Management Plan and Act, and the Bangladesh Renewable Energy Policy. The objective was to expand the existing renewable energy financing facility capable of accessing public, private, and donor carbon emission trading (CDM) and carbon funds and providing financing for renewable energy investments. According to the 2008 renewable energy policy, Bangladesh was supposed to produce 10% of its electricity from renewable sources by 2020, which would imply installing at least 2000 MW of RES by 2020. The policy also emphasized building an institution like SREDA that can provide subsidies to utilities for the installation of solar, wind, biomass, or any other renewable projects and can develop financing mechanisms by using grants, subsidies, or carbon/CDM funds for public and private sector investments in all forms of sustainable energy.

The World Bank has provided support for institutional development in Bangladesh through various methods, including the approval of a $120-million Power Sector Development Policy Credit during the tenure of the Caretaker Government. This support has facilitated financial restructuring, the development of Independent Power Producers (IPPs), commercialization, regulatory reform, and the implementation of a strategy for rural electrification.

5.4.4.2 Gas sector reform, production and use, resistance against export

In this decade, the use of gas in electricity production tripled, from 3.28 mtoe in 2000 to 9.35 mtoe in 2010. The Gas Sector Reform Roadmap 2004 provided incentives to attract private investments for exploration and production of oil and gas and gas distribution in specified franchise areas. It also proposed that private sector participation in gas transmission be encouraged while Gas Transmission Company Limited (GTCL) retains overall responsibility for gas transmission. (World Bank, 2008) Private Participation in State-Owned Gas Companies increased.

Use of compressed natural gas (CNG) in transportation

Although CNG as a vehicle fuel was introduced in the mid-1980s, its use was limited to a few cars with inadequate facilities. At that time, when CNG was being introduced as a domestic fuel as an alternative to expensive oil imports, it was initially unattractive to consumers because it required expensive engine conversions, and there were no facilities to make conversion easy for people. The escalating cost of imported oil and a rising concern about air pollution made CNG an amenable choice in the early 2000s. In 1999-2000, the government of Bangladesh decided to use CNG as a vehicular fuel as a result of increasing pressure from external actors to ensure a cleaner environment and the availability of millions of dollars in loans from international agencies to incentivize long-term programs. For example, the United Nations Development Programme (UNDP) created a training scheme in 2001 with Rupantarita Prakritik Gas Company Ltd. to expand an alternative-fuel program, which costs about $1.2 million. At about the same time, the World Bank, Asian Development Bank, and ADB supported the process of transition by investing millions of dollars and providing research and technical support. (GoB 2018a) These initiatives include the expansion of natural gas pipelines, more CNG technology development, and training engineers and mechanics to do CNG conversions and filling station installations. With the availability of financial and technical assistance from external actors, the use of CNG in the transport sector gained new momentum in 2003. The number of CNG-run vehicles increased from 9308 in 2003 to 26,141 in 2009. The demand for CNG increased 20 times, from merely 1.9 MMCFD in 2003 to 39.3 MMCFD in 2009. (Gunatilake, H., and Roland-Holst, D. 2013)

People's resistance against gas exports

"In 2001, Unocal proposed to build a pipeline from Bangladesh to India in order to export Bangladeshi gas to the Hazira-Bijapur-Jagdishpur pipeline, the backbone of India's gas infrastructure. Indian demand for gas would have built foreign exchange reserves, and the World Bank projected that Bangladesh would profit more from exporting gas than gas-intensive, value-added products like electricity or fertilizer, which were then Bangladesh's major gas-based products." (IEA 2020) Left-leaning political parties jointly built a political movement against exporting gas. This was largely motivated by uncertainty about the domestic gas reserves in the first place and, second, by nationalist demand to achieve energy security and fulfill demand at home before exporting. In the face of the movement, Bangladesh ultimately declined to export but later revived this agenda again in 2008 when a new model PSC was formulated.

5.4.4.3 Coal politics

Electricity generation from domestic coal at the Barapukuria coal mine commenced in 2005. At the outset, coal consumption amounted to 0.06 million metric tons (MT) in 2005. However, by 2010, the utilization of coal for power generation had surged to 0.24 MT. Sultana, M. (2016)

In 1994, the government of Bangladesh granted a coal exploration license to BHP Minerals, an Australian corporation. Following a thorough assessment of the mining prospects in Phulbari, Dinajpur, the business made the decision to abstain from conducting a coal mining operation due to the presence of various intricate environmental and engineering challenges. In 1999, BHP relinquished its licenses to Asia Energy. The project faced opposition from the local population since its inception. During a protest against open-pit coal mining on August 26, 2006, law enforcement authorities deployed their firearms, resulting in the deaths of three demonstrators. Following extensive demonstrations against the practice of open-pit coal mining, the project came to a halt. This serves as an outstanding case study of how people' resistance can transcend powerful external force.

5.4.4.4 Regulatory reform

Bangladesh Energy Regulatory Commission Established

During the term of the Bangladesh National Party, Parliament passed the Bangladesh Energy Regulatory Commission Act 2003, through which the newly created Bangladesh Energy Regulatory Commission (BERC) was formed. When the electricity price increased as a result of the neoliberal prescription of privatization, which was widely criticized across the world, in the name of protecting consumers' rights, there was a need to develop a regulatory institution that could mediate between consumers and producers. Like many regulatory bodies in other countries at that time, the objective of BERC was to give a wider mandate and independence, but in reality, BERC's regulatory power was mostly driven by the agenda of electricity reform, backed by the World Bank and ADB. The depoliticization of electricity pricing through regulatory control was necessary to facilitate corporate and private power generation and ensure their profitability. The mechanism of electricity pricing to protect consumers' rights has always remained questionable. (BPDB, 2020)

5.4.5 Episode 5: 2010s

Master Plans Prepared by Foreign Consultants, Dependency on Coal, Nuclear, and LNG, Accelerated Private Sector Participation, (2011-2020)

5.4.5.1 Master Plans Prepared by Foreign Consultants

Power System Master Plans, 2010, 2016, and 2023

The Power System Master Plan (PSMP) 2010 had a goal to derive the majority of power supply from imported fossil fuels. At that time the PSMP 2010 aimed to achieve a power generation mix of 50% coal (from domestic and imported sources), 25% natural gas (from domestic sources and in the form of LNG), and 25% from other sources including oil, nuclear power, and renewable energy by 2030. The government's ambiguous long-term strategy to encourage renewable energy adoption has been further complicated by the periodic revision of its targets, particularly following the inclusion of nuclear energy in its future energy mix. Bangladesh sought the assistance of the Japanese International Cooperation (JICA) to create a new PSMP aimed at fulfilling the energy requirements of a developed nation by 2041. The 2016 PSMP plan also emphasized a significant reliance on imported fossil fuels and a reduced use of domestic resources. The plan underwent revision in 2018, but, the intended energy mix remained mostly unchanged. Later in 2023, JICA formulated an additional comprehensive plan for Bangladesh. The title of the master plan was modified to "Integrated Energy and Power Master Plan" in response to criticism from civil society on the lack of emphasis on renewable energy in the predicted energy mix. The primary goal of this new strategy was to give priority to the utilization of environmentally friendly energy sources in order to minimize emissions. However, despite the declared goal of the plan being decarbonization, the new plan astutely included ammonia, hydrogen, and nuclear energy within the category of clean energy.

Table 5-2 Current Capacity and Future Targets of Power Generation Technologies

Technology	2023-24	2041		
	Existing Capacity	PSMP 2016	PSMP 2018 (Revised PSMP 2016)	IEPMP 2023
Gas/LNG	44.97%	35%	43%	41.5%
Coal	24.31%	35%	32%	14.6%
Liquid Fuel (crude oil, diesel, etc.)	23.69%	5%	2%	3.3%
Nuclear	0%	10%	7%	6%
Hydrogen	0%	0%	0%	6.5%
Ammonia	0%	0%	0%	1.7%
Renewable (Hydro, solar, wind)	4.1%	15% (Suggested Renewable energy should be imported)	10%	15.1%
Import	6.12%		5%	10.3%

Sources: GoB 2010. GoB 2016a, GoB 2018a Power Development Board Annual Report, 2018-19; Power System Master Plan 2016; Revisited Power System Master Plan, 2018, Integrated Energy and Power Master Plan, 2023

According to SREDA, the power generated by renewable energy sources in Bangladesh is 1,202 MW, accounting for 4.1 percent of the overall share. The majority of the present renewable energy in Bangladesh is derived from solar sources, including off-grid and on-grid. Specifically, 968 MW of energy is generated by solar power. In accordance with the prime minister's statement, the recently introduced IEPMP establishes a clean energy goal of 40 percent of the total installed generation capacity (23,500 MW) by 2041. The revised definition of clean energy now encompasses nuclear power, ammonia, and hydrogen in addition to renewable energy. The revised Integrated Energy and Power Master Plan (IEPMP) aims to achieve a 40 percent share of clean energy by the year 2041. (GoB 2023) According to the IEPMP, the proportion of renewable energy in total clean energy is projected to be 8.8% (5,157 MW) by 2041. However, this estimation contradicts IEPMP's other estimation.

The IEPMP emphasizes the utilization of cutting-edge technology and fuel cells to attain the objectives of clean energy. The clean energy sources include coal-fired power stations equipped with Carbon Capture and Storage (CCS) technology, nuclear power, coal co-fired with ammonia, and hydrogen co-fired with gas (LNG). The plan specifically states that in order to reach the objective of generating 40 percent of power from clean energy sources, it will be essential to incorporate hydrogen (H2) at a rate of six percent and ammonia (NH3) at a rate of two percent.

The MPEMR introduced these technologies because Bangladesh cannot reach its clean energy goals through conventional renewable energy sources. This statement appears to be in conflict with the assessment of the renewable energy capacity in Bangladesh as outlined in the final Integrated Energy Plan and Master Plan (IEPMP). Based on the Advanced Technology Scenario (ATS) renewable energy generating deployment plan, solar energy has the potential to generate 9,500 MW, while wind energy can create 7,575 MW. The biomass power plant has a capacity of 165 MW, while the hydropower plant has a capacity of 230 MW. Therefore, by 2041, it is possible to create a combined capacity of 17,470 MW from conventional renewable energy sources, representing approximately 30 percent of the total power requirement.

The new AL-led government, having assumed power in early 2009, has taken several steps to solve the problems in the power sector, including (i) introducing and promoting a rental power generation system by the private sector, (ii) awarding offshore blocks to IOCs, (iii) formulating a new model PSC, (iv) introducing a gas fund, (v) drafting a power system master plan for 2016, (vi) establishing the Sustainable a gas fund, (v) drafting a power system master plan for 2016, (vi) establishing the Sustainable and Renewable Energy Development Authority (SREDA) to promote renewable energy, (vii) importing electricity from India, (viii) starting the construction of nuclear power plants in 2017, and (ix) starting the construction of coal-based power plants. (x) The government incorporated an 'indemnity' clause in the Expeditious and Enhanced Supply of Power and Energy (special provision) Act-2010 to prevent any legal action against the government official in the matters of allowing controversial contracts and other irregularities.

Gas Sector Master Plan 2017

The World Bank provided financial support to a Denmark-based Ramboll consultancy firm to prepare the Gas Sector Master Plan 2017. In 2017, production capacity from existing fields was only 2,754 MMCFD (1.01 tcf/y), of which IOCs account for 59% and public companies account for 41%. The Gas Sector Master Plan suggested that more gas should be allocated to the sectors where the economic value is the highest. The sectors earning high economic value from gas consumption should pay more. The plan also suggests phasing out the current model, which involves Petrobangla acquiring LNG imports, purchasing gas from IOCs at PSC contract prices, mixing it with its own gas from subsidiaries, and then transmitting and distributing the gas to its customers through GTCL and distribution companies. This model would perpetuate cross-subsidies, inefficient resource allocation, distorted pricing, and potentially reduce the economic growth rate in the medium and long term. This plan proposes the establishment of an independent upstream regulator, such as BERC, separate from Petrobangla. This move could potentially reduce potential conflicts of interest between Petrobangla, its subsidiaries, and the regulated industry. This plan also suggested the private sector's involvement in exploration activities, as it assumes that the activities and work knowledge from this sector are likely to have a positive impact on public-sector activities.

The Gas Development Fund (GDF), which was created in 2009 with the extra payment made by consumers through a gas price hike of 10-15% imposed by the Bangladesh Energy Regulatory Commission, According to the Energy Ministry proposal, the money was collected from an additional 55% value-added tax and supplementary duties on gas prices. It was intended to finance the development projects of the gas sector, minimize foreign investment, and maximize the financial capacity of domestic gas companies. According to the Gas Sector Master Plan 2018, in 2014–15, 19 investment projects financed by the gas development fund were under development. (GoB 2018c) However, this fund has not been effectively used for exploring new gas fields. Rather, the fund was given as a loan to import LNG at high price. This has created further upward pressure on gas prices.

ADB proposed a gas price increase, which it justified in one of its reports (Asian Development Bank 2013) by comparing the small negative growth impact of the price increase with the higher increase in efficiency. It also prescribed subsequent subsidization of gas for fertilizer production, as it may more than compensate for the negative economic impact of a high gas price through its productivity impact on agriculture.

5.4.5.2 Import dependency in energy mix

Nuclear Technology Import

Bangladesh started construction of a 2400 MW nuclear power plant in cooperation with Russia. Russia offered to lend 11.38 billion dollars out of 12.65 billion dollars at +1.75% LIBOR rate. The loan repayment time is twenty years with a grace period of 10 years. 12.65 billion dollars was almost two third of the external debt of the country in 2017.

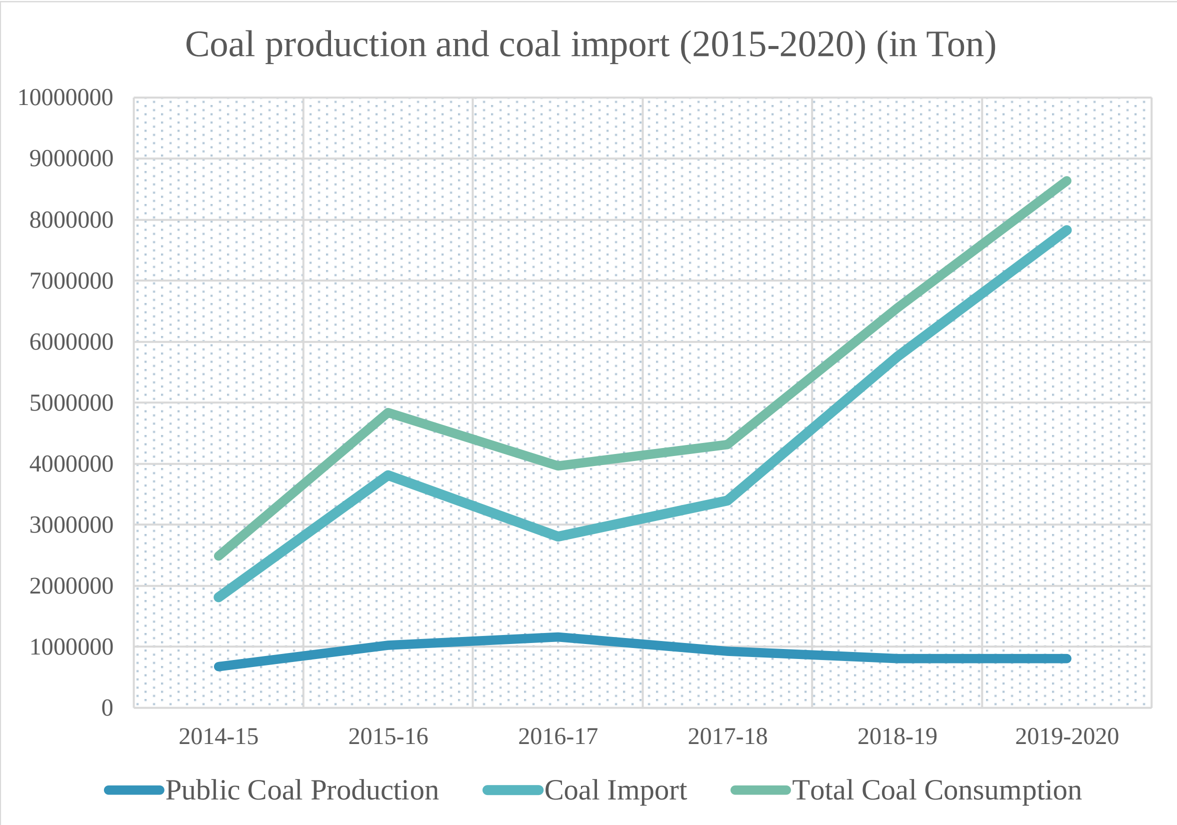
Coal Import

A report titled “choked by coal” (Market Forces. 2019) exposed that Bangladesh had a plan to build at least 29 coal-fired power projects with a total capacity of 33,200 MW. If all the proposed projects were built, the country’s coal power capacity would increase by 63 times and would cost an estimated US$2 billion annually to import coal for proposed coal plants. Unless exports increase significantly, this would add billions to a negative balance of trade, and lock in Bangladesh to costly coal imports for decades. The report also identified that foreign-led finance as the driving force behind plans for 29 coal-fired power stations. Foreign entities include state-owned enterprises, companies from the United Kingdom, India, Japan, Malaysia and Singapore.

As part of regional cooperation Bangladesh started to build a coal-based power plant, with equal ownership of BPDB and NTPC of India, to start generating 1320 MW electricity by 2018.This has faced strong resistance from the National Committee to Protect Oil, Gas, and Natural Resources. In 2016, the local community of Bashkhlai took part in a massive protest demanding cancellation of the coal power plant project partially financed by China. Five people died in police firing during demonstration. But the construction of both of the project continued amid massive protest. This indicates the government’s desperate move to support foreign finance at any cost, by suppressing movements and ignoring the demand of people.

Bangladesh has 525 MW capacity Barapukuria coal power plant which is owned and operated by Bangladesh. To run the power plant Bangladesh has started to import coal. The 660 MW first unit of Payra coal power plant, developed by Bangladesh China Power Company (BCPCL) joint venture, started operation in 2020. As a result, coal import in Bangladesh has soared in last four years.

Figure 5-10 Coal production and coal import (2015-2020)



Source: Hydrocarbon Unit, 2020

LNG Import

Bangladesh has started to import LNG from 2018 and in just one year its increase in use of LNG made it rank 7^{th} among all the LNG importing country in 2019-20. Bangladesh account for 1.2% of the global share of LNG imports in 2019-20. (GIIGNL 2021) Bangladesh imported 0.69 million ton in 2018, 4.07 million ton in 2019, and 4.18 million ton in 2020. A new power master plan, IEPMP 2023, again prepared by Japan, indicated that Japan intends to continue financing LNG projects overseas. According to Institute of Energy Economics and Financial Analysis, “the threat that over-reliance on LNG poses to the financial sustainability of Bangladesh’s power system is at least as high as coal.” (Nicholas 2021)

Electricity Import

In 2013, the Awami-led government started to import electricity from India. In return, in 2014, Bangladesh agreed to give a corridor to India to transmit electricity from its north-eastern state of Assam to Bihar by using a new electricity network passing through Bangladesh. Additional 100 MW from March 2016 from Tripura; at present, 1160 MW (hydrocarbon unit) of electricity is being imported from India, and in the near future, it will increase considerably. Imports accounted for 9.62% of the electricity consumed in 2019. The minimum retail tariff increased from 2.60 Tk/kwh in 2010 to 3.75 Tk/kwh in 2020. And the maximum retail tariff increased from 8.45 Tk/kwh in 2010 to 12 Tk/kwh in 2020. (GoB 2020)

5.4.5.3 Accelerated Private Sector Participation in Power Generation

Rentals and Quick Rentals

Bangladesh government provided support to quick rentals by obliging BPDB to purchase rental power at a high cost and to sell it at the regulated bulk tariff. The Quick Enhancement of Supply of Electricity Act 2010 provided flexibility to outrageously costly projects undertaken by the developers. As a result, BPDB’s loss increased and the government had to extend loans to BPDB. In 2011-12 the total subsidy as a percentage of government expenditure was 92%, and in the power sector it was 45.50%. In 2024, 80% of the power sector subsidies is spent on paying the capacity charge for the private power plants including IPPs, Rentals, and Quick Rental plants. Most of the subsidies/loans were spent to purchase refined oil for running the power plant and most of the subsidy/loans in the power sector was spent on giving loans to BPDB to purchase electricity at high price from the rentals and quick rentals and sell it at market price. Besides, the majority of the rental power plants were oil based. This results in increase in oil import throughout the decade.

PSC 2012 and PSC 2019

Although the government has revised the gas sector policy framework with the objective to expedite the award of contracts in the third round of bidding for IOCs for undertaking off-shore exploration activities, there has not been significant achievements in exploring offshore gas. Government first formulated a new PSC in 2012. In the decade of 2010, Bangladesh has started to award offshore blocks to IOCS. Bangladesh signed two PSCs with Singapore and Australia based Santos-Krish Energy, India based Oil and Natural Gas Corporation (ONGC) in 2014 one PSC with US oil company Conoco Phillips in 2011, and one PSC with Posco Daewoo in 2016. However, except the PSC with ONGC all of the blocks had been relinquished. Bangladesh won maritime boundary dispute with Myanmar in 2012 and with India in 2014. However, winning the dispute did not result in any significant progress in exploration of offshore blocks. In 2019 the government framed two new model PSC: one for offshore and one for onshore. In the new offshore model PSC, the government has reintroduced the provision for export of gas by the drilling companies. However, the export option is not applicable for onshore blocks

Solar Power

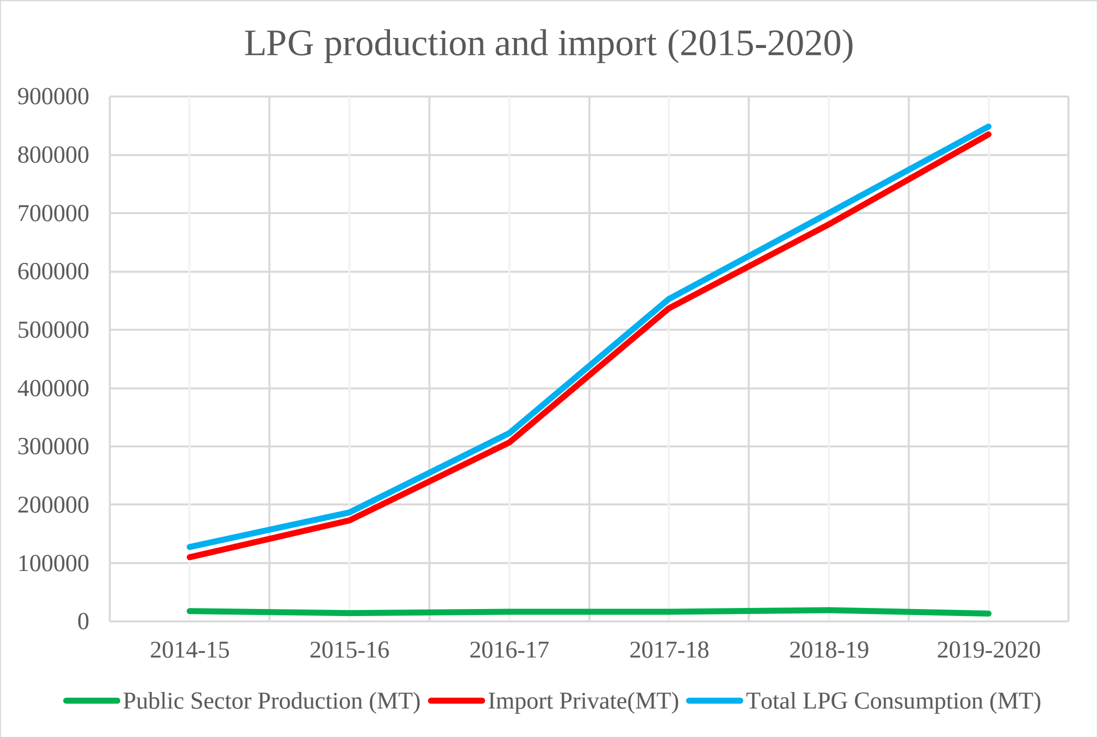
According to the renewable energy policy 2008 (GoB 2008) Bangladesh was supposed to produce 10% of its electricity from renewable sources by 2020, which would imply installing at least 2000 MW of RES by 2020. But the share of renewables in Bangladesh remains minor (3.06% including hydro, wind, biogas, biomass, and solar) and new investments are far below the worldwide trend. The solar power sector development is mostly led by the private sectors.

Liquefied Petroleum Product

Throughout the decade private sector has led the Liquified Petroleum Gas (LPG) production and import. There has been a disparity between public and private LPG suppliers.
LPG was first introduced for domestic purposes by state-owned Bangladesh Petroleum Company (BPC) back in 1978. However, it was never accepted by the urban people as a substitute of piped gas, until 2008 when the government declared to stop providing new gas connections to households due to dwindling reserves of natural gas. Although the first-generation LPG started in the late 90s, the second in around 2004-05, the and the third generation that came in 2014-15 experienced a tremendous growth in recent years. To meet the increasing demand Bangladesh's import has started to increase in an exponential rate

since 2014-15. 12.5 KG LPG cylinders of both public and private companies were selling in the retail market at an inflated price of about Tk1,000-Tk1,200 while the actual rate ranges between Tk700-Tk800. The energy regulator has rescheduled the retail price of 12.5 kg bottled liquified petroleum gas (LPG) marketed by the government at Tk591, while the price of the 12 kg LPG sold in cylinders by private companies at Tk975. (Dhaka Tribune, 2021) This shows an example of how private sector LPG companies is favored over public LPG.

Figure 5-11 LPG production and import (2015-2020)

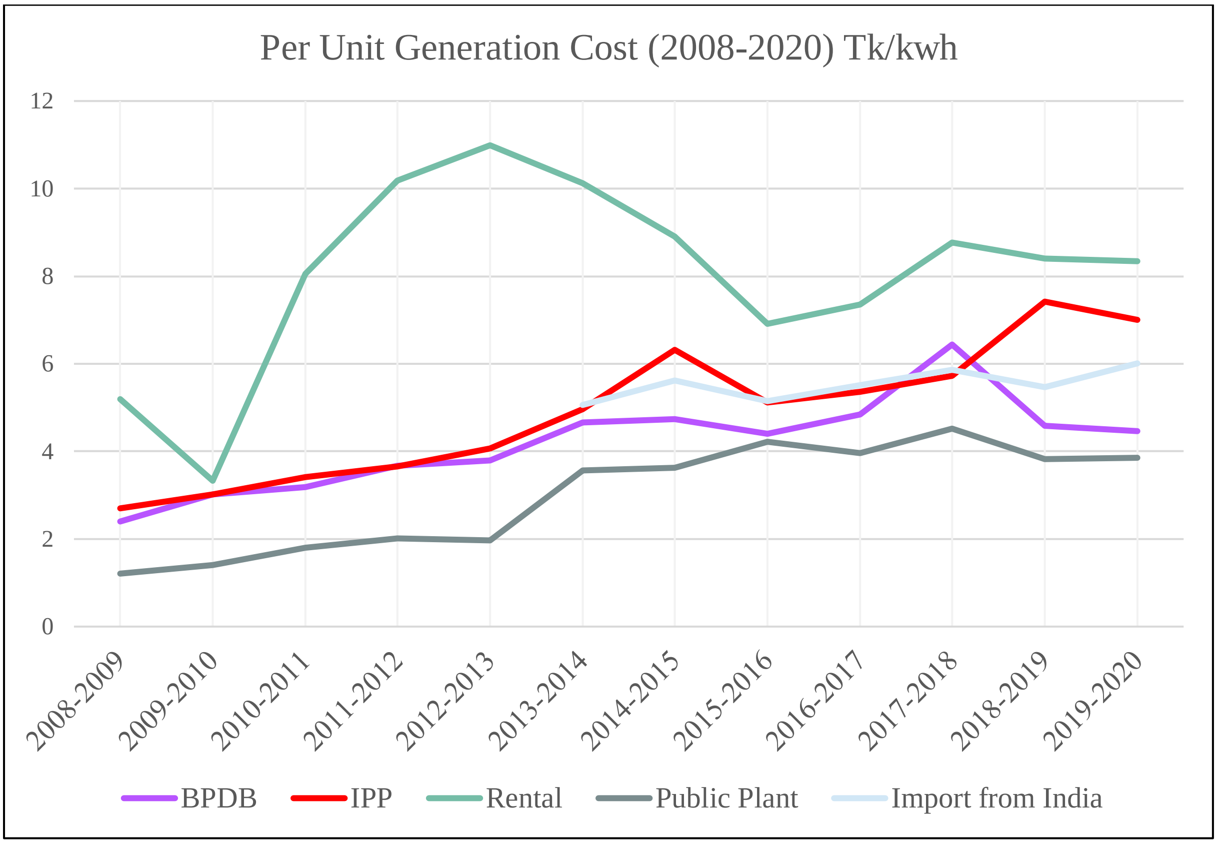


Source: Hydrocarbon Unit, 2020

5.4.5.4 Cost increase

The decade of 2020 can be marked as a significant increase in both the generation cost and price of electricity. The following figure shows that in the decade of 2010 generation cost has been highest for rental power plants, medium for IPPS, and relatively low for public plants, BPDB operated plants. The bulk electricity tariff rate has doubled in 13 years. It increased from Tk. 2.50 in 2007 to Tk. 5.8 in 2020.

Figure 5-12 Per unit generation cost (2008-2020) Tk./kwh



Source: BPDB, Annual Report 2020

The construction of the 2400 MW power plant started in 2017, with the first and second units due for commissioning in 2023 and 2024, respectively. The estimated cost of the project has stood at about $13 billion, and if the project gets delayed, it will be even higher. The external debt in Bangladesh increased from $38.48 billion in 2019 to $44.20 billion, largely because of the construction of the nuclear power plant. The project will put a heavy burden on the economy in the future and may put more upward pressure on the electricity price in the event that it is delayed.

Bangladesh's decision to increase its dependency on expensive imported LNG has already started to put upward pressure on the price. Since late 2021, since the international LNG price has almost doubled, PetroBangla has been struggling to pay for LNG purchases from global suppliers. This has put upward pressure on the gas price. The government is now planning to increase the gas price.

While the cost of solar has declined by 85% in the last decade, Bangladesh could not benefit from the declining cost. The contribution of solar to the total electricity supply is still below 1%. There are no attractive policies to incentivize solar developers. The government initiative to build a publicly owned solar project is far below what is required to increase the contribution of solar to the energy system. According to the Power System Master Plan 2016, Bangladesh was planning to build coal power plants with the support of China, India, Japan, and other countries. However, as global finances have started to move away from investment in coal, it has become difficult to finance the planned projects. As a result, Bangladesh has recently cancelled the plan to build ten coal power plants while allowing the construction of under-construction coal power plants to continue. This shows that Bangladesh changed the plan, not because of its deliberate plan to move away from coal, but rather because Bangladesh responded to the crisis of global coal finance.

5.5 Discussion

The five decades of dependency on external resources including technology, expertise, consultancy, and planning revealed that Bangladesh never had its independent national plan. Rather, Bangladesh has always responded to the crises and adopted policies that were suggested by various external actors as solutions to the crises. Islam (2014) pointed out,

"There is no permanent institutional mechanism within the country or under national planning system to transfer/accumulate the knowledge and experience of preparation of the Master Plans. As a result, the country is to depend continuously on foreign experts to prepare the Master Plans. Energy Master Plans are prepared on the basis of many assumptions. When assumed actions do not take place, progress is affected." (Islam, 2014, p.71)

The question is, why permanent institutional mechanism did not develop to facilitate national energy planning system? Is there any institutional lock-in caused by path dependence? Based on the empirical data analysis in previous sections, this section discusses that although there were possibilities of developing institutional capacity of national planning, the adoption of initial incremental planning approach created a circumstance in which it became increasingly difficult to create institutional mechanism for national comprehensive planning.

5.5.1 Early crises periods and path selection

When the oil crisis started in the 1970s economies of developing countries like Bangladesh, that relied extensively on oil, suffered immensely from oil price increase. As a war-torn country facing challenges like oil shock, natural disaster, unstable political condition, power crisis, rising import bill, high inflation, and famine, Bangladesh could not reduce oil dependency and achieve energy security in the seventies. The oil crisis continued in the eighties as well. In the 1990s the nature of the crisis changed. The crisis in the 1970s was the result of an external oil shock that disrupted the energy supply. In the 1990s, the crisis was a domestic power crisis caused by the insufficient supply capacity. The crisis of nineties became more acute in the decade of 2000 with population increase and rapid urbanization and migration from rural areas to urban areas. The decade of 2010 saw substantial expansion of the electricity supply. By 2020, Bangladesh had achieved universal access to energy by expanding its grid network to remote areas that were previously not part of the national grid system.

In the early 2020s, the crisis took a different form, with energy prices rising in the post-pandemic years following the outbreak of the Ukraine war and rapid appreciation of dollar. The energy supply was disrupted again during the 2020s crisis, this time due to a decrease in the country's purchasing power rather than a scarcity of supply in the global market.

5.5.2 Common pattern in crises responses

As a response to the 1970s crisis, there was a surge in the global quest for new sources of energy outside Middle Eastern countries. Bangladesh was one of the countries with a high potential gas reserve. In the seventies, when the IOCs flocked to discover new reserves in different parts of the world, they also approached Bangladesh and conducted surveys. After extensive surveys, those companies did not find a significant oil reserve and left the country without exploring further. However, they discovered gas fields instead. Being unable to find oil, Bangladesh sought technical support for building gas-based power plants from Russia and other European countries. Bangladesh was politically unstable throughout the 1970s. The assassination of the president, followed by military coups and countercoups one after another, destabilized the economy and society. The new leadership also failed to develop a national energy planning system of its own.

In the 1980s, there was a lot of international pressure to involve IOCs in exploring gas and oil while keeping the option of gas export. Although multilateral financial institutes held Bangladesh responsible for not responding to the IOC's interests in a timely manner, the reality was actually different. In fact, in this decade, Scimitar, an international oil company, breached a contract with Bangladesh and left without exploring. During that time, Bangladesh started to employ its own resources and capacity to extract domestic gas to meet the growing demand. As a result, Bangladesh's gas production has increased in the past decade. This has enabled Bangladesh to develop its technical capacity to a certain extent. By the late 1980s, Bangladesh had formed Bangladesh Petroleum Exploration Company (BAPEX), which continued to discover new gas fields in the following decades. However, institutional capacity building was largely ignored to support the development of technical capacity.

In the 1990s, when gas production was increasing, the electricity supply crisis appeared as an immediate problem to solve. At that time, Bangladesh needed an integrated plan to coordinate the linkage between the power and energy sectors. The plan was necessary to assess demand and supply to ensure the supply of electricity and energy in a coordinated way. Instead, Bangladesh aimed to solve the immediate problem of the power crisis following suggestions from international financial agencies. As prescribed by the World Bank, Bangladesh has started the process of liberalizing electricity. In the first step, Bangladesh restructured the state-run utility company, Bangladesh Power Development Company (BPDB), and completed vertical integration. Vertical integration involves decentralizing the generation, distribution, and transmission of electricity and forming three separate entities. In the second step, Bangladesh allowed Independent Power Plants (IPP) to generate electricity and sell it to the utility company. The objective was to increase private sector participation in the electricity generation and responsibilities of state-owned power plants.

Throughout the 1990s, BAPEX was focused on enhancing its technical capabilities by ramping up gas production. Concurrently, the Bangladesh government was collaborating with international oil companies (IOCs) to explore gas reserves. During this decade, Bangladesh entered into six Production Sharing Contracts (PSCs) with International Oil Companies (IOCs), resulting in a decline in focus on enhancing national capacity building. Although, except for three blocks, all other blocks were relinquished (see Appendix I), the signing of the PSC ensured the long-term involvement of IOCs in the energy sector. As a result, the share of gas production from IOCs increased in the following decades. While the energy supply problem was being solved gradually with increasing gas production and adapting to the gas-based energy system, the power sector lagged behind in terms of meeting electricity demand.

The power crisis of the 1990s became more acute in the 2000s. As a response, Bangladesh continued to allow new IPPs to generate electricity. The abundance of gas and its potential future flow created a sense of energy security throughout the 1990s. Growing air pollution, urbanization, and the and the availability of cheap domestic gas triggered the use of gas in the transportation sector. The decade of 2000 was a decade of introducing compressed natural gas (CNG) in vehicles. Bangladesh also increased the use of gas in captive power generation to meet the industrial demand for electricity. While the transportation sector was increasingly adopting CNG-based vehicle technology, Bangladesh decided to introduce LPG for household consumption. In the beginning of this decade, there was a fresh attempt at offshore bidding to explore gas in the sea. The external pressure kept increasing to sign PSCs with export options in PSCs. At the same time, Bangladesh was considering open-pit coal mining in Phulbari. Massive resistance in Phulbari could stop the environmentally harmful coal mining. People’s protests also became successful in making the government exclude the export option in Model PSC. Like the previous two decades, gas use continued to increase in the decade of 2000.

Despite gradual liberalization and increased participation of IOCs in gas production and the private sector in electricity production, when the electricity crisis was still acute and the transmission and distribution system was facing similar problems as before, Bangladesh found itself trapped in the recurring crisis. Despite their differences, each crisis was the result of hastily implemented policies during the previous crisis, as well as the failure to take alternative actions. For example, while Bangladesh focused on increasing private participation in electricity generation, it did not have a comprehensive analysis of its consequences or other supporting policies to ensure uninterrupted transmission and distribution. As a result, while interrupted supply, inefficiency, and leakages were obstacles to increasing revenue, the increasing cost associated with private electricity supply by IPPs appeared as an additional source of expenditure. Neither the financial problem nor the load-shedding problem was solved. This was largely due to a hasty, incremental approach to crisis resolution that lacked thorough planning. Every time an external consulting body or group of experts planned anything; their goal was to complete specific targeted projects that partially solved the problem rather than implement projects necessary for long-term energy system development.

In the 2000s, when the problem resurfaced, the government undertook an effort to develop a comprehensive strategy for the power and energy industry. On this occasion, Bangladesh once again sought the assistance of external experts to carry out the planning task. In 2005, the ADB sponsored the consultation for developing the first power system master plan for the country by engaging private consulting company Nextant. (GoB 2006) In 2010, Japanese International Cooperation Agency (JICA) provided financial assistance to develop a comprehensive plan, in which JICA employed Japanese consultants to develop the plan. (GoB 2010) Bangladesh's reliance on external resources in the past and lack of a clear political objective to enhance its own institutional capacity led to the involvement of an external agency in developing a plan for the country. This indicates that despite the repeated crises, Bangladesh was still lagging in terms of formulating its own comprehensive national plan and was making gradual efforts to address issues.

5.5.3 Repeated reliance on external resources

I refer to the 1970s as the initial critical juncture, when the external oil shock led Bangladesh to prioritize finding the easiest solution to the crisis through an incremental strategy rather than a comprehensive one. The incremental approach refers to the practice of granting IOCs (International Oil Companies) permission to explore oil and gas reserves without doing a thorough evaluation of the costs and benefits to the nation. Additionally, it involves increasing energy production, namely gas, without improving the efficiency of the current electrical supply system. A comprehensive approach entails implementing a concise strategy to address urgent crises while simultaneously adhering to a meticulously formulated power and energy plan to accomplish a long-term objective.

Once Bangladesh committed to an incremental approach, it became progressively more challenging to backtrack due to the successive crises that arose. These crises created circumstances when making quick decisions to address them took priority, as they were politically more favorable and easily achievable. I identify the electricity crisis in the 1990s as the second critical juncture, in which a recurring solution pattern was perpetuated. In the 1990s, the country faced power issues and recognized the need for fresh investment in the development of the energy sector. As a result, they sought an expedient answer. The politicians, bureaucrats, specialists, and consultants found the availability of a new loan flow more appealing and advantageous than actively participating in the development of a complete strategy.

In the past, Bangladesh implemented policies without an overarching strategy to assure energy security and inexpensive electricity for its citizens. Instead, these policies were a response to the crisis that arose due to a lack of proactive planning. In the 2000s, Bangladesh recognized the necessity of creating its own master plan. However, the reliance on external consultants and experts grew deeply ingrained in the institutional framework, making it challenging to formulate a comprehensive strategy using internal resources. Bangladesh enlisted the services of JICA to formulate its plan in both 2010, 2016, and in 2022. Developing a plan using domestic resources has become progressively challenging for Bangladesh due to the approval, execution, and implementation of projects outlined in the early master plans. With the increasing number of projects in progress at various stages, it became progressively more challenging to rectify the issues. The regulatory, financial, and institutional measures implemented between 2000 and early 2010 significantly contributed to the increased dependency. The growing benefits resulting from the dependency were evident through the gradual execution of the projects and the opportunities they generated for various groups of individuals seeking financial gain.

5.5.4 Why potential alternative path was not taken?

The alternative to an incremental plan is a comprehensive plan that addresses both short term solution and long-term solution. A comprehensive plan could develop a long-term goal of energy security instead of relying only on the external technical, institutional, and financial resources. (Cannone 2023) Now, the question is why Bangladesh could not develop a long-term plan and at the same time take immediate measures.

During the 1970s, the government took control of a number of gas fields that were formerly controlled by numerous multinational oil corporations. This was one of the steps that the administration took in order to expand its capabilities on a national level. This particular step, on the other hand, did not coincide with the various forms of technical and financial assistance that it receives from outside sources. However, there was no obvious ideological preference of the country, despite the fact that they were present in the political domain in a rhetorical capacity. During that period of time, the decision to nationalize the gas sector was an example of the diffusion of policy that was followed by a number of emerging countries. Not only does this demonstrate that there was a desire to establish a national objective, but it also demonstrates that there was the possibility of selecting an easy incremental solution. As a result, the government made a well-informed decision when it decided to prioritize the strategy of external dependency over the establishment of national institutions.

From a political standpoint, it was more practical and preferable to demonstrate that the government is implementing immediate actions rather than presenting a long-term strategy. This was particularly important considering the constant emphasis on limited financial resources as a driving force behind adopting creative strategies. Furthermore, the existence of influential interest groups promotes an incremental approach to decision-making in order to avoid aligning with any conflicting social or national objectives that would hinder the implementation of their favored project. Given the government's limited resources, it is preferable to have a new source of capital rather than a new institutional innovation. Developing a national innovation system, such as institutional innovation, necessitates the involvement of various organizations, stakeholders, perspectives, and political vision. The lack of a dominant set of actors benefiting from such a national institutional innovation was another reason why the alternative comprehensive strategy was not first adopted.

5.5.5 Evolution of actors and institutions in crises

The evolution of actors and institutions were very much related to the solution Bangladesh sought to solve the crises in different times. 1970s crisis had a long-lasting impact on the economy of Bangladesh. Bangladesh was heavily impacted because oil import bill stood at around 80% of Bangladesh's import bill in the beginning of 1980s. Since 1970s the World Bank has been keen on mobilizing resources to facilitate capital investment of IOCs in Bangladesh. As a result, Bangladesh signed two PSCs with Shell and Scimitar in 1980s and six PSCs in 1990s. International Financial Institutions appeared as dominant actors to initiate international policy diffusion.

Over the course of the 1980s and 1990s, there was an increase in the scope of work for international specialists and consultants to participate in a variety of development initiatives, including those connected to power and energy. In response to the implementation of neoliberal policies, an increasing number of engineers and consultants who had received their education in Western countries began to establish themselves in the development projects.

During the 1990s, as the energy sector became more liberalized, a new group of actors began to emerge. At first, with assistance from outside organizations, and later with support from the government, local commercial entities began to establish themselves in the power industry. During the 1970s and 1980s, private entities were involved in many infrastructure projects, serving a supplementary role in infrastructure development. Subsequently, in the 2000s, they solidified their existence by receiving growing government assistance aimed at strengthening them and establishing a dominant position by 2010. These private actors within the domestic power and energy industry were primarily motivated by their own self-interest in obtaining government support, rather than being driven by a desire to enhance the country's overall capabilities.

In the decade of 2010, private ownership in electricity generation increased with increase in IPPs and government's decision to introduce oil based quick rental projects. Despite its intended purpose of accelerating the expansion of installed capacity, quick rental power plants have some drawbacks. These projects bypassed competitive bidding, resulting in increased electricity prices, and required substantial subsidies. These subsidy dependent rental and quick rental power plants are rewarding because the producers are guaranteed to earn capacity charges even if they don't generate anything. This incentive had a detrimental effect on the development of interests among them in creating comprehensive national programs. In the 2010s, despite the master plan recommended by JICA being ineffective in addressing the crisis, the private beneficiaries of fossil fuel subsidies showed no interest in national planning.

Table 5-3 Evolution of actors

	Critical Juncture		Critical Juncture			Critical Juncture
	1970s	1980s	1990s	2000s	2010s	2020s
Crisis	Oil crisis	Oil crisis continued	Power crisis	Power crisis continued	Power crisis partially solved	Energy crisis (purchasing power decline)
Responses	IOCs doing surveys	Domestic Gas production increased	Electricity liberalization	More IPPs installed, Rental and Quick Rentals introduced	Universal access achieved. Imported fossil fuel-based electricity	More fossil fuel-based power plants start operation
Internal Private Actors	Supporting role in infrastructure development	Supporting role in infrastructure development	Gradually engaging with power and energy sector	Empowered by government support	More Influential with government support	Continue to be influential
External Actors	Incremental plan and implement	Incremental plan and implement	Incremental plan and implement	Comprehensive plan and implement	Comprehensive plan and implement	Integrated Plan to include clean energy agenda

The institutional structure changed together with the emergence of actors at various times. The degree of reliance on foreign actors developed over time. During the 1970s, the government allowed international actors to operate in the country. Since the 1990s, the government has rebuilt its institutions to promote liberalization and create chances for international actors. Since 2000, internal private players have collaborated with external actors, gaining government assistance. In 2010, the connection between internal private actors, external actors, and the government grew stronger, with each playing a complementary role in carrying out plans.

5.5.6 The constraints in breaking path dependency

The greater the intensity of constraints the more difficult it is to break the path dependency and therefore un-lock institutional lock-in. Having the constraints does not immediately mean that it is impossible to eliminate the constraints. The interactions between the actors and institutions in breaking the path dependency require substantially strong political feasibility or a crisis that can substantially change the system. The constraints in breaking path can be categorized into two different types: (i) Domestic constraint: (ii) External constraint.

5.5.6.1 Domestic constraints

It has often been the case that previously undertaken projects and under-construction projects have been costly to cancel. Bangladesh took out external loans to finish almost all the power and energy projects, either through joint ventures with foreign companies or through government-to-government agreements. Once the projects are built, the dependency on foreign technologies and finance cannot be replaced immediately. Although it is feasible to create a fresh master plan with the involvement of local experts and consultants, the technologies that Bangladesh has already embraced have established a new interdependence that is challenging to restructure. There is also a scarcity of financial resources to take reform measures and move away from the existing plan. Several proposed coal power stations in Bangladesh have been terminated in the past due to the country's planning beyond what was necessary to achieve its target. The potential for technological lock-in in the future is already being revealed. Domestic actors have already found ways to benefit from the current institutional structures. There is a strong vested interest in restructuring. Enforcing new laws and removing existing incentives is a politically sensitive matter. Even if new institutional procedures are developed, the level of dependency has been ingrained in the institutional structure to such an extent that it hinders the ability to create new plans based on national ambitions. Removing the constraints requires an overhaul of the existing social and political system to such an extent that it requires a radically groundbreaking approach, which is difficult to implement by the actors who emerged in the last few decades.

5.5.6.2 External constraints

The undergoing projects are dependent on the overseas power and energy strategies of countries involved. For example, US pursued LNG expansion strategy and Russia pursued nuclear expansion strategy overseas. Similarly, coal expansion has been prioritized by India, China, and Japan in the decade of 2010. These interests of external actors in various technological expansion sometimes appear to be diplomatically inflexible and intervening when Bangladesh tries to establish itself as part of global and regional community. Even when Bangladesh had a national renewable energy plan, Bangladesh missed the target. While the countries mentioned above are financing and cooperating in nuclear, coal, and LNG projects, the growth of renewable has missed the target as planned and Bangladesh is moving more towards transitioning to more expensive and imported fossil fuel energy than increasing its capacity to deploy renewable energy.

Bangladesh commissioned JICA to create its power system master plan. The ownership of Japanese corporations in the coal power project and LNG terminal highlights the inherent conflict of interest involved in formulating a plan that is primarily dependent on coal and LNG. The idea that the foreign consultants are superior and that Bangladesh lacks the ability to make its own plan has been deliberately constructed during the five decades. In the absence of a national innovation system, the universities' persistent reliance on foreign experts hindered their ability to develop their own knowledge and contribute to the planning process. Even when Bangladesh had the ability to utilize its own technological expertise and resources to explore its own energy resources, Bangladesh employed foreign companies at a higher cost. For instance, although BAPEX in Bangladesh has the capability to conduct surveys and dig wells for gas exploration, they have chosen to hire foreign state-owned corporations like Gazprom for these services.

5.6 Summary

This chapter identifies that Bangladesh has experienced an institutional lock-in caused by path dependence. The path dependence can be traced back to the 1970s when an exogenous external oil shock created a circumstance in which quick crisis recovery got immediate priority in the policy arena. As a result, Bangladesh adopted an incremental planning strategy to solve immediate problem instead of a comprehensive one to address immediate problem as well a setting future action plan for the long term.

Bangladesh has a long history of dependency on external resources, including technology, expertise, consultancy, and planning. The country has never had its own independent national plan, and instead, it has adopted policies suggested by external actors as solutions to crises. There is no permanent institutional mechanism within the country or under national planning system to transfer knowledge and experience of preparing Master Plans. This has led to a lack of institutional capacity for national comprehensive planning.

The source of path dependence is random and exogenously determined because the circumstance in which the country responded was created by an external oil shock in the 1970s. This was the first critical juncture when the path was taken. Although there were other alternatives available for Bangladesh, Bangladesh decided to take a path that relied extensively on foreign experts, technical support, and financial resources. The other alternative is a comprehensive plan to set long term goal as well as solution to crisis. This includes developing an institutional mechanism for developing capacity for planning.

The incremental approach, which involves granting IOCs permission to explore oil and gas reserves without thorough evaluation of costs and benefits, became increasingly challenging to reverse as successive crises led to prioritize solving immediate crisis with the help of external resources. The 1990s electricity crisis was another critical juncture, where the country sought expedient solutions rather than actively participating in the development of a complete strategy.

When Bangladesh recognized the need for creating its own master plan in the 2000s. However, the reliance on external consultants and experts grew so deeply ingrained in the institutional framework, that it became difficult to formulate a comprehensive strategy using internal resources. Developing a plan using domestic resources has become progressively challenging due to the approval, execution, and implementation of projects outlined in early master plans.

Bangladesh could not develop a long-term plan and take immediate measures due to the government's prioritization of external dependency over the establishment of national institutions. The lack of a dominant set of actors benefiting from such a national institutional innovation also contributed to the delay in adopting this alternative comprehensive strategy.

The evolution of actors and institutions in Bangladesh has been closely linked to the solutions sought to address different crises. In the 1970s, the country faced a long-lasting economic crisis due to its oil import bill. The World Bank played a significant role in mobilizing resources for capital investment, leading to the signing of Production Sharing Contracts (PSC) with major oil companies. International financial institutions emerged as dominant actors in policy diffusion.

In the 1990s, local commercial entities began to establish themselves in the power industry, with private entities playing a supplementary role in infrastructure development. However, these private actors were primarily motivated by their self-interest in obtaining government support rather than enhancing the country's overall capabilities.

In 2010, private ownership in electricity generation increased with the increase in IPPs and the government's decision to introduce oil-based quick rental projects. These projects bypassed competitive bidding, resulting in increased electricity prices and required substantial subsidies. This incentive had a detrimental effect on the development of interests among them in creating comprehensive national programs.

Breaking path dependency requires strong political feasibility or a crisis that can substantially change the system. There are both domestic and external constraints in breaking path. Domestic constraints include costly cancellations of projects, dependence on foreign technologies and finance, vested interest against restructuring, and a scarcity of financial resources to take reform measures. External constraints involve the interests of overseas power and energy strategies, such as the US, Russia, India, China, and Japan, which can be diplomatically inflexible and intervene when Bangladesh tries to establish itself as part of the global and regional community.

Appendix I

Year	IOC	Oil/Gas Field
1973	Atlantic Richfield,	Offshore Block
1973	Union Oil of California (later renamed as Unocal)	Offshore Block
1973	Ashland Oil of USA	Offshore Block
1973	Superior Oil Company of Canada	Offshore Block
1973	Ina-Naftaplin of Europe	Offshore Block
1973	Bengal Oil Development Co. (BODC), a Japanese Company	Bay of Bengal
1981	Shell Oil	Chittagong Hill Tract Salbanhat well
1987	Scimitar Oil	Jalalabad
1994	Shell Cairn Halliburton Later,Cairn Energy Sangu Field Ltd, Santos Bangladesh Ltd, and Halliburton Brown and Root. Santos shut down parmanently in 2013 https://www.dhakatribune.com/uncategorized/2014/10/26/conocophillips-pulls-out-of-deep-sea-blocks-10-11	Block 16
1995	Occidental In 1997, The Occidental allegedly gave subcontract of well No 1 (Block 14) under Magurchhara Gas Field to German company Duetag in violation of the terms and conditions of PSC, and the well exploded on June 14, 1997 when the Duetag was working there. Unocal acquired Occidental in 1999. Chevron acquired the entire Unocal company in 2005.	Block 12, 13, 14
1995	Shell Cairn Relinquished in 2005	Block 15
1996	US Meridian Corporation Tranferred to Ocean Energy in 2005 Terminated	Block 22
1997	Tullow-Oakland- Rexwood Relinquished	Block 17, 18
1997	United Meridian corporation relinquished	Block 22
2000	Unocal Bapex Later acquired by Chevron in 2005	Block 7
2001	Shell Cairn Energy Bapex Reliquished by Cairn Energy plc	Block 5, 10
2001	Tullow-Chevron-Texaco-Bapex Acquired by Tullow and Niko The Joint Venture Agreement (JVA) between BAPEX and NIKO was formally signed on October 16, 2003.	Block 9

	A blowout occurred on January 7, 2005 and a second blowout occurred on June 24, 2005.	
2011	Conoco-Philips Pulls Out in 2015 (i)	Deep sea blocks (DS-08-10 and DS-08-11)
2008	Tullow	Shallow sea block (SS-08-05)
2014	ONGC Videsh LTD	Blocks SS-04 and SS-09
2014	Santos-Kris Energy Contract terminated and relinquished in 2019	SS-11
2016	Posco-Daewoo Corporation relinquished in 2020	SS-12

Source: Petrobangla Annual Report, 2018-19

6 Solar Power in Bangladesh

6.1 Introduction

Having tropical and sunny climate, Bangladesh is one of the countries in the world with high potential of solar power. Yet, the growth of solar in Bangladesh has been very slow compared to most of the lower middle-income countries in the world. Despite 89% decline of the levelized cost electricity of solar PV technology from 2010 to 2022, (IRENA 2023) Bangladesh could not reap the benefit of the highly potential solar. Instead, in last decade Bangladesh has adopted coal, LNG, and nuclear and has become more dependent on imported fuel and energy technologies than ever before. While the recent developments reveal Bangladesh's objective of achieving a target that is clearly moving towards the direction of fossil fuel dependency, at the same time Bangladesh has set ambitious target to increase the contribution of clean energy. This contradiction calls for an examination of the historical understanding of why Bangladesh has departed from an energy security policy that was dependent on domestic low-cost energy resources to a policy that has prioritized costly imported energy sources. The recent history of slow solar adoption may provide an insight on the future direction of achieving an ambitious solar target. In an attempt to explain the causal mechanisms for which adoption of solar has been slow, this chapter focuses singularly on the solar adoption in Bangladesh.

While Bangladesh's plan for solar growth is still being debated, the question arises about why Bangladesh could not continue to sustain the growth of solar that started in 1980s. In order to answer the question, there is a need to identify the techno-economic mechanisms, socio-technical mechanisms, and political mechanisms through which Bangladesh has undergone a policy of increasing import dependence and decreasing domestic energy dependence. This chapter provides an explanation of the slow growth of solar by using interviews of experts and policy makers as well as analysis of the observations obtained from secondary data and literature.

In Chapter 5, the history and context of the energy transition reveals that Bangladesh has started to liberalize the electricity sector since the 1990s. Since then, the share of the private sector in electricity generation has increased to more than 50%. While some scholars argue that electricity liberalization will attract more investors (Dos Reis et al., 2023) and therefore promote solar growth, the case of Bangladesh shows the opposite. Bangladesh’s heavily privatized power sector does not support the argument that liberalization is favorable to the transition to solar. This chapter explores the aspects of liberalization that were unsuccessful in promoting solar power, as well as other factors that negatively impacted the growth of solar energy.

Similar to this chapter, the next two chapters (7, 8) focus on the other three recently adopted new energy sources: coal, LNG, and nuclear. Chapter 7 discusses why Bangladesh has adopted nuclear. Chapter 8 discusses why Bangladesh adopted coal and LNG. This chapter focuses solely on solar to fully explore the interplay of techno-economic, socio-technical, and political mechanisms that led to the slow adoption in the last decade. This chapter contributes to providing an explanation of the broader puzzle of the dissertation.

One of my journal articles that focused on the multidimensional feasibility of solar power in Bangladesh published parts of this chapter, including the context and mechanisms. The article compared Bangladesh with a developing country (Vietnam) and a developed country (Germany) to find out whether the solar target in Bangladesh is feasible, moderately feasible, or ambitious, and under what conditions the feasibility differs. (Sultana 2023b) In the initial phase of my PhD research, I received a research grant from the Bureau of Economic Research of the University of Dhaka for conducting research on the multidimensional feasibility of solar targets in Bangladesh. In this chapter, I incorporate the interviews I conducted for that research. In the advanced stage of my PhD, the research helped me formulate a research question relevant to my dissertation's broader question. In addition to utilizing the interviews from my initial research, I conducted additional interviews to aid in the writing of this chapter. I also updated some secondary data for this dissertation chapter. Although the chapter has a different focus than the published article, one is related to the other because both used the same observations from some interviews. Despite some common elements, the chapter's scope is broader than that of the article because it focuses on the question relevant to the dissertation. While the published article focuses on solar's multidimensional feasibility, this chapter uses three perspectives on energy transition to find the causal mechanisms behind solar's slow adoption.

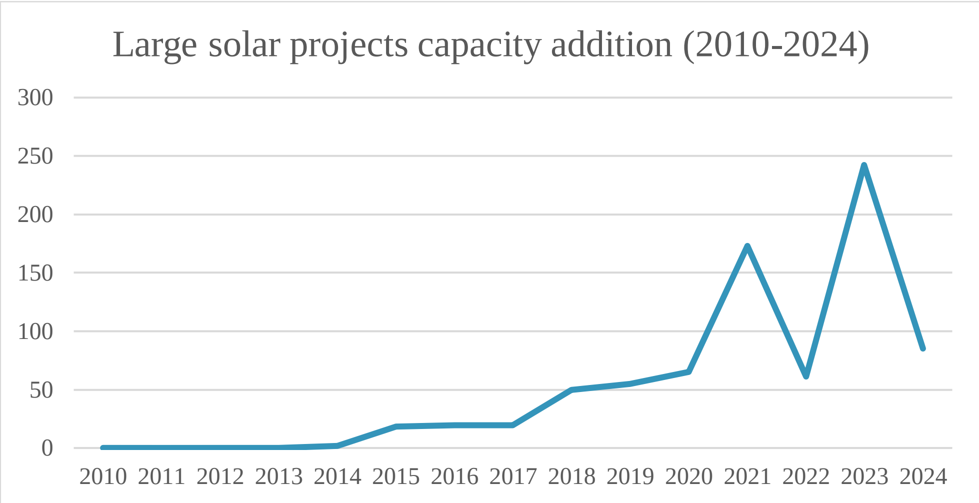
This chapter looks into the historical mechanisms of solar adoption to explore why solar growth has become so slow in Bangladesh. Despite Bangladesh's remarkable achievement in installing a large number of solar home systems in the last few decades, why has Bangladesh not been able to make use of the declining price of solar and benefit from the techno-economic advantages? This chapter uses three perspectives in analyzing the combination of causal mechanisms to explain the solar energy outcome that Bangladesh faces today. This single case study reveals what has worked and what did not work in the case of solar growth. It systematically analyzes why the already-adopted policies failed and investigates whether other factors, such as the technology's characteristics, its innovation system, technological lock-in, and regional spillover of knowledge, could have contributed to the slow growth of solar power.

The first section of the chapter reveals various techno-economic mechanisms relevant to pricing, policy adoption, policy design, and suppliers' responses to the techno-economic factors. The second section deals with the socio-technical mechanisms largely connected to the past experience of technology adoption, the inherent risk-taking behavior of society, institutional learning, capacity, and evolution of innovation systems. The third section explores the political mechanism, which involves policies, actors, the ideological position of the state and society, interest groups, and their rent-seeking attitude. Most of the mechanisms identified are interrelated and often overlap to such an extent that it is difficult to categorize them as belonging to certain mechanisms. The point of this chapter is not to sort mechanisms into groups based on how directly they affect the outcome. Instead, it is to look at how the mechanisms have changed over time, how they interact with each other, how their paths depend on each other, what causes what, and what this means for the future of solar adoption.

6.2 Context

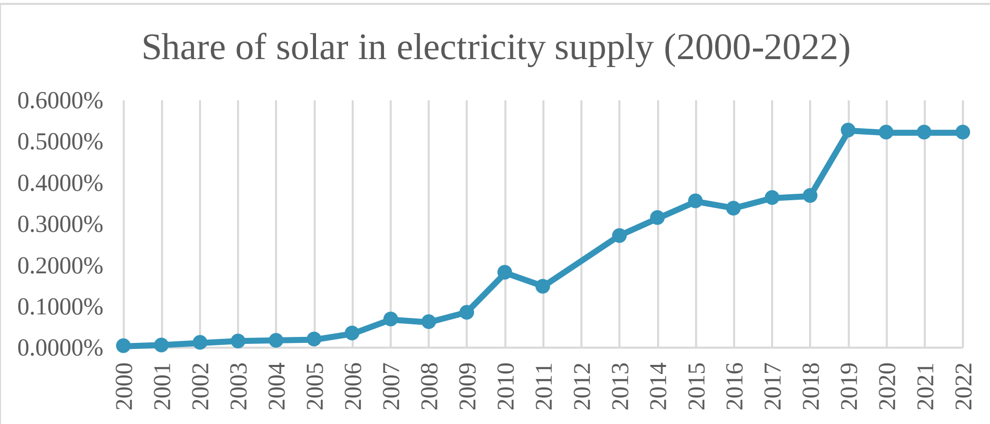
The history of solar power in Bangladesh spans more than 30 years. It started in the late 1990s with the installation of off-grid solar home systems (SHSs), mostly in remote rural areas where the grid network could not reach them. By now, Bangladesh has the highest number of off-grid SHSs in the world. Bangladesh now has more than six million solar home systems with a 372 MW capacity. (SREDA 2024) Bangladesh introduced a solar home system to reach areas outside grid coverage. Currently, the off-grid solar electricity generation capacity is 1.35%[4] and the on-grid solar electricity generation capacity is 706.15 MW 2.56.% (BPDB 2024) of the nationwide electricity generation capacity (27,054 MW). Although slow in development, in 30 years (1990–2020), off-grid solar technology has been able to reach remote off-grid areas. Now, there is a challenge to incorporating electricity into the grid. Large solar projects started in 2000, but large on-grid project generation stood at only 557 MW by July 2024. (SREDA 2024)

Figure 6-1 Capacity addition of large solar projects (2010-2024)



Source: SREDA National Database 2024

Figure 6-2 Share of solar in electricity supply of Bangladesh (2000-2022)



Source: Ember 2023

[4] Solar off-grid solar capacity is 372 MW as of July 2024 (SREDA 2024). Installed Capacity is 27,515 MW as of June 2024 (BPDB 2024) Off-grid capacity as a percentage of total generation is 1.37%)

Bangladesh started using solar home systems in the late 1990s. After 2000, the share of solar began to contribute to total supply. From 2001 to 2010, the share increased, but it remained below 0.20%. After 2010, solar share of total electricity supply rose sharply and grew moderately throughout the decade until 2019. Although the installed capacity of solar increased from 2020 to 2024 as some utility-scale solar power plants started commercial operation during this time, the share of electricity supply remained almost stable because supply from coal, oil, and gas-based electricity generation also increased during this time.

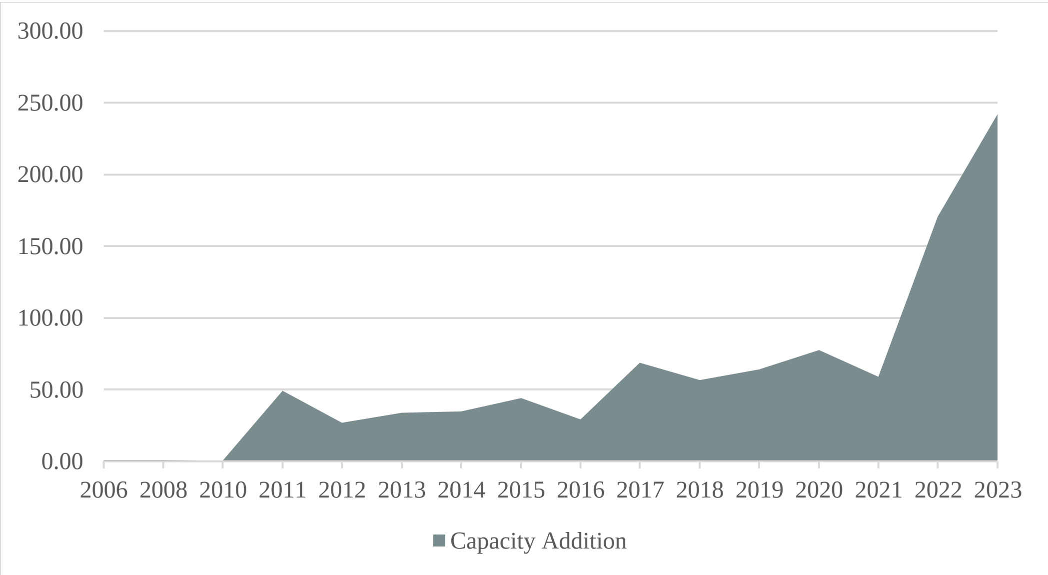
Table 6-1 Share of solar technology

Type of Technology	Number of Projects	Off-grid (MW)	On-grid (MW)	Total (MW)
Solar Park	11	0	536	536
Rooftop Solar Except NEM	236	27.778	50.299	78.077
Net Metering Rooftop Solar	2364	0	108.473	108.473
Solar Irrigation	3381	54.616	2.742	57.359
Solar Home System	6037689	263.793	0	263.793
Solar Minigrid	28	5.805	0	5.805
Solar Microgrid	0	0	0	0
Solar Nanogrid	2	0.001	0	0.001
Solar Charging Station	15	0.275	0.016	0.291
Solar Street Light	297691	17.104	0	17.104
Solar Powered Telecom BTS	1933	8.06	0	8.06
Solar Drinking Water System	82	0.095	0	0
Total	6343432	377.527	697.53	1074.963

Source: SREDA National Database 2024

Although the share of solar has increased, it will only be slightly more than 0.50% in 2024. When the world witnessed a gradual decrease in the cost of solar in the decade of 2010, Bangladesh could not take advantage of the global cost decline, and the share in total supply did not grow significantly. According to scholars (Gruber, Nakicenovic, and Victor (1999; Malhotra and Schmidt 2020), technology diffuses faster in the periphery than in the core. The core countries take a longer time to innovate, customize the technology to their specific needs, learn from it, and finally benefit from technology adoption. The periphery countries, on the other hand, adopted readily available technologies and used the knowledge already gathered by the core. Therefore, according to Schmidt's law, diffusion proceeds at a faster rate in regions that adopt the technology later. We expect peripheral countries to adopt technologies faster than the core. However, the case of Bangladesh shows that, as an early adopter country, although Bangladesh had a longer experience of deploying solar, it did not benefit much.

Figure 6-3 Solar capacity addition (MWp) (2006-2023)



Source: SREDA National Database 2023

When grid-connected electricity from conventional sources became cheaper and more accessible to consumers, the demand for solar home systems dropped. Investment in solar home systems became less attractive. Similarly, mini-grids that require large storage appeared to be more expensive compared to grid electricity. Recently, rooftop solar in commercial and industrial buildings and utility projects has become more attractive than off-grid, mini-grid, and SHS. The rapid expansion of the grid, technological advancements, rising efficiency, and changes in transmission and distribution systems made some technologies more profitable and attractive than others. As a result, learning from the experience of installing SHS had little impact on the growth of other solar technologies, including utility scale, rooftop, irrigation, and other solar technologies. While the solar home system started to grow in 2000, the solar rooftop and irrigation pump grew in 2012, and the solar park grew in 2015.

The Renewable Energy Policy of 2008 initially aimed to generate 5% of total electricity from renewable sources by 2015 and 10% by 2020. However, Bangladesh failed to meet the first target. When the targets were set, the costs of various solar technologies were higher than current levels, but they gradually decreased over time. The Power System Master Plan 2016 set a target to generate 10% of Bangladesh's electricity from renewable sources by 2041 (GoB 2018a). To meet this goal, renewable electricity capacity must grow by more than 10 times compared to solar capacity in the 2020s. The 2016 master plan (GoB 2016a) projects a generation of 70.5 GW of electricity by 2041, compared to the current capacity of 29 GW (BPDB 2023). To meet the target, it estimated a 10% electricity growth rate. The master plan also suggested increasing dependency on imported LNG, coal, and nuclear. However, as new investment in coal became difficult, Bangladesh scrapped the plan to build ten coal power plants.

In 2020, the Sustainable Renewable Energy Development Authority (SREDA) created a National Solar Energy Roadmap for 2021–2041. SREDA, the country's coordination body for renewable energy development, under the Power Division of the Ministry of Power, Energy, and Mineral Resources (MPEMR), prepared this draft roadmap. This draft has proposed 6,000 MW of solar PV (10%) capacity under the business-as-usual scenario, 20,000 MW (33%) under the medium-case scenario, and 30,000 MW (50%) under the high-case scenario by 2041 (SREDA 2020). The roadmap has not officially declared this target as the national target.

Later, the Ministry of Forest and Climate Change of the People's Republic of Bangladesh prepared the Mujib Climate Prosperity Plan in 2022, with the goal of producing 40% of the electricity from renewable energy by 2041. (GoB 2022)

The Japanese International Cooperation Agency (JICA) developed the latest Master Plan. To address the climate concern, they changed the name of this master plan from Power System Master Plan to Integrated Energy and Power Master Plan (IEPMP). (GoB 2023) Instead of using the term renewable energy, this plan has used the term clean energy to include hydrogen, ammonia, and nuclear, along with previously defined renewable sources like solar, wind, and biomass. This newly developed plan targets producing 40% in the clean energy category by 2050. It sets a new target for renewable energy: 15.1% of electricity will come from renewable energy by 2041 and 23% by 2050. The new Master Plan 2023 sets a target to increase Bangladesh’s capacity to 74.3 GW against a maximum estimated demand of 50 GW. The new target sets the share of gas/LNG at 41.5%, coal at 14.6%, oil at 3.3%, nuclear at 6%, import at 10.3%, renewable at 15.1%, hydro at 1.1%, hydrogen at 6.5%, and ammonia at 1.7% by 2041.

Bangladesh is aiming to become an upper middle-income country by 2030, a lower middle-income country by 2030, and a high-income country by 2041. Yet, its national solar target is not clear. The various existing and future renewable and solar targets, as expressed in plans and oral declarations, create ambiguity in the common understanding of the actual solar target within Bangladesh's overall power and energy plan. None of these plans explicitly set separate targets for the expansion of solar, wind, hydro, and biogas. Although Bangladesh's solar capacity has expanded recently, the actual supply will remain below 1% as of 2024.

Since the start of the Ukraine war in 2022, the rising prices of coal and LNG have begun to impose a strain on the economy. In response to the US dollar crisis, Bangladesh depreciated its currency, the taka, against the dollar. This has made imported LNG, oil, and coal far more expensive for Bangladesh than ever before. Moreover, the low supply of dollars in the economy and the payment of large import bills and installments for expensive megaprojects have led to the depletion of Bangladesh's foreign currency reserves. During the economic crisis, it has become difficult for Bangladesh to import LNG, oil, and coal. As a result, a decrease in the supply of imported energy has forced many power plants to either run below capacity or shut down. To meet the existing demand during a crisis, investment in solar has become more desirable, both from a political and economic perspective. The question has arisen: how can we promote solar growth? What policies should we implement to enhance solar capacity? Where will the investment come from? What kinds of regulations will promote solar deployment? Which actors, with their respective ideological preferences, will facilitate solar growth? What should the state's role be in incentivizing solar growth? These questions have taken us back to the history of solar adoption in Bangladesh in order to find a sufficient explanation of where Bangladesh is in terms of solar growth and why the growth has been slow in the recent past.

Bangladesh has a long track record of embracing solar home systems, however its progress has been rather sluggish in comparison to other nations where solar technology is still relatively novel. Therefore, it is crucial to assess whether the process of constructing a solar home system has significantly enhanced the country's institutional capabilities and if there is evidence of experiential learning. Additionally, there are other rules in place that promote the reduction of costs, increase profitability, and provide incentives for investment. Hence, it is vital to consider the political processes that have the ability to facilitate the attainment of the objective.

6.3 Method

This research uses a single-case study method based on interviews, historical secondary data, and statistical analysis. The selection of Bangladesh's solar case stems from several factors: (i) Solar's potential as a decarbonization energy source; (ii) Bangladesh's historical solar growth failed to keep pace with the expansion of the grid in remote areas; (iii) despite declining costs, Bangladesh failed to grow solar, instead increasing its use of coal, oil, and LNG in the last decade; and (iv) this case is intriguing due to Bangladesh's status as a lower middle-income country striving for development by 2040 and the high growth in electricity demand for its economic development.

I design this research to address a specific research question. The goal is to explain a known outcome by identifying the causal mechanisms behind it. It uses a mixed method because neither quantitative analysis nor qualitative analysis alone can provide a sufficient explanation of the outcome. The energy transition is a dynamic process that is evolving with new advances in technology, sources of finance, new actors, and lessons from policy designs. Energy transition research requires a multidisciplinary perspective. This research uses a metatheoretical framework involving three perspectives: techno-economic, socio-technical, and political. In order to identify causal mechanisms, this research looks back at recent historical precedents that shaped the current energy outcome. Scientific research has not yet fully codified all experiences and observations in an ever-changing world. Therefore, to fill the vacuum of information availability, this research selectively uses interviews to explore deeper causal relationships.

This research uses interviews with policymakers, technical experts, solar developers, entrepreneurs, energy journalists, bureaucrats in utility companies, experts in different institutions working with renewable energy, and experts in green energy finance.

The research also uses a statistical comparison of Bangladesh's growth in solar with the 29 lower middle-income countries in the world in order to find out whether experience with solar deployment is necessary when technology is readily available globally.

This research also uses policy documents, annual reports, newspaper reports, documents of acts, and regulations to support analysis. Occasionally, I validate the observations from interviews using published documents.

6.4 Existing explanations

Bangladesh adopted some policies, including net metering on solar rooftops, mandatory solar installation requirements, and unsolicited bidding in utility-scale solar power construction. These policies were adopted because of common expectations that these techno-economic factors and regulatory approaches would encourage investors to invest more in solar. The existing explanations relied heavily on the use of these economic and regulatory incentives, and they blamed the failure to use those incentives effectively as the cause of solar's slow growth. These explanations failed to critically assess the causal mechanisms of solar adoption in Bangladesh. In the following, I highlight the three primary approaches that the existing explanations rely on. The current body of literature does not systematically explain the reasons for slow adoption. Therefore, rather than relying on the explanations offered by scholars, I utilize the existing justifications for policy adoption as a means of explaining the failure to implement those policies.

First, the existing explanation suggests that rooftop solar in Bangladesh was uncompetitive due to its high cost. The high upfront cost of rooftop solar is presumed to be one common obstacle to rooftop solar demand. Moreover, the high LCOE compared to the market electricity price did not provide an incentive for rooftop solar adoption. Some argued that liberalizing electricity prices would widen the gap between the cost and price of solar electricity, thereby stimulating solar investment. The expectation stems from the idea that electricity liberalization stimulates private investment due to the significant potential for cost recovery. Based on these expectations, experts and policymakers suggested a net-metering policy to incentivize rooftop solar growth. In 2018, Bangladesh approved a net-metering guideline to promote solar growth. The advantage highlighted at that time was that there was no need to provide subsidies as costs went down below the price. However, despite a further decline in the cost of solar roof tops since 2018 and a significant increase in the price of electricity, Bangladesh has yet to experience significant solar growth. This inquiry calls into question the validity of the current explanation. Are technological and economic mechanisms causing solar growth to slow?

When both the demand and supply for credit to invest in solar have been low, the emphasis has now shifted to making financial loans available to investors without considering the socio-technical and political mechanisms behind the slow adoption of solar. Thus, the existing explanations are biased by techno-economic perspectives. Incorporating political and socio-technical perspectives will reveal previously unexplored perspectives and enhance understanding of the dominant mechanisms of solar transition.

Second, having the largest solar home system program indicates that Bangladesh has the capacity to develop solar. Based on the previous experience, the Bangladesh government used a regulatory mechanism to promote solar growth. This idea posits that making solar rooftop installation mandatory in specific buildings will contribute to high solar growth. However, this expectation also failed to materialize. The mandatory installation requirement could not ensure growth in net-metering solar. The explanations that learning by doing can promote solar growth and that a regulatory approach will encourage solar growth did not have much impact on solar adoption. The existing explanation failed to address the real causal mechanism behind the slow adoption of solar.

Third, uncompetitive bidding on utility-scale solar provides incentives to investors as it helps fast-track investments and expedite the construction of utility-scale solar. Bangladesh enacted the Quick Enhancement of Electricity and Energy Supply (QEEES) Provision Act 2010 to speed up the construction of power plants and guarantee electricity. This was one way to encourage private investors to take part in unsolicited bidding and gain government support. However, this regulation worked in favor of coal, LNG, and nuclear and did not contribute much to the adoption of solar.

6.5 Techno-economic mechanisms

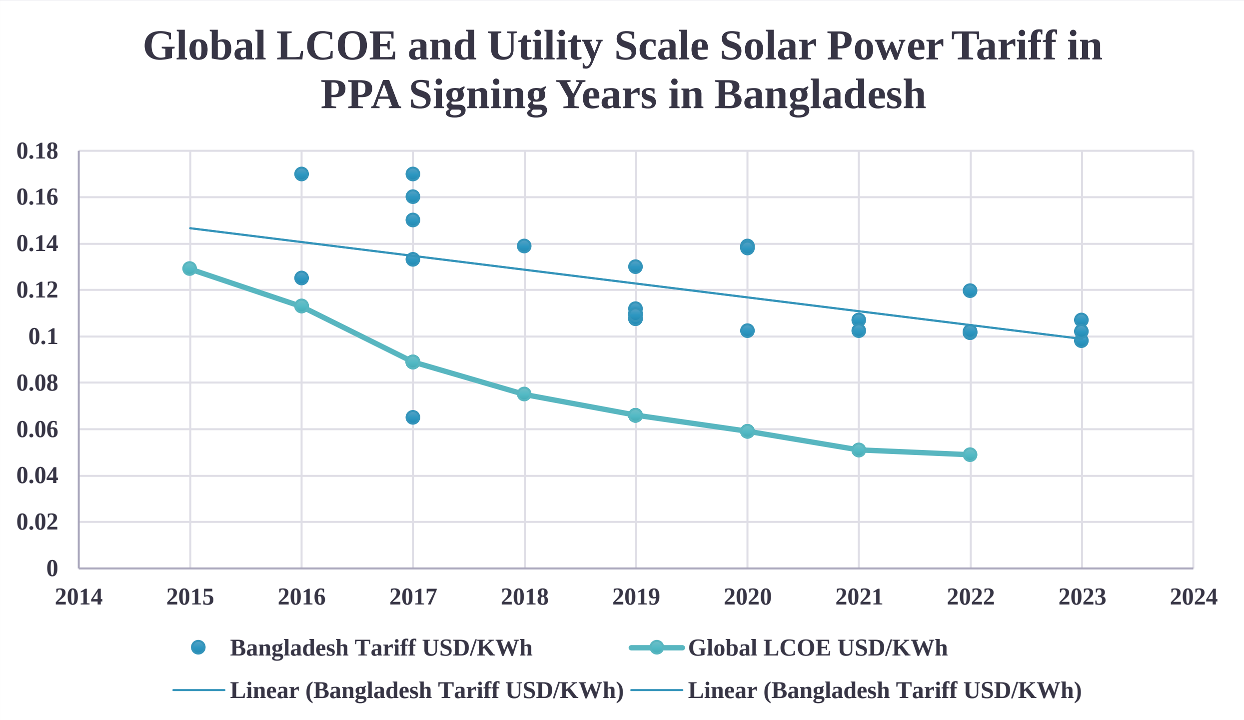
6.5.1 Decline in global cost of solar of utility scale solar in Bangladesh

The price declines of PV modules, PV panels, and PV inverters have been the main cause of the solar cost reduction over the decade of 2010. Module and inverter cost reductions were responsible for 61% of the global weighted-average total installed cost fall between 2010 and 2020, according to the 2020 IRENA study “Renewable Power Generation Costs in 2020." This indicates that the global weighted-average total installed costs dropped, and that BoS (balance of system) expenses played a significant role in this decline. A total of 16% of the global reduction between 2010 and 2020 comes from a variety of minor categories: 7% from racking, 3% from other BoS gear (such as cables, junction boxes, etc.), and 13% from lower installation costs. Greater installer experience and competitive pressures have improved installation processes and reduced soft development costs, leading to BoS cost reductions. BoS costs, which decrease in direct proportion to plant area, have fallen in tandem with rising module efficiencies. (IRENA 2020, p. 7)

The IRENA analysis also revealed that between 2010 and 2020, the cost of electricity produced by utility-scale solar photovoltaics (PV) fell by 85% worldwide. The main reason for this loss was the balance between system costs and module prices, which have dropped by 93% since 2010 as production has gotten more efficient and scaled up and module efficiency has increased.

The currently available data (IRENA 2023) for Bangladesh indicates that, whereas the average LCOEs worldwide decreased more quickly, the PPA tariff (GoB 2023) for utility-scale solar power did not decrease at the same pace. While there is a downward tendency, Figure 3.1 demonstrates that certain PPAs signed in subsequent years have higher tariff rates than agreements signed earlier. This demonstrates that the tariff rates were determined at random without competitive bidding and without a strong justification for the high cost relative to the LCOE for the entire world.

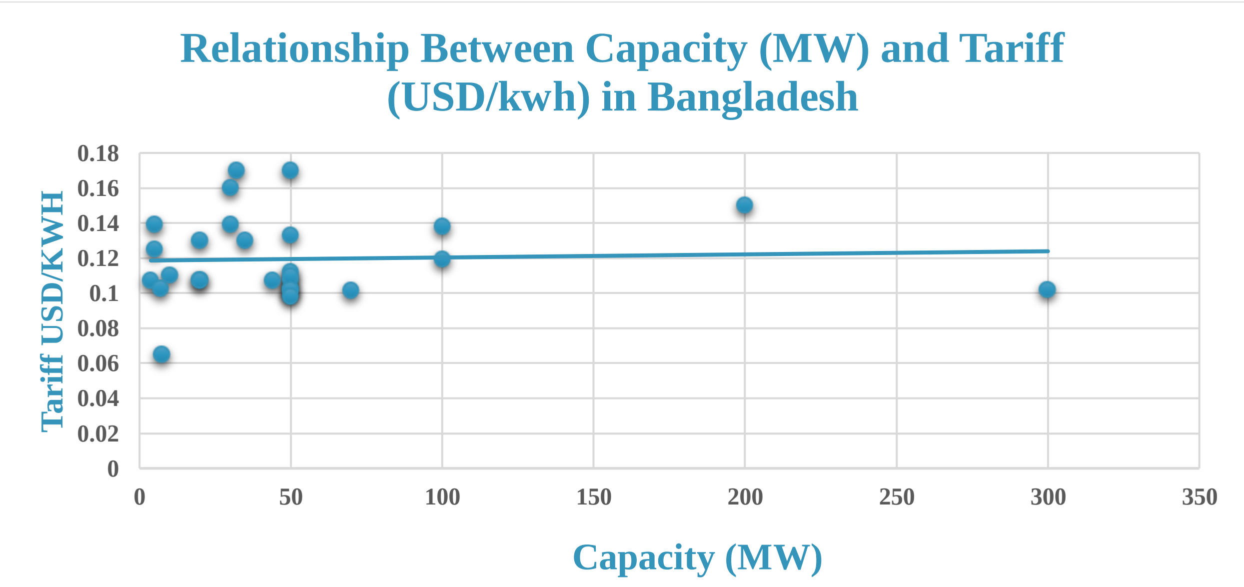
Figure 6-4 Global LCOE and Utility Scale Solar Power Tariff in Bangladesh



Source: IRENA 2023, and BPDP 2023

Figure 6-6 shows that the size of the plant and the tariff are not correlated. The utility scale solar power plants with higher capacity do not have lower tariff rate, indicating no existence of economies of scale. Or even if there exist economies of scale, the PPA tariff rates do not reflect its existence.

Figure 6-5 Relationship Between Capacity (MW) and Traiff (USD/kwh) in Bangladesh



Source: Bangladesh Power Development Board

The LCOE data for each solar power plant in Bangladesh is not available. Therefore, I compare the tariff of utility scale solar power with the global average LCOE. It appears that tariff of utility-scale solar power is higher than the global average LCOE. It indicates a lack of competitiveness in the Bangladeshi solar market. Solar energy is economically less competitive in Bangladesh compared to the global average standard. During the conversation with the solar developers [3], they presented a different reality. They stated that uncompetitive bidding is the reason for the higher tariff rate. They did not outright dismiss the reality that solar electricity in Bangladesh is more expensive than the worldwide average. They provide specific explanations for the high cost. They cited the imposition of high import tariffs on solar technology, insufficient government assistance in infrastructure development, and prolonged project execution times due to the protracted process of acquiring land as key factors contributing to the high cost. Techno-economic considerations do not solely influence these characteristics; current political and socio-technical aspects interconnect with them.

6.5.2 Pricing policy of net metering system for rooftop solar

Bangladesh introduced a net-metering guideline in 2018. (GoB 2018d) A net metering system is one in which rooftop solar producers can supply their excess electricity to the grid, and in return, they can consume the same amount of grid electricity at the market price. In cases of under consumption of electricity, the unused electricity remains as accumulated credit for future days of underproduction due to weather and other unfavorable conditions or unavoidable risks. Although the offer seems to be a win-win situation for both consumers and the utility company, in reality, there are other realities that make this less than an incentive. When designing this policy, the assumption was that rooftop solar would be more profitable the lower the LCOE and the higher the electricity price. Therefore, we anticipated that prosumers would reap benefits from installing solar rooftops. Particularly, we anticipated that industrial and residential prosumers would reap these benefits. However, I later discovered that other techno-economic and socio-technical issues were hindering the enthusiasm of industrial and residential prosumers to invest.

The solar developers [3] who were interviewed have identified several reasons why net metering has failed to generate significant enthusiasm among users. Obtaining financial credit for investing in solar rooftop installations proved to be challenging for industrial users. Either the sectors that required credit had already utilized their assets as collateral for their own enterprises, or the opportunity cost of investing in solar rooftop increased due to two factors. Firstly, the opportunity cost of potential earnings from investing in alternative variable inputs is greater. Furthermore, the cost of the investment in solar rooftop can be recouped at a faster rate compared to the time it takes to save and recover the investment over a longer period of time. Despite the enthusiasm of certain prominent industrialists, they encountered difficulties due to the potential for cost overruns resulting from various risk factors. Despite the seemingly low projected levelized cost of electricity (LCOEs), there are additional concealed expenses associated with the suboptimal efficiency of solar panels, the costs of maintenance, and the poor public views regarding the sustainability of rooftop panels and grid reliability.

Residential prosumers had challenges in reaching a consensus among apartment owners regarding joint investments. Based on previous instances of investing significant amounts of money in solar rooftop systems, residential users did not derive substantial benefits. Multiple factors have been identified during the interviews with UN organizations and with residential prosumers [5, 7]. One factor is the substandard quality of panels sold by a syndicate that exploited the lack of adequate information and guidance for prosumers throughout the entire process. Another reason is the absence of a regulating entity capable of assessing and endorsing the quality of the panels. Furthermore, the dealers did not offer any maintenance service. In general, the inadequate regulatory design and institutional deficiencies prevented investors from reaping the advantages of rooftop solar installation. Despite the high price of power and the low levelized cost of electricity (LCOEs), the response from residential consumers remains negligible.

As per the SREDA national database, as of February 2024, a total of 2138 net metering systems have been established, with a combined capacity of 90.505 MW. The SREDA published brochure states that the Levelized Cost of Electricity (LCOE) for rooftop installations is Taka 3.10 (equivalent to 3.6 cents). In comparison, the retail rate for commercial on-grid electricity is Taka 10.82 (equivalent to 12 cents), and for industrial on-grid electricity, it is Taka 8.98 (equivalent to 10.5 cents). The interviewees, including solar developers, specialists, and financial actors, entrepreneur, [1, 2, 3, 8] provided insights on the significant incentives offered by rooftop solar due to the substantial disparity between the reported rooftop levelized cost of electricity (LCOE) and the market tariff rate.

The net metering strategy transfers the risks associated with various uncertainty to producers. For instance, the actual levelized cost of electricity (LCOE) may exceed the standard level due to adverse weather conditions. Similarly, unexpected high maintenance costs and the need to replace older technology with more efficient alternatives in the future can also contribute to higher LCOE. Additionally, if the quality of photovoltaic (PV) equipment is low, it can lead to increased production costs due to inefficiency.

The interviewees [2,3,4] revealed that the SREDA authority published an LCOE value of Taka 3.10 for a 60-kw rooftop project with a 20-year lifetime. However, the method of calculating the LCOE is a topic of debate. The Interviewees [2, 3, 4] from IDCOL, BPDB, as well as solar equipment suppliers and developers, highlighted that SREDA's published standard LCOE value is low due to its failure to follow the standard LCOE calculation procedure, account for variable costs in electricity procurement and construction, and account for associated risks. Interviewees pointed out that the Levelized Cost of Electricity (LCOE) calculation method, the project's projected lifespan, the need to replace inefficient technologies, and additional variable expenses due to challenges in solar installation on specific structures and unforeseen developments in the vicinity all influence cost variations. Including all these costs would have resulted in an LCOE of at least Taka 6 (7 cents). So, there is a difference between the published LCOE (3.6 cents) and the actual LCOE (7 cents).

Despite the LCOE being 7 cents, it remains lower in comparison to the market pricing. This raises the question of why the market in Bangladesh did not respond despite being offered increased profits after receiving a signal of profitability. When questioned about the cause of this result, the participants provided several reasons.

First, potential deployers often struggle to clearly see the benefits of installing solar rooftops, as these producers typically consume less grid electricity and pay less for it without receiving any credit in the form of cash from the power development board. The implementation of net metering is still in progress, and its impact has not yet become apparent. The net metering system is not an economic incentive, and it does not require any subsidies from the government. Furthermore, the production cost fluctuates with the price of PV modules, panels, and inverters, as well as the associated importation cost.

Second, a supplier made the argument that investing in solar has a higher opportunity cost than other alternative investments due to its longer payback period (6-7 years). If the installed rooftop solar system has a 20-year lifespan, the investor begins to receive benefits after the investment recovers in 6–7 years. The quick returns from investing in other inputs are more alluring to investors when they contrast rooftop solar with other investments in variable production inputs. For instance, a garment factory owner can quickly recoup the cost of his investment in fabric and hired labor compared to his solar investment. Solar rooftop projects can have significant internal rate of returns (IRR), but it takes longer for the benefits to materialize. As a result, investors are not very eager to make solar investments.

Third, solar irrigation pump developers [3] highlights that Bangladesh faces a greater susceptibility to solar implementation challenges compared to other areas. This is mostly due to the frequent occurrence of natural disasters such as cyclones in the southern region and seasonal floods across the entire nation. This requires distinctive components in the construction and design. As a result, the cost increases. Moreover, floods pose a significant risk of causing harm, especially to certain technological devices such as solar pumps. Solar irrigation pumps incur higher costs because to their limited utilization period of three to four months each year, resulting in idle periods for the remaining months of the year. When there are no transmission or distribution facilities, the irrigation pumps are usually not linked to the grid. Due to the lack of government funding for essential infrastructure, the developer is required to financially invest in the transmission line in order to establish a connection to the grid. Here are several factors contributing to the increase in expenses for solar irrigation.

Overall, Bangladesh's failure to harness the techno-economic advantages of net metering can be attributed to inadequately formulated laws and a deficiency in institutional capability to supervise, synchronize, and administer the responsibilities of suppliers, developers, financial institutions, and investors. Hence, the inquiry revolves around whether the selection of the suitable techno-economic incentive relies primarily on socio-technical factors or on market-oriented pricing schemes such as net metering.

6.6 Socio-technical mechanisms

Socio-technical mechanisms refer to the ways by which society and technology systems interact. The relationship between humans and machines involves reciprocal interactions, characterized by learning, feedback, and the development of skills to effectively utilize the technology. The diffusion of solar technology, the influence of acquired knowledge, the presence of positive or negative path dependence, the development of human capacity to adapt to new technology, and the contribution of research to technological advancement are all socio-technical mechanisms that can help explain the slow growth of solar energy.

6.6.1 Learning by doing

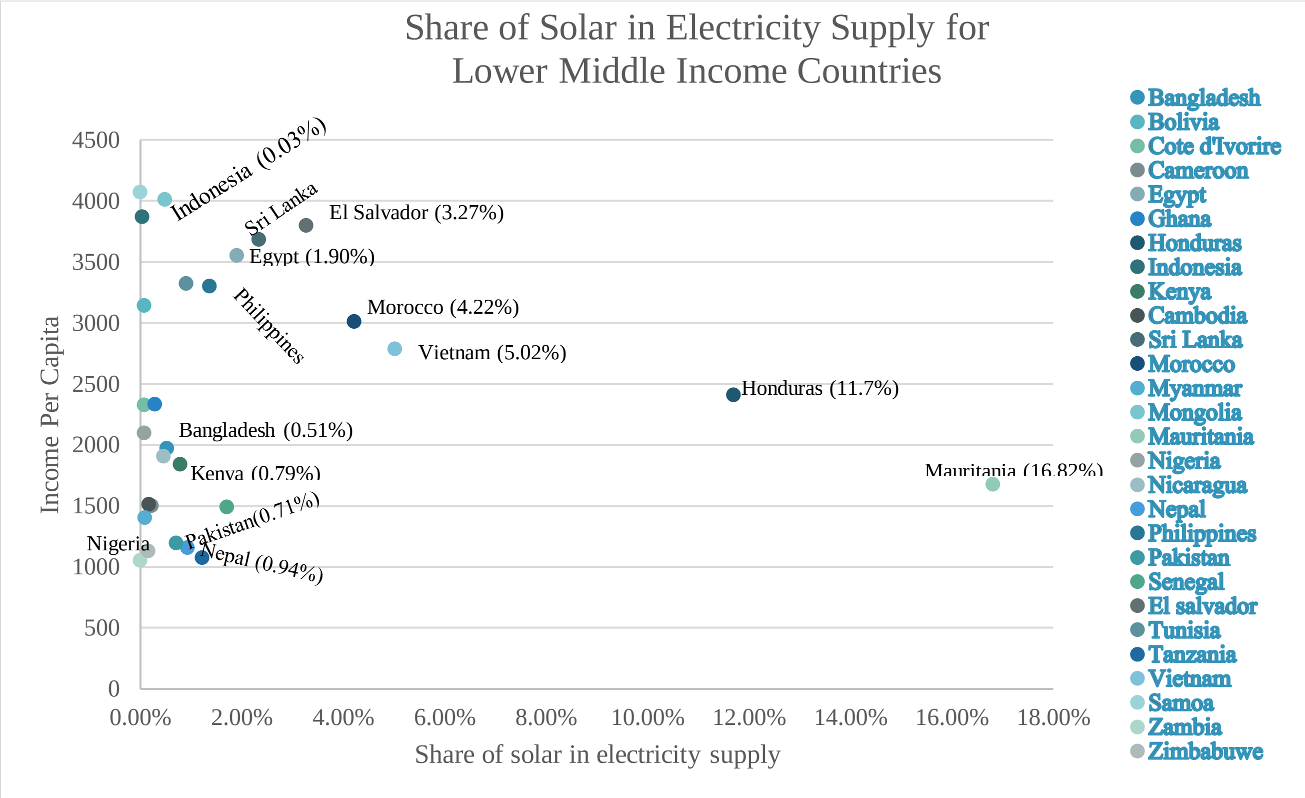
Solar deployment in Bangladesh commenced in the 1990s, making it a rare occurrence among developing nations. Bangladesh has demonstrated global leadership by successfully implementing 6 million solar home systems, establishing itself as one of the leading solar home system providers worldwide. New funding mechanisms were devised to address the challenge of high expenses, social awareness was raised to enhance social acceptance, and knowledge was disseminated to remote off-grid regions to establish solar home systems as a viable and enduring energy source. During the period from the 1990s to 2010s, the energy system underwent a thirty-year process of trial and error in adopting solar residential systems. Based on the overall pattern of technology adoption and the learning process, the accumulation of experience typically should have a beneficial effect on the rate at which future technology is adopted. This is due to the transfer of information and the advantages of scale. The study conducted by Grübler et al in 1999. Bangladesh is an intriguing scenario where the practice of learning from experience did not yield any favorable outcomes when the cost of solar energy began to decline. At this stage of solar expansion, it is worthwhile to wonder if the process of learning from experience truly contributes to the growth of solar energy.

To determine the significance of learning, I conduct a comparative analysis of the time it takes for lower middle-income nations to embrace solar technology. The objective is to ascertain if this trend is also observed in other countries. The deployment of renewable energy varies among countries in terms of the timing. It is a well-established fact that certain wealthy countries are pioneers in their progress, whereas emerging ones tend to lag behind. To establish the transition to solar, it is crucial to determine the specific timeframe when the deployment commenced. Deployments of solar energy systems in underdeveloped nations may occur in a haphazard manner, and it is uncertain whether there will be substantial knowledge gained from these experiences that will accelerate future growth. As an illustration, Bangladesh asserts that it has implemented over six million solar residential systems. However, it is important to note that a significant proportion of solar home systems are not currently linked to the main power grid. Additionally, in the past, some of these systems have ceased functioning due to a lack of maintenance and consumers transitioning to alternative sources of electricity from the grid. Therefore, the ongoing utilization of solar energy and its sustained expansion over a specific period of time are key factors in determining the likelihood of future growth. Furthermore, the decrease in cost of various solar technologies is not uniform. The answer to this question is contingent upon various factors, including the magnitude of the project, the availability of suitable land, the accessibility to advanced technological resources, and the overall cost of implementation.

The completion of the formative phase of solar deployment represents major advances in solar deployment. Different countries define formative phases differently. Researchers have described the formative phase in various ways. A few defined it according to the amount of R&D support needed (Jacobson and Lauber 2006), while others predicated it on hitting a specific prospective market share barrier (Bento and Wilson 2016). According to some definitions, it's the stage at which a nation's power production from renewable sources surpasses a particular threshold relative to its overall electricity production (Vinichenko, 2018). Some define it as the stage preceding the onset of exponential growth during the take-off phase. I define the formative phase as the period in which the percentage of solar energy in the electrical supply is less than 2% of the total electricity supply, based on an analysis of the share of solar energy in lower middle-income nations.

Figure 6-6 shows the share of solar in electricity supply for 28 lower middle-income countries, for which data were available until 2020 or at least until 2019. It reveals that most of the lower-middle-income countries are still in the formative phase of their solar deployment. There are only six countries—Sri Lanka, El Salvador, Morocco, Honduras, Vietnam, and Mauritania—whose solar share is higher than 2%.

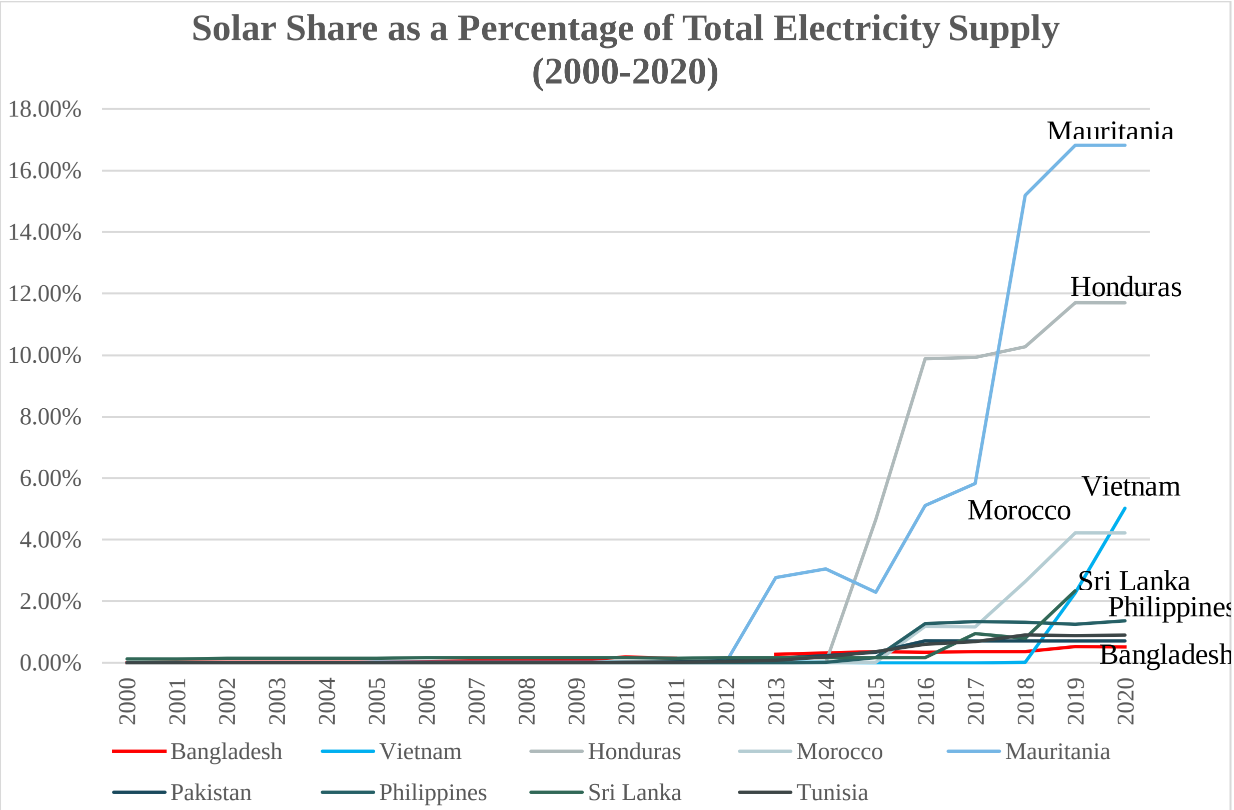
Figure 6-6 Share of Solar Electricity Supply for Lower Middle-Income Countries



Source: Ember (2021)

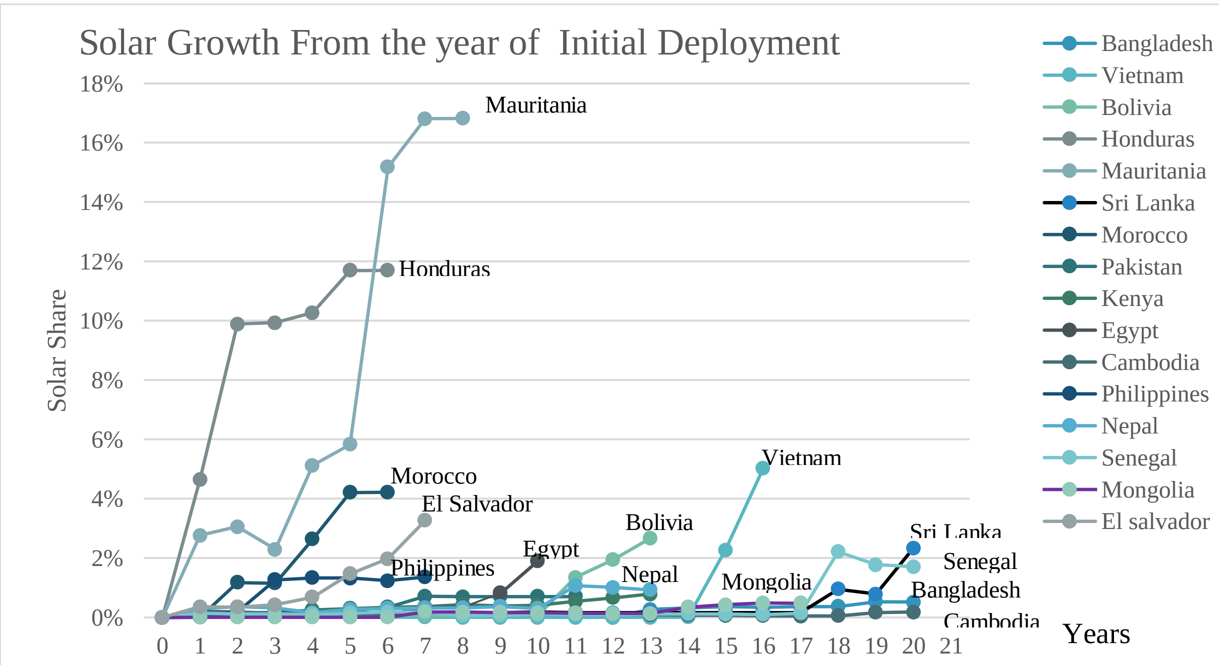
Figure 6-7 shows how the solar share grew in two decades (from 2000 to 2020). It shows no particular trend in the duration of the formative phase. For example, the solar share in Bangladesh, Nicaragua, Senegal, Cambodia, Zambia, and Sri Lanka grew slowly in the first decade, but none of the countries except Sri Lanka could have a solar share greater than 2%. On the other hand, countries like Vietnam, Morocco, Mauritania, and Honduras that achieved a high share of solar did not have a long formative phase before their solar share increased to more than 2%. Vietnam, Honduras, and Mauritania achieved more than a 2% share of solar in just one year; Morocco took 4 years to increase its solar share to exceed 4%. It shows that the countries that started solar deployment earlier did not necessarily take off earlier. Rather, the countries that made significant progress in a shorter time continued to grow rapidly. It is evident that learning from experience was not a significant factor for the countries that experienced faster growth. Therefore, we can say that factors other than learning by doing played a more important role in the faster increase in the solar share.

Figure 6-7 Solar share as a percentage of total electricity supply (2000-2020)



Source: Ember (2021)

Figure 6-8 Solar growth from the year of initial deployment



Source: Ember (2021)

Table 6-2 categorizes the countries according to their duration of deployment and growth stage. Bangladesh falls into the category of longer duration and low growth, indicating that learning by doing did not accelerate growth. The countries with shorter durations and high growth have very low installed capacity and total electricity supply. Examples like Mauritania (0.4 GW), Honduras (5 GW), and Morocco (8 GW) are not comparable to other big countries where installed capacities are more than 20 GW. Vietnam is the only country with a solar deployment duration greater than 10 years that has higher solar growth. Like Bangladesh, Vietnam is also known as a fast-growing economy with rapidly rising electricity demand. But Vietnam grew very fast, from almost zero to 19.4 GW in two years. According to a report from national utility EVN, Vietnam installed 19.4 GW of solar capacity by 2020, of which rooftops constitute 9.3 GW and utility-scale 10.1 GW. This means Vietnam has surpassed the 2030 target it set in 2016. On the other hand, Bangladesh could not meet the 10% target by 2020.

Table 6-2 Categorizing countries according to growth and duration of solar technology use

	Low Growth Less than 2%	Medium Growth (more than 2% and less than 4%)	High Growth (more than 4%)
Shorter Duration (10 years or shorter than 10 years)	Philippines, Egypt, Zimbabwe, Zambia, Tunisia, Myanmar, Indonesia, Ghana, Cote d'Ivoire	El Salvador	Mauritania, Honduras, Morocco
Longer Duration (more than 10 years)	Bangladesh, Pakistan, Nicaragua, Cambodia, Samoa, Mongolia, Nepal, Kenya, Tanzania, Nigeria, Cameroon.	Bolivia, Senegal, Sri Lanka	Vietnam

Note: Categorized by authors based on the Ember Global Electricity data (2021)

In Vietnam, from 2019 to early 2020, the majority (80%) of solar development consisted of utility-scale solar projects, which were encouraged by a Feed-in Tariff of $0.093 per KWh. The tariff for utility scale solar was subsequently decreased to $0.079 in April 2020, while the tariff for rooftop solar, valid for a 20-year period, was set at $0.0838 per kilowatt-hour and scheduled to expire on December 31, 2020. The investors exerted a significant endeavor to transition enterprises from utility-scale to rooftop solar. Vietnam has demonstrated exemplary progress in expanding its solar electricity generation, surpassing all other countries, particularly those classified as lower middle-income nations.

6.6.2 Low trust to the society

A net metering system could not generate sufficient interest among residential consumers because of their previous bad experience of installing solar home systems. In 2010, the government made it mandatory for new domestic, industrial, and commercial electricity connections to include solar energy in order to increase renewable energy production. Households were required to generate at least 3% of their energy needs from solar power, while industrial and commercial establishments consuming over 50 KW of electricity had a higher target of 10%. The expectation was that this mandatory rooftop solar installation would boost solar adoption. However, it led to non-functioning solar installations. As a result, both industrial and residential consumers lost trust in the suppliers and, in general, in the society that facilitated the previously failed projects.

The experience of installing solar home systems and rooftop solar had led prosumers to spend a significant amount of money without reaping the promised benefits. The quality of previously installed solar panels was poor, maintenance facilities were unavailable when needed, intermittent supply could not meet demand, and most importantly, the services were not worth the money they invested. This has created negative path dependence. Inadequate regulatory capacity, along with a lack of credibility in the energy system to support the adoption of solar technology, hampered the response to the late-adopted initiatives. The negative feedback from early diffusion slowed down the next level of diffusion. Even when the cost came down below the market price, the investors were not responsive to the profit signal.

6.6.3 Research, human resource, financial, and institutional capacity

Since the preparation of the first renewable energy policy in 2008, the government and universities have undergone numerous institutional changes aimed at supporting research, human resource development, and capacity building to aid in the development of renewable energy. In 1981, the University of Dhaka opened its first center for renewable energy research. But up until 2010, it operated in a restricted capacity. In 2011, Renewable Energy

Institute was founded to educate the workforce responsible for creating renewable energy sources. However, in order to broaden its scope of work to include various forms of energy, the institute renamed itself the Institute of Energy in 2013. This rebranding reflects the institute's incapacity to survive with a solely renewable focus.

Other private universities, such as MIST, BRAC University, and United International University, later began to offer courses intended to train future human resources in the field of renewable energy. Among these, the founding of the Center for Energy Research at United International University in 2010 significantly contributed to the development of human resources. Respondents to inquiries [1] about the percentage of graduates employed in the renewable energy sector at United International University, a private institution, and the University of Dhaka, a public institution, revealed that 80% of graduates from private universities and only 5% from public universities hold such positions.

This demonstrates that capacity is developing unevenly among educational institutions, and the private sector has been contributing more to Bangladesh's efforts to develop human resource capacity.

Bangladesh developed financial institutions to introduce financial instruments to address the need for financial capacity in solar investment. Initially, when solar home systems were costly, they were less attractive to consumers. In the absence of grid connectivity, SHS first gained popularity among the rural elite who could afford to install it. To make it more attractive to rural consumers, innovative financial instruments were necessary. Moreover, to make the financing recoverable, an institutional setup was required to oversee, assess, and implement the financial drive necessary to finance solar. The World Bank and other international financing institutes needed to collaborate with an institution that could provide loans and other technical support to promote renewable energy projects. The government of Bangladesh established the Infrastructure Development Company Limited (IDCOL) in 1997 in response to this necessity. Licensed by the Bangladesh Bank as a non-bank financial institution (NBFI) in 1998, IDCOL has been working to bridge the financing gap for developing medium- to large-scale infrastructure and renewable energy projects in Bangladesh. IDCOL worked with a wide range of actors, including donors, financial institutions, NGOs, suppliers, developers, and government bodies, to develop sustainable financing instruments. IDCOL's development was a significant milestone in institutional reform aimed at promoting solar.

The Bangladesh government enacted the Sustainable and Renewable Energy Authority Act 2012 with a view to reducing global warming, environmental hazards, and energy security by reducing dependency on fossil fuels through the use and expansion of renewable energy. In 2014, the government established the Sustainable and Renewable Energy Authority (SREDA) as a dedicated institution to promote the use of renewable energy. However, since its inception, it has been under the government's Ministry of Power, Energy, and Mineral Resources and has no independent institutional capacity to influence policy; rather, it has remained a body developing implementing capacity.

If the government provides support to attract international actors, private sector developers [3] believe Bangladesh has the capacity to develop solar manufacturing. According to the interviewee, solar manufacturing is not an energy-intensive or knowledge-intensive sector. Moreover, there is no huge land requirement for this sector to grow in Bangladesh. With properly channeled political interest, it is possible for Bangladesh to grow solar manufacturing.

Solar developers [3] stated that solar projects in developing countries can generate more employment opportunities than in developed countries. Manual maintenance, assembling, racking, and developing a market for spare parts of solar equipment can create more jobs and increase capacity faster than in developed countries. They [3] identified the lack of coordination among different bodies as one of the challenges to achieving high feasibility. The city planners, architects, and transportation planners need to coordinate to maintain building codes and prevent unplanned construction of high-rise buildings that can slow down rooftop solar development. In Bangladesh, the weaknesses of governance and law enforcement are a major obstacle to faster growth. The irregularities in charging import duties and the absence of a laboratory for quality assurance hamper competitiveness and quality assurance. These factors ultimately lead to an increase in costs and serve as deterrents for developers and suppliers.

6.7 Political and policy mechanisms

Adopted policies ideally should align with the interests of the most powerful interest group among the different competing political interest groups. The underlying factors that contribute to the preference of certain policies over others shed light on the political mechanisms that have hindered the growth of solar energy in the past decade. Policies do not possess political neutrality. The imposition of import duty on solar equipment, the recipients of income tax waivers, the acceptance of unsolicited and solicited proposals, the allocation of infrastructural support, and the beneficiaries of the net metering system in solar rooftop are not merely policy choices driven by economic rationale. These inquiries pertain to political matters and should be addressed within the context of political and policy frameworks.

There are also certain policies that have not yet been put into action or are inconsistent with the government's actual practices. In such circumstances, it is important to be cautious when assessing the practical execution of policies, since their effectiveness may be deceiving if they are not executed efficiently and are only enacted for political purposes. Despite the Mujib Climate Prosperity plan 2022 aiming to raise the proportion of renewable energy to 40% by 2041, the current policies do not provide evidence of the target being desirable or achievable. However, in certain scenarios, the policies seem to contradict each other, highlighting the inherent conflict between the purpose of developing national capability (protectionist policy) and the objective of promoting a free market (liberal policy). Therefore, it is necessary to thoroughly examine the state's involvement, as well as its ability and authority to oversee the implementation of approved rules, in order to obtain a comprehensive understanding of the reasons behind the sluggish uptake of solar energy.

6.7.1 Rent seeking

This section examines the technological features of solar technology and their connection to chances for rent seeking. Additionally, it conducts an analysis of certain policies by identifying the individuals involved and their conflicting interests, as well as the elements that provide advantages to these individuals as a result of the existing regulations.

The adoption of power and energy technologies creates opportunities for rent seeking, which serves as an incentive for rent seekers to enter the energy market. They aim to safeguard their monopolistic profits or take advantage of being the first to enter the market. Three factors limit rent-seeking potential in the solar technology sector in Bangladesh. Solar technology eliminates the need for purchasing and selling fuel for the whole lifespan of the plant, thereby avoiding the involvement of various actors in the production, logistics, and distribution networks. Once the solar panels are placed, there is no longer a requirement for regular fuel supply, which eliminates the necessity for a group of individuals seeking rent throughout the year. This inherently precludes any recipients from the manufacture and distribution of gasoline.

Furthermore, it should be noted that solar panels are classified as durable commodities, meaning that they are not subject to incremental investments for the purpose of enhancing their efficiency. In order to transition to a more sophisticated technology, it is necessary to replace the current panels and equipment with new, more efficient ones. This will entail making new investments in a set of more complex equipment. Consequently, there are few possibilities for improvement and minimal prospects for using existing technologies for personal gain. Furthermore, solar power plants do not require capacity payments, which sets them apart from other power plants that rely on fossil fuels. Capacity payment serves as a form of rental income for power plants that rely on coal, liquefied natural gas (LNG), and oil. Private power plants receive payment from the government for their capacity, even if they are not actively generating electricity. Solar energy is very unappealing to investors due to its lack of year-round profitability guarantee. Without a cost or price signal indicating higher profitability in the long term, investors have little motivation to make major investments to improve efficiency.

Despite the potential for future rent-seeking opportunities for the current government, the lack of strong regulatory capacity in Bangladesh to enforce sustainable energy policies has undermined investor confidence and discouraged them from taking advantage of any such opportunities. The absence of a strong connection between the government and the solar energy sector, primarily due to the limited financial and political advantages compared to other sectors in the economy, resulted in a lack of motivation from the government to create a favorable environment for business groups to benefit from cost and price incentives.

In the case of utility scale solar, solar developers [3] commented that the government initially allowed only a few selected big business groups to submit unsolicited proposals and build expensive utility scale solar plants, which created limited opportunities for rent seeking. This changed when the government was compelled to promote solar energy during the acute energy crisis in 2022 and 2023. Nevertheless, the imposition of a 37% tax on inverters remains a significant factor contributing to the high cost of solar energy. This tax creates a barrier to entry, limiting market access to just a selected few wealthy investors who are willing to invest substantial cash and view this as a chance to secure profits as early adopters. The sluggish expansion of utility scale solar between 2015 and 2023 can be attributed to the scarcity of rent-seeking options available to a restricted group of developers.

6.7.2 Import duty

All independent power producers (IPPs), including those that rely on solar energy and traditional fuel sources, are exempt from import taxes or duties on power plant equipment and spare parts. As a result, solar IPPs have the same advantages as other IPPs. Nevertheless, the import tariff exemption does not apply to net-metering solar rooftop OPEX operators or engineering, procurement, and construction (EPC) contractors. The respondents [3] voiced their dissatisfaction with the differential incentives that apply to various solar technologies. Smaller projects with greater growth potential do not receive the same benefits as larger projects, even when the latter receive more indirect subsidies.

The import tariff policy calls into question how well import duty waivers work to promote solar energy. As of 2024, Bangladesh had installed utility-scale solar projects with a total capacity of 461 MW, and more were in the construction and planning stages. Had this duty waiver been a sufficient motivator, we could have seen a greater rate of IPP growth. Trade barriers are not the bottleneck; rather, it is other policy decisions that have prevented solar energy from growing to the desired level in the past. There must be other workable policies that support the expansion of solar power in order for investors to make decisions based solely on the import tariff waiver.

Currently, the 1% customs duty on solar panels and the 37% customs duty on inverters appear to be a hindrance. In contrast to the optimistic solar target of the State Ministry of Power and Energy, the imposition of duty has resulted in additional hurdles, hence raising the costs of solar energy in Bangladesh. On the other hand, India either waives or greatly reduces import taxes on plant equipment. Tax holidays and other advantageous legislative incentives and regulations help the Indian supplier by lowering the cost of doing business.

6.7.3 Income tax waiver

An income tax waiver is commonly seen as a form of incentive in a competitive market. It reduces costs for a specific group of suppliers, giving them a competitive edge over other suppliers. While income tax waivers for solar developers are sometimes seen as incentives, they do not effectively fulfill their intended purpose since all electricity providers receive the same income tax waiver.

Independent Power Producers (IPPs) who sell power to the national grid are granted a tax exemption on their earnings for the initial 15 years of commercial operation. All categories of private power generation firms, including solar independent power producers (IPPs), can equally gain advantages from this form of indirect assistance (Bangladesh Bank, 2021). Therefore, it is not feasible to see this incentive as providing the solar developer with preferential treatment. Solar-powered power generation does not enjoy the same advantages as fossil fuel-based power generation companies, such as capacity charges, exorbitant tariffs in Power Purchase Agreements, inexpensive energy, and infrastructure support in the form of roads, transmission, and distribution facilities. Consequently, the solar independent power producer (IPP) developers do not receive a substantial profit due to the income tax exemption.

The efficacy of import tax waivers in promoting solar energy is being questioned by the import tariff policy. By 2024, Bangladesh had successfully implemented utility-scale solar projects, boasting a cumulative capacity of 536 MW. 385 MW capacity projects other projects in the implementation phase. 3250 MW is still in the planning phase. (SREDA 2024) If the tariff waiver had been an effective incentive, the respondents [3, 2] thought that it would have observed a higher rate of IPP (Independent Power Producer) growth. The hindrance to the growth of solar energy in the past has not been trade barriers, but rather other governmental decisions. For investors to rely exclusively on the import duty waiver, there need to be additional feasible policies that promote the growth of solar power.

At present, the 1% tariff on solar panels and the 37% tariff on inverters seem to be an obstacle. Contrary to the optimistic solar goal set by the State Minister of Power and Energy for Bangladesh, the application of duties has resulted in increased costs for solar energy in the country. Conversely, India either exempts or significantly decreases import duties on plant equipment. Indian suppliers benefit from tax holidays and other favorable legislative incentives and regulations, which effectively reduce the expenses associated with conducting business. [1]

6.7.4 Infrastructural support

The government may allocate funds towards power and energy infrastructure primarily for strategic purposes, driven by its ideological commitment to delivering essential services, as well as for political reasons to demonstrate the safeguarding of national interests. In the past, Bangladesh has made significant investments in the development of infrastructure to facilitate the extraction and utilization of gas, coal, LNG, and nuclear energy. Nevertheless. If the government did not have any interest in giving infrastructure support, it would be the situation with solar energy. In Bangladesh, the Independent Power Producers (IPPs) are responsible for bearing the expenses related to the grid impact assessment, line root survey, building of transmission lines and evacuation sub-stations, as well as the costs associated with acquiring the right of way for the transmission network. These expenses are ultimately manifested in the increased cost of electricity generation. (Chowdhury 2018, p.11)

There is a substantial disparity in the extent of government assistance between Bangladesh and India. In Bangladesh, developers are required to bear the cost of specific infrastructure construction, whereas in India, the government takes responsibility for constructing not only the essential roads and transport networks but also the transmission line and substation for solar projects. Undoubtedly, these charges are crucial for the operation of a sizable solar power station. In Bangladesh, the expenses associated with building infrastructure rise when project developers are obligated to both create it and secure approval from multiple authorities. The absence of infrastructure support for solar power plants, in comparison to other technologies such as nuclear, LNG, gas, and oil-based power plants, clearly indicates the government's preference for fossil fuel-based electricity suppliers. These suppliers have effectively utilized lobbying campaigns and established connections with the government to ensure their continued support.

6.7.5 Net metering system in solar rooftop as a poor policy design

In 2018, the government developed the net metering guideline as the first regulatory step to promote solar rooftops in Bangladesh. The government's introduction of the system also shows its political interest in promoting solar. However, there is concern about the extent to which this can be considered an incentive to promote solar. The reason is that, in the five years since its implementation, the net metering system has not significantly contributed to the growth of solar rooftops. In actuality, the net metering system doesn't provide producers with any economic incentives. It is rather a market-based solution that compares the cost with the going market price, and when the cost is less than the existing market price, theoretically, it is profitable for the consumers. This approach ignores the fact that net metering in the very formative phase of solar growth works like a risk-shifting process from the government to the prosumers. This market-based pricing policy is politically desirable as it allows the government to leverage the logic of profitability without the need for government resources or developer support, while simultaneously demonstrating its ideological preference for a market-friendly policy. In reality, information is imperfect, and neither consumers nor producers fully understand the potential future risks. This risk increases the cost, which most prosumers are unable to predict due to their limited familiarity with the technology. In this scenario, the interplay of socio-technical and political mechanisms renders the pricing policy ineffective in leveraging seemingly lucrative techno-economic processes.

In the section on techno-economic mechanisms, I demonstrated why, despite the huge potential benefits of a net-metering system, investor responses have been minimal. An interviewee's mention of an additional element provides a further, equally significant explanation. Within the framework of a technological globalization that is developing at a rapid pace every year, new technical advances are reducing the competitiveness of older technologies through the introduction of more efficient technologies, the marketing of less expensive technologies, or both. Investors now expect to use more efficient technologies due to the exponential advancements in technology over the past ten years.

This has set the stage for speculation. In several cases, the requirement to upgrade older projects to increase efficiency has made them less expensive and competitive. Amidst the competition to employ advanced technologies at reduced costs, some investors choose to postpone their investments. However, a time-bound feed-in tariff offer increases the profitability of the investment by providing an instant return in exchange for solar electricity, lowering the uncertainty surrounding future cost recovery due to falling costs, and offsetting the need to replace outdated technology with more energy-efficient models.

Although Bangladesh's net metering scheme theoretically provides more long-term benefits, the recent response to time-bounded feed-in-tariff proposals in Vietnam and China prompted investors to rush to take advantage of higher tariffs for a longer period of time. Feed-in-tariffs decrease investor risk, but net metering systems increase consumer risk, making them less appealing to investors with diverse investment options. In contrast to feed-in tariffs, Bangladesh's policy of introducing net metering is a market method that distributes the risk to consumers and does not offer any subsidies because of its poorly designed policy and inability to adjust to techno-economic hazards.

6.7.6 Unsolicited proposal

As per the Quick Enhancement of Electricity and Energy Supply (Special Provisions) Act 2010, the government and its affiliated enterprises have the authority to carry out plans for improving the production, distribution, transportation, and sale of electricity or energy. They can also consider proposals to import electricity or energy from other countries and implement those plans efficiently. (GoB 2010, 2)

When project implementation receives top priority, this Act may not guarantee low-cost production. Unlike competitive bidding, this Act provides an opportunity for private players to generate their targeted profit. It facilitates the possibility of targeted bidding, where rent-seeking behavior results in the transfer of public resources to private entities. Increasing the tariff in purchasing power agreements (PPAs) has the potential to provide strong incentives for the solar industry, accelerating the growth of solar projects.

However, this has not been true for Bangladesh. Despite receiving clearance, there has been a significant delay in the implementation of the project, mostly owing to several obstacles, such as delays in acquiring property, preparing the land, and connecting to the transmission and distribution network. The inclusion of unsolicited proposals without competitive bidding did not expedite the provision of electricity supply, nor did it adequately facilitate the rapid growth of solar energy without additional incentives. On the other hand, this legislation serves to justify the exorbitant costs of privatel- owned power generation corporations that depend on fossil fuels, nuclear energy, and imported liquefied natural gas. Thus, rather than granting advantageous treatment to the solar developer, this regulation prioritized the interests of electricity companies reliant on fossil fuels. Furthermore, the prioritization and expedited approval of nuclear and fossil fuel-based projects created a perplexing non-market signal for the prospective expansion of the solar business.

6.7.7 Protecting local manufacturing

Bangladesh has a very small solar manufacturing sector. Solar manufacturing in Bangladesh is not competitive when compared to imported solar equipment. It is difficult for Bangladesh to keep pace with rapidly changing technology and perform in the global innovation system as a small player. In Bangladesh, solar manufacturing has a capacity of only 10 MW. If the capacity needs to increase, it must be able to find an export market. Some solar manufacturers experienced growth in the mid-2010s, but they found it challenging to compete. Out of the nine assemblers, half are no longer in production, while the remaining ones are supplying to the local market. These manufacturers exerted pressure on the government to levy an import duty on solar equipment to safeguard domestic manufacturers (Parvez and Adhikary 2017).

The 2017 budget proposed a high import duty on solar panels to safeguard domestic manufacturers, but the low-cost imports from solar suppliers and developers [3] demanded the proposal's withdrawal. They [3] argued that the limited capacity of domestic manufacturers was insufficient to penalize the vast potential of developers. Finally, the government imposed a 10.5% import duty on panels used for rooftops, irrigation, mini-grids, etc., while offering zero import duty to large-scale IPPs. In a bid to create a balance between protecting local manufacturers and incentivizing solar investors, the government took an interventionist policy that neither fully protected the domestic industry nor, at the same time, fully supported the private developers. [3] As a result, the muddled industrial policy left all investors perplexed by the government's desire to support solar development while in practice implementing non-supportive policies. The manufacturers faced both market and non-market signals that hindered the growth of an already ailing industry.

6.8 Summary

This chapter demonstrates that socio-technical and political factors have a greater influence than techno-economic factors on the solar industry's slow and low growth. Liberalization does not ensure that the cost of doing business is low because it ensures competition. There are other risks. I attribute the high cost to a lack of capacity, a lack of government support, and poor policy design. It is not electricity liberalization that increases the price and creates incentives in the market; rather, it is the lack of competition in bidding.

The solar power market in Bangladesh may appear uncompetitive due to higher tariffs, but developers argue that this is due to uncompetitive bidding and factors like high import duty on equipment, lack of government support, and long project execution times. Political and socio-technical factors closely relate to these factors, rather than solely being techno-economic.

Techno-economic mechanisms like market-based pricing policies in rooftop solar and uncompetitive bidding in utility-scale solar both proved to be counterproductive in promoting solar growth. The profit-driven approach did not reflect the proper functioning of techno-economic mechanisms in driving prices down. None of these policies were effective in driving solar growth because they were more than a market signal that had the potential to contribute to solar growth. The net metering system overlooks the risk transfer process between the government and consumers due to incomplete information and insufficient awareness among consumers and producers about potential dangers. Although a net-metering system has the potential to provide numerous advantages, investors have shown little interest in it.

Technological globalization is reducing the competitiveness of outdated technologies, resulting in speculation and investment delays. Although there are potential long-term advantages in theory, Bangladesh's net metering policy is a market-based approach that transfers risk to prosumers and does not provide subsidies due to its inadequately constructed policy and incapacity to adapt to techno-economic risks.

Poorly designed policies and a lack of institutional capacity to oversee and coordinate the roles of suppliers, developers, financial institutions, and investors have prevented Bangladesh from realizing the techno-economic benefits of net metering. The chapter's findings suggest that choosing the appropriate techno-economic incentive depends more on socio-technical and political considerations than market-based pricing strategies like net metering.

As the 2010 Quick Enhancement of Power and Energy Supply (Special Provisions) Act is in effect, this policy grants preferential treatment to electrical companies that rely on fossil fuels, discouraging the growth of solar businesses through a non-market mechanism.

Solar technology's rent-seeking opportunities are limited due to factors such as lack of fuel buying and selling, durable panels, and no capacity payment. The government's lack of regulatory capacity and political interest discourage investors from using these opportunities, contributing to the slow growth of utility-scale solar from 2015 to 2023.

This chapter reveals that the high costs are a result of socio-technical risks and a lack of political interest in promoting solar growth through measures such as lowering import duties, providing infrastructural support, developing manufacturing bases, giving preferential treatment to solar over other fossil fuel-based technologies, and inviting unsolicited proposals to prevent competition. The characteristics of solar technology and the inherent lack of rent protection in production and innovation systems limit the scope of rent seeking.

The study reveals that learning is less important in solar adoption in lower-middle-income countries, such as Bangladesh. Despite having a longer learning duration, the country struggled due to technology availability and global innovation systems. Past failures and negative path dependence have made learning less important in promoting solar. Future growth depends on factors like continuous use, scale, land availability, technology accessibility, and deployment cost.

Most lower middle-income countries are still in the formative phase of solar deployment, with only six having a share higher than 2%. Countries with shorter durations and high growth have low installed capacity and total electricity supply. Vietnam, with higher solar growth and a deployment duration greater than 10 years, installed 19.4 GW of solar capacity by 2020.

The government's 2010 mandate for solar energy in electricity connections led to non-functioning solar installations, causing consumers to lose trust in suppliers and society. The quality of solar panels, maintenance facilities, and intermittent supply were unsatisfactory, creating negative path dependence. Insufficient regulatory capacity and credibility in the energy system hampered the response to late adoption initiatives. Even when costs were lower, investors were not responsive to profit signals, resulting in a slow diffusion of solar technology.

Bangladesh has made efforts to support renewable energy research, human resource development, and capacity building since 2008, with the private sector leading. The government has developed financial institutions and established the Sustainable and Renewable Energy Authority, but these measures are insufficient for developing necessary capacity. Government and law enforcement weaknesses hinder competitiveness and disincentivize developers.

Bangladesh's solar manufacturing sector, with a capacity of 10 MW, struggles to keep up with global innovation. The government-imposed import duties on rooftop, irrigation, and mini-grid panels, balancing local manufacturers with incentivizing solar investors.

Currently, 1% of customs duty on solar panels and 37% of customs duty are associated with higher solar energy costs in Bangladesh. India provides tax holidays and other incentives to reduce the cost of conducting business. Although there are import duty waivers for all IPPs, smaller projects with greater growth potential do not receive the same benefits as larger projects.

Solar-powered power generation does not receive additional benefits like capacity charges or infrastructure support, resulting in a lack of profit for solar IPP developers. Income tax waivers in competitive markets lower costs for solar developers, but not all power producers, including independent IPPs, benefit from these exemptions, resulting in lack of profit. However, these exemptions are not exclusive to solar developers, as all power producers, including independent power producers (IPPs) selling electricity to the national grid, benefit from this indirect support.

Governments invest in power and energy infrastructure for strategic reasons, ideological preferences, and political protection. In Bangladesh, the government does not prioritize solar energy, burdening developers with costs like grid impact studies, line root surveys, and transmission line construction. This lack of support reflects a preference for fossil fuel-based electricity suppliers, who have strong lobbying campaigns and tie with the government to maintain their support.

6.9 List of interviewees

The interviewees have been identified to be in the following categories. For example, Experts, consultants, policy makers are grouped together and assigned [1]. I use the numbers [1] [2] [3] assigned to each category in in-text reference. The following individuals are grouped into categories because some of the interviewees provided same answer to the questions they asked.

6.9.1 [1] Experts/ Consultants/ Policy Makers

1) Shahriar Ahmed Chowdhury, Chairman, Centre for Renewable Energy Services Ltd. (CRESL), and Director, Centre for Energy Research, United International University, Bangladesh Researcher, policy maker (Drafted National Solar PV Action Plan, 2021 – 2041)
2) Saiful Huque, Director and Professor, Institute of Energy, University of Dhaka.

6.9.2 [2] Financial Institutions

3) Farzana Rahman, Executive Vice President and Unit Head (investment), Renewable Energy, Infrastructure Development Company Limited (IDCOL)
4) Tauhidul Islam, Project Director, Infraco Asia (providing leadership and capital to develop early stage infrastructure projects into viable investment opportunities)
5) Tanuja Bhattacharjee, Energy Specialist, World Bank.

6.9.3 [3] Solar Developers/ Equipment Suppliers

6) Md. Nurul Aktar, CEO & DIRECTOR, Energypac Electronics Limited
7) Taher Sherpa, Director, SHERPA POWER ENGINEERING LTD
8) A.K.M Kamrul Huda, Project Director, Spectra Solar Park Limited
9) Shafiqul Alam, Lead Energy Analyst, IEEFA
10) Mostofa Al Mahmud, Director, Gtech Solar.
11) Dipal Chandra Barua, Founder and Chairman, Bright Green Energy Foundation

6.9.4 [4] Public Utility/ Renewable Energy Authority

12) Md. Rashedul Alam, Assistant Director, Sustainable and Renewable Energy Authority
13) Ahmed Zahir Khan, Director, Renewable Energy Department, Bangladesh Power Development Board
14) Jahangir Alam, Engineer and Project Coordinator, Kaptai Solar Power Project

6.9.5 [5] UN Organizations

15) Arif Mohammad Faisal, Programme Specialist, Environment and Energy, UNDP
16) Mowdud Rahman, Energy Associate, UNHCR

6.9.6 [6] Journalists

17) Ismail Ali, Energy Reporter, Share Biz

6.9.7 [7] Residential Prosumers

18) Mir Muhammad Morshed, Uttara Residential Area
19) Mizanur Rahman, Ena Real Estate Company

6.9.8 [8] Renewable Energy Entrepreneur

20) Niloy Das, Electric Engineer and a young entrepreneur.

7 Geopolitics and Nuclear Power in Bangladesh

7.1 Introduction

The construction of the first 2.4 GW capacity nuclear power plant (NPP) in Bangladesh, has begun in 2017 with the financial and technical support from Russian State Energy Commission (ROSATOM). This plant, commonly known as Rooppur nuclear power plant (RNPP), is the largest project ever undertaken in the country in terms of technical complexity, cost, and risk profile. The investment for this project is $12.5 billion, which was roughly half of Bangladesh's outstanding external debt ($26 billion) in 2017 when the construction started. With the increase in external burden in the following six years the cost stood at 13% of external debt in 2023. The eventual cost of generating power would be "at least 60 percent higher than the present retail cost" of electricity in Bangladesh (Froggat et al, 2018).

As nuclear adoption of developing country is a new phenomenon, there is limited understanding on the origins of this development, its potential for success and growth, and whether it indicates a recurring trend in other developing nations. The discourse over the contribution of renewable energy sources and nuclear power in reducing carbon emissions from the power grid is becoming more intense due to the remarkable decrease in the cost of renewable energy sources (Lovins et al, 2018). At least 2.4 GW utility scale solar capacity could be installed by investing only $3.6 billion, which is about one fourth ($12.5 billion) of the investment in Rooppur nuclear power plant.[5] Nevertheless, the discussions primarily focus on advanced economies, despite the fact that the majority of the increase in energy demand is occurring in emerging countries. Hence, it is crucial to comprehend the paths that nuclear power is taking in developing nations.

Bangladesh is an important case-study in this respect. Because Bangladesh will be the third lower middle-income country after India and Pakistan to have nuclear power plant after NPP operation starts in 2025. Currently, among the 32 countries with nuclear power plant, only

[5] Calculated by the author using investment in 200 MW solar power plant and the investment in nuclear power plant, from the estimate given in new report. (Star Business Report 2023)

India and Pakistan fall in the criteria of lower middle-income country (AIEA 2022). Both India and Pakistan are also the only two nuclear weapon countries in South Asia region. There is a long history of rivalry between these two countries. While these nations initiated their nuclear weapon programs as a strategic reaction to the geopolitical tensions at both the global and regional levels, Bangladesh has made the decision to construct its first nuclear power plant without any aim of developing nuclear weapons. Furthermore, the under construction nuclear power facility does not confer any regional strategic benefit to Bangladesh.

This chapter explores why and how a developing country like Bangladesh has launched an expensive nuclear power program and why a country like Russia could find it attractive to provide technological and financial assistance for such a program. It examines the driving forces and the nature of international nuclear cooperation in particular, and how the interplay of economic and strategic drivers shapes the cooperation in project initiation and implementation phase. Economic cooperation is defined as cooperation driven by purely economic need, decided on cost benefit considerations and involving comparison between two or more suppliers. Strategic cooperation is defined as cooperation between two countries when one or both countries cooperate primarily not for economic but for political gain.

One of the energy technologies that Bangladesh is currently in the process of adopting is nuclear energy. Nuclear technology stands apart from other technologies due to its exorbitant upfront capital expenditure, which far exceeds the costs associated with other technologies that require less investment. The case of nuclear adoption by Bangladesh holds significant importance in comprehending the context of developing countries. This is due to the fact that it is frequently recommended by practitioners and experts as a technology, without fully grasping the many complexities associated with it. The complexity of nuclear technology is not solely limited to its technical aspects, but also encompasses socio-technical and political factors that set it apart from other technologies. While other chapters discuss the adoption of new technologies such as solar, coal, and LNG in Bangladesh, this chapter specifically examines the adoption of nuclear energy from a unique standpoint. The international community's comprehension of the cost and value of nuclear adoption is limited due to their predominant reliance on techno-economic and socio-technical mechanisms to elucidate the feasibility of nuclear adoption. There is limited knowledge regarding the various limitations, such as technological, financial, and institutional, that contribute to the adoption of nuclear energy by developing countries like Bangladesh.

It is puzzling that a country like Bangladesh has chosen to pursue nuclear power despite the challenges it presents. From a techno-economic standpoint, it is a risky decision for Bangladesh to spend a significant amount of foreign currency and remain dependent on a technology for which it lacks adequate capacity. Politically, this decision also carries risks. Therefore, it is worth examining Bangladesh's risk-taking attitude from three perspectives: techno-economic, socio-technical, and political. This chapter holds particular importance as it delves deeper into the research of geopolitical and political mechanisms, specifically focusing on the techno-economic mechanism. It highlights that the conventional economic liberalism, which is based on competitive cost, fails to adequately explain the actuality of the situation. The chapter's findings are valuable for addressing the broader concerns of the dissertation, namely, which energy transition factors elucidate the energy outcomes of emerging countries, particularly Bangladesh.

7.2 Bangladesh nuclear roadmap

Back in 1960, during Bangladesh's time as part of Pakistan, the Rooppur Nuclear Power Plant was initially planned by the Pakistan Atomic Energy Commission. In 1963, Pakistan initiated discussions with USAID regarding a 70 MW nuclear power plant, but unfortunately, the negotiations did not yield the desired outcome. In 1968, a Soviet company suggested the construction of a 400 MW Pressurized Water Reactor (PWR), while in 1969, a Belgian firm proposed a 200 MW PWR plant. (Ehsan et al, 2014)

During the 1970s and 1980s, following Bangladesh's independence from Pakistan in 1971, feasibility studies were conducted by French, German, and Swiss companies for a nuclear power plant. In 2001, the Bangladesh government implemented a national Nuclear Power Action Plan. In 2007, a proposal was drafted by the country's Atomic Energy Commission (BAEC) for the construction of two 500 MWe reactors at the same location. China, Russia, and South Korea have shown interest in financing the project and offering technical expertise to establish the power plants. (Karim et al. 2018). Nevertheless, there was no formal bidding process.

Following a formal proposal by Russia in 2009, the two countries signed a bilateral nuclear cooperation agreement. Since then, Bangladesh has not received any other offers from other countries. In 2011, the Bangladesh Government expressed its interest in partnering with the Russian Government to build two nuclear reactor units, each capable of generating 1000 MW of power. The units were planned to be finished by 2018, with a projected cost of US$2 billion.

The expense of the reactor has been escalating while the scheduled date for its activation has been continuously postponed. In October 2013, a ceremony was conducted to officially commence the preparatory stage. Commencement of the formal construction was anticipated to take place in 2015. During the event, the construction cost was increased and it was proposed that each unit would have a price range of US$1.5-2 billion. In April 2014, the cost estimates increased after a top official at the Ministry of Science and Technology proposed that the price was more likely to be US$6 billion. In a 2015 declaration made by the finance minister, it was said that the objective was to have the two Rooppur reactors functioning by 2022, with the anticipation of two more reactors being active by 2030. The government of Bangladesh has declared that it has identified eight potential locations for the construction of the second nuclear power station. Similar to the Rooppur plant, this new facility was also planned to be imported.

In May 2016, discussions were finally completed for the Rooppur nuclear project, which had reached a total cost of US$12.65 billion. Russia provided a credit of US$11.385 billion for the project. Russia would offer 90 percent of the funds as a loan, at an interest rate of Libor + 1.75 percent. Bangladesh is obligated to repay the debt within a period of 28 years, following a grace period of 10 years (2017-2027).

As a result, the construction of 2400 MW power plant started in 2017. Originally, the first- and second-unit were supposed to be commissioned 2022 and 2023 respectively and the entire project was supposed to finish by 2025. The project deadline has been extended by 2 years now. Because of the delay in constructing the transmission line across two rivers, the whole process has been delayed. Till 2024 June, 80% works have been finished. The new expected date of commissioning is 2025 and 2026, and the project completion deadline is extended to 2027.

The onset of Ukraine war and the subsequent sanctions set by the US on Russia made the payment process complicated. There were also delay in shipping equipment in time due to US sanctions on Russian ship. The delay in nuclear projects is usually causes cost to increase.

7.3 Framework for analysis

Based on the World Nuclear Industry Status Report (2018), approximately 20 countries worldwide have concrete plans to implement nuclear power, while an additional 20 countries are currently considering the nuclear option. According to the 2022 World Nuclear Industry Status Report, Nigeria, Poland, and Saudi Arabia have made some progress in their plans for nuclear energy. However, these countries have not yet chosen a specific design or secured funding for their projects. Several countries, such as Indonesia, Jordan, Kazakhstan, Thailand, Uzbekistan, and Vietnam, have decided to suspend or cancel their previous plans. At present, construction of nuclear power plant projects is underway in 15 countries. Out of all the countries, only Bangladesh and India, both developing nations, are currently constructing nuclear power plants.

In a thorough analysis conducted by Jewell (2011), the feasibility of implementing nuclear programs in newly established countries was examined. She made the case that a country's ability to initiate a nuclear power program is contingent upon its capabilities and intentions. She grouped Bangladesh together with Egypt, Indonesia, and Nigeria, stating that nuclear power development is considered "too risky" in these countries due to their high motivation but low capacity. She utilized electricity demand growth as a measure of motivation. When examining the measures of capacity, she considered factors such as the size of the electricity grid, the level of international cooperation, GDP, GDP per capita at PPP, the government effectiveness indicator, and the political stability index.

She pointed out that attracting investment in nuclear power would be challenging in countries with low governance effectiveness and political instability. Looking at it from a scientific perspective, the situation in Bangladesh is quite puzzling as it continues to have a low ranking in terms of governance effectiveness. Her analysis failed to take into account the evolving landscape of international nuclear cooperation, where countries like Russia and China are actively assisting newcomers in overcoming these constraints, or in some cases, disregarding the lack of national capacities altogether. (Brutschin and Jewell 2018).

Since 2009, when Jewell's study paper was published, four countries have embarked on the construction of their first nuclear power plants: Bangladesh, Turkey, Belarus, and the UAE. Only Belarus and the UAE have successfully completed the construction of nuclear power plants among these countries. Russia is the primary contractor in the first three. In a study conducted in 2015, Jewell and Ates delve into the ways in which Russia's involvement played a crucial role in assisting Turkey in navigating the challenges associated with investment uncertainty. International cooperation is increasingly recognized as vital for the advancement of nuclear power in emerging economies. However, there remains inadequate number of studies examining this type of cooperation.

Lantis (2014) is an interesting case investigation that explores the underlying motivations behind nuclear cooperation. In a study conducted by Lantis (2014), two potential bilateral nuclear cooperation options were examined to determine their alignment with either the neoliberal model of economic competition or the model of strategic cooperation in security studies. In order to understand the dynamics of economic competition and the importance of strategic cooperation on a global scale, Lantis put forth two key propositions: 1. Strategic cooperation: Suppliers are more inclined to enter into bilateral nuclear cooperation agreements and offer favorable terms for civil nuclear assistance to established partners. These agreements are often driven by strategic considerations, such as strengthening alliances, improving relations with adversaries of adversaries, or supporting existing democracies. 2. Economic Competition: Supplier states are more inclined to enter into bilateral nuclear cooperation agreements and offer favorable terms for civil nuclear assistance when they are in direct economic competition for a potential client. This competition is often driven by short-term gains, regardless of strategic imperatives. In a study conducted by Lantis (2014), the factors that drive suppliers' motivation were explored. These factors include the establishment of strategic relationships, direct economic competition for clients, and future strategic imperatives. He made a case for Russia's exploration of nuclear technology, highlighting the influence of both strategic and economic factors. The economic considerations primarily stem from the desire to broaden the sources of hard currency earnings beyond the energy market. Russia has established itself as a leading nuclear supplier in the world, offering comprehensive deals that include financing and human capacity building.

While Lantis (2014) addressed on certain factors that drive suppliers, such as their strategic relationship with the recipient country and economic competition from other potential suppliers, his analysis overlooked the potential benefits that recipient countries may offer. He also failed to consider the collaboration from a core-periphery perspective. In addition, his work primarily centers around enrichment and sensitive nuclear technologies in civil nuclear cooperation. He only identifies strategic objectives that are focused on geostrategic factors, such as enmity, alliances, or agreements, which are used as tools to impose strategic costs on rivals. (Lantis, 2014, pp. 23)

In a recent study conducted by Jewell et al (2019), the intricate relationships between nuclear supplier countries and nuclear technology receiving countries were examined. The findings revealed that as of 2019, Russia emerged as the primary supplier in nearly half of all agreements. Additionally, France, the US, China, Korea, and Japan collectively accounted for approximately 40% of the agreements. Russia and the US have been found to have a significant influence on international technological nuclear cooperation. The United States excels in ensuring safety and security, while Russia takes the lead in nuclear power plant construction, reactor and fuel supply, decommissioning, and waste management. They emphasized that the collaboration among nations, driven by economic and political factors, particularly energy security, will be crucial in shaping future nuclear power scenarios. Brutschin et al (2022) went beyond the debate of strategic versus economic cooperation and instead focused on contextual variables that can influence the adoption of nuclear. They found that the adoption of nuclear power can be explained by ease of diffusion from proximity to a major technology supplier, electricity demand growth, the size of the economy, and energy import dependence.

Neither of the frameworks can adequately explain the development of nuclear power in Bangladesh. Because these frameworks either deal with suppliers' motivation and recipients' capacities or with contextual variables facilitating introduction of nuclear. The nature of interdependencies, particularly for a new comer country like Bangladesh and a supplier country like Russia, is insufficiently explored from demand and supply point of view. The demand is largely explained by the growth of electricity demand. The political and strategic motivations of both recipient countries and supplier countries are largely missing in the framework.

I will explore several distinct mechanisms potentially relevant to adoption of nuclear power in Bangladesh by differentiating between core (technology innovator country) and periphery (technology receiving country). In contrast to the power- and agency-neutral understanding of 'core' and 'periphery' in technology diffusion studies (Grübler, 1999, Eaton, 1999) I will interpret these concepts in terms of the world-systems theory. The world-system theory suggests that capitalist development takes place unevenly, not only creating the gap between "core" and "periphery", but also tending to concentrate productive advantage among the core states. Since the capitalist world-system creates inequality by definition, cooperation between the core and peripheral areas is necessarily imperialist by its character. (Siitonen, n.d. 1990). The theory of world-systems helps distinguish between cooperation based on mutual economic benefit and cooperation based on uneven power relation between core and periphery. It conceptualizes cooperation not as a harmonious relationship where no conflict may exist between two unequally developed countries, rather it recognizes the hidden power struggle between the cooperating countries and the mode of dominance of one over another. It also stresses the power and agency of the supplier state as important variables in technology diffusion.

This chapter uses the three-perspective framework discussed in chapter 3 of the dissertation. The three-perspective framework brings three perspectives including techno-economic, socio-technical, and political perspective into analysis using the causal mechanism approach described in chapter 3.

First, the techno-economic perspective involves formation of state goals to address insecurity of supply-demand balance associated with rapidly rising demand for electricity.

Second, the socio-technical perspective involves the mechanisms through which social, environmental, and financial risks are managed individually by core and periphery and through cooperation between two uneven power in both the initial phase and implementation phase. The role of existing innovation network, the evolving character of it, and the dependency on it by the periphery can explore the causal mechanism of adopting nuclear project in periphery.

Third, the political perspective involves the exploration of how having nuclear power project by periphery is closely related to national identity in the politics and its aspiration to become developed country in near future, and the desire of economic expansion of core by exploitation of the aspiration to become developed country. The political mechanism also involves the core and periphery's action to promote particular solutions (e.g. nuclear power) as constrained by capacities to build necessary infrastructure and to establish related regulatory environment, health and safety issues, and conditions of finance.

7.4 Gaps in existing explanations

Many countries in the past expressed their interest in pursuing nuclear energy for various reasons. These include meeting increasing energy demands, reducing import dependency, diversifying energy sources, and addressing local and global air pollution concerns (IAEA, 2016). Bangladesh has consistently cited meeting the rising demand as the primary reason for pursuing nuclear power.

In 1960, the rationale for the first nuclear plant was to address the power supply shortage, and this driving force has remained consistent ever since. Sultana (2016) asserts that a lack of energy resources or an overreliance on one resource for power generation did not cause the power crisis. Instead, it was due to a structural issue in planning and policymaking regarding the use of local resources. The 2023 energy crisis has once again highlighted the underlying issue of relying heavily on imported energy sources such as coal, oil, and LNG. Given the current challenges with foreign reserves and the increasing costs of LNG and coal, Bangladesh is facing difficulties in meeting its energy payment obligations.

Over the past six decades, the power sector in Bangladesh has undergone significant transformations to address the supply-demand gap by utilizing its own gas resources. However, the concept of constructing a nuclear power plant persisted, reviving multiple times from 1960 until construction finally began in 2017.

Brutschin et al. (2022) identified high demand growth and import dependency as significant drivers for the introduction of nuclear power. However, their study did not focus on the potential for alternative energy sources or the extraction of indigenous resources. In Bangladesh's case, the history of nuclear project planning demonstrates that there have always been options to meet demand from other indigenous sources, and meeting demand was not the primary motivation for building nuclear projects. If meeting demand is still not the real reason, then the question is what drives Bangladesh to undertake such an expensive project now, even after having alternative options.

Bangladesh possesses a significant amount of proven and probable recoverable gas in both land and shallow sea areas, according to data provided by the Ministry of Power and Energy. Currently, Bangladesh consumes approximately 1 tcf of gas per year. The Hydrocarbon Unit and the Norwegian Petroleum Directorate conducted a survey, which revealed significant gas reserves and undiscovered gas in Bangladesh. The estimated amount is 55.12 tcf with a 50% probability and 32.02 tcf with a 90% probability. According to the Energy and Mineral Resource Division (EMRD) in 2018, Bangladesh has already developed the capability to generate 69% of its power from its own natural gas sources. If gas extraction persists, projections suggest that we could potentially utilize the undiscovered and reserve gas until 2042, with a 50% probability, and until 2039, with a 90% probability. This timeline allows for a gradual development of renewable energy sources to meet the rising demand for electricity. In addition, if Bangladesh were to begin exploring the potential gas reserves in the deep sea, particularly in the Arakan sea basin, it could significantly boost its gas production. It is worth noting that a Korean company, Daewoo, has recently made a significant natural gas discovery in the Arakan basin. This discovery is particularly intriguing because it occurred in sea blocks owned by Myanmar and adjacent to a Bangladeshi-owned sea block with a similar geological structure. This reinforces the possibility of further gas discoveries in the area. (Filipov et al., 2017)

An esteemed group of institutions, such as the Renewable and Appropriate Energy Laboratory (RAEL) at the University of California, Berkeley, the National Renewable Energy Laboratory (NREL), and the Institute of Energy Economics and Financial Analysis (IEEFA), have conducted studies on the solar energy potential in Bangladesh. Their estimates suggest that the country has the capacity to generate 120 GW and 240 GW of solar-based energy, respectively. (NREL 2014, IEEFA 2016). Furthermore, RISOE National Laboratory, Denmark, Denmark Technical University (DTU), and the National Renewable Energy Laboratory (NREL) have conducted research and determined that Bangladesh has a wind energy potential of approximately 20 GW. This estimation is based on a hub height of 100 meters and a rotor diameter of 130 meters. In a study conducted by Saifullah et al. (2017), while it may not be sufficient to meet the energy needs of the entire nation, this level of capacity is nearly eight times greater than what the proposed nuclear reactors can offer. In 2024, the majority of Bangladesh's energy production, about 45%, will depend on natural gas. Oil generates another 23 percent, coal contributes 24 percent, imports contribute 4.2%, and hydro, solar, wind, and biomass sources account for the remaining 23 percent. In Bangladesh, the new integrated energy and power master plan 2023 outlines the energy mix target for 2041. It includes a combination of imported coal, imported LNG, natural gas, oil, nuclear power, and import and renewable sources. People often overlook the potential of renewable energy and domestic gas, which casts doubt on their willingness to explore alternative sources.

Not only is the nuclear project highly expensive for Bangladesh, but it will also produce electricity at a very high cost per unit. Different sources provide different price estimates. The official source estimates the cost without accounting for operation, maintenance, and decommissioning costs, resulting in a per unit cost of only 5.67 cents. One expert demonstrated that adding construction, fuel, maintenance, and decommissioning costs will increase the per-unit cost to 11 cents. (Rahman 2015) Currently, the per-unit cost of a utility-scale solar project in Bangladesh is 7 cents. This shows that neither demand nor low cost sufficiently explain why Bangladesh launched the highly expensive nuclear program. Carefully derived deductive reasoning is necessary to explain the causal mechanism of Bangladesh’s nuclear power adoption. The following section will elaborate on plausible causal mechanisms and explain the reasons for nuclear adoption.

7.5 Geopolitical mechanisms

7.5.1 Global geopolitics: getting foothold of economic expansion by core

Bangladesh has a historical connection with Russia that dates back to 1971. During the Bangladesh War of Independence, the Soviet Union supported India, while the United States supported Pakistan. From that point on, the Soviet Union viewed Bangladesh as both a valuable strategic ally and a promising economic opportunity. This expansion focused primarily on the advancement of electrical power and natural gas. Now, this policy is facing growing threats from China. China's emergence as a significant economic and political force in Asia raises concerns about increased economic competition. In addition, Myanmar, a neighboring country of Bangladesh, has a significant connection with China, which also maintains a presence in Pakistan. In the past, Bangladesh has had a significant history of importing Chinese military weapons. Bangladesh currently imports solar equipment from China. Therefore, it can be argued that Russia's economic expansionist policy, carried out through state-owned energy industries, is a deliberate effort to maintain a consistent presence in the region. In addition, the collaboration between Russia and India in the RNPP is a clear indication of Russia's support for India's membership in the Nuclear Suppliers Group, which has been a source of disagreement between Russia and China. Cooperation in the nuclear sector can provide Russia with an opportunity to tap into a country where significant investments have already been made by major players like China, Japan, and the USA. Russia's presence in this country has been limited, with only sporadic assistance in the power sector.

Schepers (2019) noted that while determining the impact of NPP projects on other trade agreements can be difficult, it's important to note that the execution of a Russian NPP project coincides with the conclusion of arms deals with Turkey and Bangladesh. In December 2017, Turkey and Russia signed a contract worth approximately \$2.5 billion to acquire S-400 surface-to-air missile systems. Russia does not rank among Turkey's primary arms providers, while the United States, Spain, and Italy often contribute a greater quantity. Bangladesh, a country that predominantly procures its weaponry from China, has acquired a range of military weapons from Russia. These include the Yak-130 aircraft for training and light assault, R-77 missiles beyond visual range, and Mi-17 helicopters. A portion of these acquisitions were funded by a $1 billion loan that was provided in addition to an original $500 million credit for the development of the Rooppur Nuclear Power Plant in 2013.

7.5.2 Regional geopolitics: India-Pakistan, India-China tension, and Bangladesh's nuclear energy development

Indian firms are building onshore electricity transmission lines of the RNPP project under the Line of Credit funding. Besides, India is providing training to develop the human resource capacity needed for RNPP. Why India has been involved in the construction of RNPP has a reginal geopolitical dimension in it.

To explain the geopolitical mechanism through which India was included in the nuclear cooperation agreement it requires a historical understanding of the regional geopolitics in which Bangladesh has a role. India and China launched their ambitious nuclear weapon program in the 1940s and 1950s with a vision to develop their image as both global and regional leader. Pakistan became serious about developing nuclear weapon after the war in 1971, through which West Pakistan lost East Pakistan (currently Bangladesh). Besides, Pakistan and India have a dispute over Kashmir. The tension between India and Pakistan occasionally escalates, with each country exhibiting their nuclear weapon capacity through nuclear weapon test. In this backdrop, a nuclear cooperation between Bangladesh and India works as a strategy to empower India as a regional player in the region.

Beside India-Pakistan tension in the region, there is another regional dimension which can unfold the mechanism of geopolitics that can explain how regional geopolitics influenced the decision of nuclear power plant in Bangladesh. The regional nuclear geopolitics of South Asia is an exceptional case because of four reasons. 1) Among the 32 nuclear countries, two South Asian countries India and Pakistan are the only two lower middle-income countries. 2) These two countries are also the only two South Asian countries having a long history of developing nuclear weapons. 3) India and Pakistan are the two nuclear weapon countries that did not sign the non-proliferation treaty, the objective of which is to prevent the spread of nuclear weapons. 4) These two countries of South Asia also want to join the nuclear supplier group (NSG) but did not get entry to NSG because of China’s objection to include India to the group and China’s support for Pakistan’s nuclear program development.

India has emerged as a highly attractive market for nuclear suppliers, especially the United States, resulting in the removal of sanctions on India's exports in 2008. However, these regulations remained relevant to Pakistan, a market that failed to attract nuclear exporters from the United States. As a result, China, a member of the Nuclear Suppliers Group (NSG) since 2004, has begun building new Nuclear Power Plants (NPPs) in Pakistan. This has elicited mixed reactions from the international community. Although there is a clear disagreement in the guidelines, the members of NSG have not yet reached a consensus on how to restore its collaborative role in maintaining the non-proliferation regime. While Russia may not have the authority to persuade all NSG members to change their position, it can take advantage of the situation to promote nuclear cooperation with Asian countries and strengthen the expansion of nuclear energy in the South Asian energy market.

While some nuclear weapon countries including US, France, Russia, UK have support for India’s entry to the NSG, China strongly opposes India’s entry to the NSG. India can benefit from joining the NSG as the membership will allow India to gain access to better nuclear equipment, and have access to the market for nuclear related materials. Without the membership India cannot directly get involved in construction and export of nuclear equipment abroad. With India’s involvement in the tripartite nuclear cooperation agreement with Bangladesh and Russia, India will be able to participate in the construction and installation works in the “non-critical” category for the construction of Rooppur nuclear power plant in Bangladesh. It is the first nuclear power plant project where India is able to participate in nuclear power project abroad without being a member of nuclear suppliers’ group. However, India’s role in the construction of RNPP in Bangladesh is not a random decision independent of a precedence.

As a part of longstanding nuclear cooperation strategy, in December 2014, India and Russia agreed to strengthen nuclear cooperation by developing a 'Strategic Vision for Strengthening Cooperation in Peaceful Uses of Atomic Energy'. According to the agreement between India and Russia, both parties agreed to investigate possibilities for obtaining materials, equipment, and services from the Indian industry to build Russian-designed nuclear power plants in other countries. The tripartite nuclear cooperation agreement is an outcome of the strategic vision which was set in 2014. This is an initiative of Russia to give India an opportunity to showcase its capacity to work abroad. Then, the question is what is Russia's strategic interest behind involving India in the nuclear cooperation.

While China has nuclear cooperation agreement with Pakistan and Pakistan has a longstanding rivalry with India, and India also has a geopolitical tension with China, the possibility of China agreeing to give India the membership to NSG is very low.
For India, to showcase its capacity to cooperate in peaceful nuclear energy cooperation in South Asian countries will take India one step further in displaying its power to the dominant regional power China. Russia's strategic interest in expanding its nuclear business in South Asia was driven by the limited market expansion worldwide. With limited social acceptability, risk perceptions, and high cost, nuclear market has already been limited worldwide. In that respect South Asia is a big market for Russia. (Mikhailov 2022) By having a cooperation agreement with India to allow it to work abroad strengthen their historical relationship and creates new avenue for further expansion of nuclear technology. Both Russia and India gain from the cooperation in different ways.

While pleasing India by creating an opportunity for India to work abroad is a global geopolitical move for Russia, for India, the regional power balance in South Asia is one of the driving forces behind involvement of India in the nuclear power plant construction. The US sanctions on Russia, as a result of the ongoing conflict with Ukraine, has made Russia's nuclear market more limited throughout the decade of 2010. It is an opportunity for Russia to build a long-term energy cooperation with India and safeguard its long-achieved friendship through involving India in this geopolitically strained environment. The unique geopolitical characteristics of the region and the mechanism of it has more explanatory power than the existing demand supply balance and energy security explanation, frequently identified as the cause of nuclear power adoption.

7.6 Mechanisms of rent seeking

Large energy dealings typically have a greater likelihood of rent-seeking. Large projects such as nuclear power plants involve rent-seeking risks due to their extensive infrastructure construction and the involvement of various vendors, licensees, researchers, consultants, and subcontractors. (Martin and Winkler 2014) In large nuclear project huge network of actors benefit for long duration construction projects. Although geopolitical mechanism work as a strong driving force behind nuclear power adoption the role of rent seeking mechanism cannot be completely eliminated as a mechanism. Because rent seeking mechanism works as a complementary mechanism to geopolitical mechanism. In the following I elaborate how institutional lock-in create different types of rent seeking opportunities that work as driving force behind the decision to adopt nuclear.

7.6.1 Regulatory capture: regulation in favor of nuclear

Bangladesh has taken a number of regulatory measures that facilitated the adoption of nuclear power plants. These regulatory measures worked more to encourage rent seeking than to ensure safety and security of the citizens. The objective of these regulatory measures is to accomplish the projects and ensure preferential treatment to the suppliers.

First, the main act governing nuclear power projects is the Nuclear Power Plant Act of 2015. The legislation establishes the Nuclear Power Company of Bangladesh (NPCB) with the purpose of managing the operation of the plant. The power plant is owned by the Bangladesh Atomic Energy Commission (BAEC). The law lacks safeguards or compensation for any probable consequences of any catastrophe and offer indemnity protection to the operator. According to the Nuclear Power Plant Act of 2015 article 28, “Protection of actions taken in good faith.- No suit or prosecution or other legal proceeding may be instituted against the Government, Chairman, Managing Director, Project Director, any other Director, consultant, adviser, officer or employee for any act done in good faith regarding the construction and management of nuclear power plant before or during or after the enactment of this Act.” (GoB 2015) Rather than adopting complete legislation pertaining to nuclear power generation, which is essential for ensuring safe energy production and regulating nuclear safety and liability regulations in the future, the act offer indemnity to those responsible for disaster, reflecting the intention of the state to support suppliers' interest.

Second, in 2019, Bangladesh entered into an agreement with Russia to procure uranium for the Nuclear Power Plant (RNPP). According to the agreement, Russia would provide the necessary nuclear fuel for the whole lifespan of the facility. In 2017, the two countries inked an agreement for the management of high-level nuclear waste from the Plant, specifically for the return of spent fuel. The Bangladesh government has failed to adequately address the technological challenges related to the storage, transportation, and disposal of mid-level and low-level radioactive materials and waste, except from establishing a corporation to handle waste. If Russia refuses to repatriate the radioactive waste in the future, it might significantly increase the likelihood of severe ecological harm to Bangladesh.

Third, the government of Bangladesh has granted the NPP complete exemption from all taxes and duties, such as regulatory duty, import duty, advanced VAT, and other additional duty, on all imported goods, components, and machinery. This priority to nuclear project is a strategic decision of the government. However, the "cost-plus-fee" contract will allow vendor to have the authority to incorporate any increase in costs into the total sum specified in the contract. As result of cost increase the price of electricity will also increase, putting additional burden on the public, whose money could be more likely to be transferred to the suppliers.

7.6.2 Resistance capture

There are three different approaches that have been utilized in Bangladesh in order to maintain control over anti-nuclear resistance. To begin, the risk of the project being scrapped was mitigated from the very beginning by the deliberate suppression of any prospective anti-nuclear movement at the local level. This was accomplished by physically repressing protests and by intimidating any voice that expressed disagreement with the administration. The second factor that contributed to the manipulation of the concept of public acceptability was the absence of any visible dissent in the media. a campaign that was supported by the government with the intention of influencing public opinion by spreading some information about the risks associated with the projects. Third, there is currently no significant anti-nuclear movement that can focus public criticism towards the project. This is especially true given that the environmental impact assessment was not published to the public. The government was responsible for compensating all of the costs associated with the campaigns, as well as mobilizing local resources in order to put down the initial movement and capture the resistance by utilizing public resources.

7.7 Mechanisms of public demand

The mechanism of public demand did not operate in Bangladesh because the government aggressively attempted to influence public opinion through a variety of channels and crushed anti-nuclear movement through a variety of strategies. The level of public acceptance is widely regarded as one of the most important considerations in the establishment of nuclear power plants. Regarding Bangladesh, the subject of how public acceptability is judged continues to be a matter of debate. The first thing that happened was that the government of Bangladesh made a hasty decision to sign a primary deal with Russia for the installation of a 2400 MW nuclear power plant at Rooppur. According to the plan, a feasibility study and an environmental impact assessment were going to be carried out prior to the beginning of construction on the NPP in the year 2017. The citizens, on the other hand, were not informed about the existence of any document of this kind.

The Bangladesh Atomic Energy Commission did not conduct an accurate evaluation of public acceptance because it did not provide the people with appropriate information and did not disclose the findings of any feasibility study or environmental impact assessment. In the past, there have been studies (Alfee and Islam 2021 and Sadia et al. 2018) by independent researchers on the subject of public acceptance. According to According to the findings of Alfee and Islam (2021), there is a shortage of awareness among the many stakeholders. In addition to this, they discovered that there is a lack of faith in the activities taken by the government in relation to radiation and environmental protections. They discovered that forty-four percent of the population believed that public awareness efforts were necessary. The researchers suggested that rather than interpreting this finidng as evidence that there is a lack of public acceptance, they should instead advocate for a big communication campaign that makes use of public resources in favor of nuclear power plants.

There is also an instance of intentionally taking advantage of the ignorance of responders who were chosen at random. Prior to the beginning of construction, there was not a lot of information available regarding the public's acceptance of the project. Following the commencement of construction in 2017, Sadia et al. (2018) carried out a survey on a total of one hundred individuals on Facebook, which served as the platform for the completion of an online questionnaire. Due to the lack of scientific sampling and survey design, the results of those surveys cannot be relied upon to provide accurate information.

Hosan et al (2022) found that there exists a huge knowledge gaps and “misconceptions” among the public regarding nuclear energy. Surveying 661 respondents they found that there is a lack of credibility on the government’s capacity to operate the national nuclear power project because of the rampant corruption and the political instability. The research also reveals that there is low faith in the existing rules & regulations for nuclear power programs. Lack of information about the nuclear technology among one third of the respondents seriously challenges the fact that there is public acceptance to the project. The research suggested public awareness campaign to increase public acceptance five years after the construction has started. This shows public acceptance has been ignored before starting construction of the project.

There was question raised by experts about the radioactive waste management. In response to the questions, it was claimed through the media that the contract signed between Bangladesh and Russia has a clause on spent fuel take-back. As the contract was not available to public, the question continued to persist until another agreement on radioactive waste take-back was signed. In August 2017 the "Agreement between Government of the People's Republic of Bangladesh and the Government of the Russian Federation on Cooperation on Concerning Returning of Spent Nuclear Fuel from Rooppur Nuclear Power Plant to the Russian Federation" was signed. This has created a public perception that Russia is taking back the radioactive waste and therefore the risk of contamination is negligible. In an interview by a leading daily newspaper an official familiar with the process reassured that “the agreement will safeguard the country from the hazard of nuclear waste and it would help dispose of nuclear waste in accordance with nuclear safety standards.” (The Daily Star, 2017) Prime Minister Sheikh Hasina has assured the people of Bangladesh not to worry about the nuclear power plant being built at Rooppur as sufficient safety measures have been taken.

In reality, Russia temporarily takes it back for temporary storage, reprocessing, and separating plutonium and return the radioactive waste to the country of origin. “The legal basis for the current policy in Russia has existed since 2001, when legislation was passed to allow for the temporary storage and reprocessing of foreign spent nuclear fuel and to establish a mechanism to regulate such imports.” (Feiveson 2011) The fact that the storage and reprocessing is temporary and that there is huge risk involved in storing the returned waste in Bangladesh, were largely suppressed by the media. The persistent effort by the government to feed development fetishism of a certain class of conscious citizens finally overpowered the perception of potential risks.

Despite persistent resistance and criticism from a group of well-informed individuals and specialists regarding potential concerns, the government chose to withhold the Environmental Impact Assessment (EIA) and feasibility assessment, as asked. In addition, the project's danger of cancellation was minimized from the start by forcefully suppressing possible anti-nuclear movements at the local level, including the use of protest repulsion and the intimidation of dissenting voices. The absence of any noticeable demonstration in the media facilitated the manipulation of the concept of public acceptability.

7.8 Mechanisms of Internal Political Gain

7.8.1 National pride

The admiration of nuclear power as a symbol of modernity and pride and the prestige attached to it is one of the reasons for the adoption of nuclear power. An example of this would be the Prime Minister of Bangladesh addressing the country on the day that building of the Nuclear Power Plant (NPP) began, saying, "Bangladesh enters the world of nuclear energy with the beginning of the construction work regarding the main structure." An additional statement made by the Minister of Science and Technology was that "we have entered the nuclear age." To achieve its goals of being a developed nation by 2041 and a middle-income country by 2021, Bangladesh has set a goal for itself. The nuclear power construction provides a sense of accomplishment to the ruling politicians their political term. Additionally, the current government views new participation in the nuclear club as a new national identity that is prestigious to the international community.

7.8.2 Aspiration for development and political gain

In comparison with mega projects like nuclear power, alternatives like renewables require more decentralized efforts involving diverse group of actors and are less visible. This long-term plan demonstrates the country's preference for predominantly relying on imported fossil fuel and nuclear energy, despite the presence of other viable options. Therefore, it appears that nuclear power provides a rapid means to generate tangible results, thereby facilitating the acquisition of greater political backing. Most people in the developed countries gladly accept the fruits of technological advances, and people in less prosperous countries aspire to catch up. (Bodansky, 2004)

Frequently, developing nations view the possession of nuclear power as a sign of a sophisticated economy rather than solely as an energy source. The prevailing belief that nuclear power is indicative of a developed economy motivates nations to initiate nuclear programs. Jewell (2015) indicated that energy mega projects in Turkey possess a strong appeal despite their inherent limitations. The rationale is rooted in a broader societal context that celebrates large-scale endeavors and prioritizes state objectives over public input. Therefore, a nuclear power plant possesses significant political value, serving as an incentive for initiating a nuclear program.

7.9 Mechanisms of technology diffusion

7.9.1 Core's strategy of exploiting potential technology cluster

"Clusters" typically represent a significant level of local activity, characterized by spatial density and connections between local businesses. (Porter 1998). Technology cluster is typically characterized by spatial concentration of technology any area or region as they benefit from knowledge spillover. Lantis (2014) used data on the growth pattern of nuclear cooperation agreements (NCA) to show that NCAs often form in groups around countries that are seeking nuclear accords, prompting both governments and corporations to engage in negotiations. A bilateral Nuclear Cooperation Agreement (NCA) can give rise to numerous supplementary agreements concerning various aspects of nuclear cooperation, such as collaborative research initiatives, uranium enrichment, nuclear waste reprocessing, and storage. (Lantis, 2014).

Due to its proximity to India, the adoption of RNPP (Renewable Nuclear Power Plant) in Bangladesh has a future potential of forming a technology cluster. ROSATOM has a substantial track record of nuclear cooperation in India. As part of its extensive goals, there is a strategic plan to construct additional nuclear power plants with the support of Russia in the long run. In 2009, India inked an arrangement with Russia that grants them the autonomy to carry out the closed fuel cycle, encompassing activities like as mining, fuel preparation for reactors, and reprocessing of spent fuel. Bangladesh has recently entered into civil nuclear cooperation agreements with both Russia and India. The Nuclear Power Corporation of India Limited (NPCIL) will have a significant part in constructing a nuclear power station in a foreign country for the first time. This would involve providing equipment and materials for the project. India is providing assistance for capacity development and has been providing training to nuclear experts from Bangladesh for the project. India can demonstrate its credibility as a responsible nation in the global nuclear market and justify the 2008 exemption granted by the International Atomic Energy Agency (IAEA). In addition, the offer of knowledge services to Bangladesh, despite the apparent absence of a functional export-worthy reactor, reinforces India's argument for membership in the Nuclear Suppliers Group (NSG).

7.9.2 Diffusion incentive: flexible financial conditions

The agreement between Bangladesh government and 'Rosatom' follows a *cost-plus* model in which the Russian state provides the loan covering 90% of capital costs, but Bangladesh is responsible for cost overruns. This gives flexibility to the Russian construction company to raise its cost along with its profit margin in different times. In 2009 the project expense was estimated to be between 3 to 4 billion dollars. Later, the expense stood at 13.5 billion dollars. (Byron and Rahman 2015). Finally, the agreed cost was 12.65 billion dollars. Russia offered to lend 11.38 billion dollars out of 12.65 billion dollars at +1.75% LIBOR rate. The loan repayment time is twenty years with a grace period of 10 years. 12.65 billion dollars is almost two third of the current external debt of the country.

The first unit (1200 MW) of the project started in 2017 and although initially it was scheduled for commissioning in 2022, later it was rescheduled to start operation in 2025. After Ukraine war has started the project is facing number of obstacles that are delaying the project. According to the agreement signed by both countries for any delay in construction, no matter which party is responsible for the delay, Bangladesh has to pay delay charge to Russia. Therefore, there is a higher possibility of further cost increase.

Furthermore, the Bangladesh government has recently enacted an indemnity Bill that provides protection to the partner company in the event of any unforeseen harm occurring during the operation of the NPP. According to the legal terms of the contract, Bangladesh bears full responsibility for repaying the loan, together with any accrued interest, regardless of whether the plant is delayed, cancelled, or mistakenly harmed. These factors provide suppliers with flexibility, which in turn motivates them to cooperate.

Initially, Indian suppliers were also attracted to RNPP due to its flexible financial incentive. The complete power evacuation infrastructure of the Nuclear Power Plant (NPP), which includes 20-kilometer electricity transmission lines, was planned to be established using India's third Line of Credit (LoC) credit facility valued at US$1.0 billion. According to the conditions of the third credit line, which was agreed upon in October 2017, a minimum of 75 percent of the purchases for service-oriented projects and 65 percent for public-works projects must be sourced from India. (Rahman 2022) However, the proposed bid from the designated Indian contractor for the installation of the energy transmission lines across the river is far higher than the expected cost. Despite the rejection of project funding, suppliers have been able to benefit from the supplier's credit, which has provided an opportunity to take advantage of the flexible financial condition in the ongoing onshore transmission line construction.

7.10 Summary

Analysis of the demand side mechanisms indicates that Bangladesh has stronger strategic considerations for initiating a nuclear program compared to economic and technical justifications. In order to fulfill Bangladesh's future energy requirements, there are alternative options available, including natural gas and renewable energy sources. Bangladesh prepared an environmental impact assessment for the nuclear power project, but it was never disclosed to the public. There is no cost benefit analysis that could justify the implementation of the outrageously costly project, which has an initial budget comparable to one third of the country's total external debt at the time the project was initiated. When especially compared to declining cost of renewable energy the cost of nuclear is outrageous. The ruling political party's nationalist identity politics can be attributed to Bangladesh's aspiration to become a nuclear power and the desire for prestige that comes with being acknowledged as a member of the nuclear club. The emphasis on technology and progress played a crucial role in garnering popular backing against potential opposition to nuclear power. By intimidating those who express disagreement, suppressing attempts to protest, and effectively controlling local discontent, all potential avenues for anti-nuclear resistance have been greatly reduced. On the demand side, the rationale for nuclear power is primarily strategic rather than driven by economic considerations. It is motivated by the country's strong emphasis on national identity and aspiration for being modern.

The supplier also had strategic motives for establishing a presence in the specific geographic region. The freedom granted by Bangladesh in financial contracts, safety issues, and liability only highlights the country's weakness in the partnership. Russia, as a prominent nation, exerted significant influence by shifting the responsibility of risk onto Bangladesh. Engaging India in the construction of a power plant is essential as it demonstrates Russia's ambition to capitalize on a group of geographically close nuclear nations. Russia's pursuit of economic expansionism is not an isolated occurrence. Every nuclear-armed nation has a vested interest in broadening its economic endeavors on an international scale. However, the potential advantages of certain countries over others depends on numerous variables and qualities. Due to its enduring alliance, Russia has no difficulty in gaining entry to Bangladesh. Russia capitalized on the lack of any rival. When faced with a competition, it may be necessary to provide more favorable conditions in order to gain an advantage, even if it means sharing part of the associated costs. The supply side mechanisms indicate that Russia's involvement was driven by strategic cooperation, influenced by both regional and global geopolitics.

The approach demonstrates that the spread of technology is not impartial in terms of power and influence, and can be understood by considering the motivations, relative power, and capabilities of both the technology supplier and the recipient state. Russia's support to Bangladesh during the liberation war established a basis for collaboration between two unequal powers. This collaboration is evident in their recent nuclear cooperation, where strategic considerations stemming from the unequal power dynamic took priority over potential economic benefits.

8 New Fossil Fuels: Coal and LNG

8.1 Introduction

Since the first discovery of domestic gas resources in 1955, Bangladesh has gradually increased its dependence on natural gas. At some points, electricity from natural gas accounted for as much as 80% to 90% of the country's total electricity generation. Many international oil companies competed to sign production sharing contracts (PSC) with Bangladesh to explore gas. Bangladesh has also developed its capacity to explore onshore gas. Bangladesh still has unexplored onshore and offshore gas reserves, but it has recently increased its imports of LNG and coal. The question is, Why? The existing explanations point mostly to the need for ensuring reliable, diverse, and affordable supplies. However, the process of ensuring energy availability has overlooked the risk of high import dependency. As a result, the Bangladeshi economy has been more susceptible than ever before to any external supply shock or global crisis that makes imports unreliable and unaffordable. The rapid growth of imported fuel in the last decade and the subsequent downsides of import dependency have prompted a revival of the question: What triggered the decision to increase its dependence on coal and LNG two decades ago? And why has the use of coal and LNG grown so fast in the last decade?

This chapter mainly focuses on finding the causal mechanisms to explain why Bangladesh planned to adopt coal and LNG and why the capacity grew so fast that a significant portion of the capacity remained underutilized and created high social costs. This chapter contributes to meeting the broad objective of the dissertation by explaining the causes of Bangladesh's transition to two fossil fuels: LNG and coal. In an already gas-dependent country where both natural gas and solar offer less costly solutions to the country's energy crisis, Bangladesh adopted more nuclear, less solar, and more coal and LNG.

While Chapter 6 deals with Bangladesh's slow transition to solar and Chapter 7 deals with Bangladesh's adoption of nuclear, this chapter (chapter 8) focuses on the transition to LNG and coal. This chapter solely concentrates on two fossil fuel energy sources, elucidating the rationale behind their introduction.

This chapter aims to answer the question by first introducing the context (section 8.2) and laying out the existing explanations (8.3). Second, the chapter begins by providing a thorough overview (section 8.4) of the historical adoption of coal and LNG followed by alternative solutions. Third, this chapter aims to identify the causal mechanisms (section 8.5) by using process tracing. In section 8.6, this chapter analyzes the empirical qualitative data from a span of forty years and deductively identify the stronger causal mechanisms from the weaker ones behind the adoption of these two technologies. Section 8.5 summarizes the finding

8.2 Context

The decade of 1960 was the golden year for gas field discoveries. Residential and industrial purposes were the initial uses of gas. After the 1970s oil crisis, to reduce dependency on imported oil, Bangladesh started to explore natural gas with the help of international companies. In 1980/81, 38% of the gas was used in the power sector, 36% by the fertilizer industry, 16% by other industries, and 10% by the domestic and commercial sectors. Gradually, over the years, the percentage of gas use in total energy has increased to as much as 80%. Bangladesh also developed some of its national capacity to explore gas by building new institutions in the 1980s and 1990s. In the decade 2000, Bangladesh was perceived as a gas surplus country with a high potential for unexplored gas reserves. Bangladesh drafted model PSCs with the option to export surplus gas. At that time, the USA was actively setting up LNG terminals for trade. The demand for gas was increasing. At that time, some international oil companies were also interested in exploring offshore gas. However, because of a dispute over profit sharing and gas export options, the IOCs left before exploring gas. In the decade of 2010, the Power System Master Plan incorporated LNG and coal imports as new energy sources. Why a potentially gas-exporting country suddenly planned to be a gas-importing country remained a puzzle. The planners and policymakers justified this change in plan by citing the depletion of the gas resource, the need to balance supply with growing demand, and the need to introduce cheap energy sources to ensure energy security.

In the past, Bangladesh imported coal for industrial and other purposes before using it for power generation. Bangladesh has coal resources, but so far, only one coal mine in Barapukuria has been explored. A 525 MW coal power plant uses the coal from that mine. When coal production from the Barapukuria coal mine began to decline, Bangladesh had to start importing coal for the power plant. Furthermore, from 2020 to 2023, three coal power plants (Maitree 1320 MW, Payra 1320 MW, and Banshkhali 1224 MW) with a capacity of 3864 MW began commercial operation. Additional coal power plants are currently in the trial and construction phases. According to the latest data provided by the Bangladesh Power Development Board, Bangladesh now has an installed capacity of 5332 MW of coal-based power plants. This constitutes about 20.85% of the installed capacity as of December 2023. Construction is underway for some coal plants, while cancellations have occurred at others. Despite having a coal-based installed capacity, Bangladesh could not fully utilize it because of the high price of coal in the international market. Bangladesh has been paying the capacity charge for the unused installed capacity.

Bangladesh began planning LNG imports well in advance of their actual commencement in 2018. The construction of the terminals was finished toward the end of the 2010s. The two floating gas and re-gasification units (FSRUs) at Maheshkhali in Cox's Bazar have a 1000 mmcf capacity to inject gas into the national gas transmission grid per day. Excelerate Energy of the United States operates one FSRU with a daily capacity of 500 million cubic feet, while the local investor Summit Group operates another. Bangladesh imported both of these technologies from the United States. Bangladesh used to use around 650 mmcf to 800 mmcf of capacity from imported LNG on the national grid before the global LNG spot market price increased because of the Ukraine war. In 2022 and 2023, the import has come down to around half of the capacity (500–553 mmcf). The LNG price increase and the unused capacity have created enormous social costs as businesses started to shrink output, residential consumers suffered from heavy load shedding, and inflation crippled the lives of the poor and the middle class.

Importing coal and LNG is not a sustainable solution and does not ensure availability and affordability in times of crisis. Prior to the onset of the crisis, people perceived coal as an affordable energy source and LNG as a substitute for domestic natural gas. After the foreign reserve started to deplete rapidly in 2022 and coal and LNG became more expensive, the government reduced the use of LNG in the 2022–23 fiscal year. To manage demand, the government decided to ration gas and reduce load shedding. The coal plants have also started to run well below their capacity. The question that remained a puzzle in 2010 was revived in 2022. Why did a gas-abundant country with the potential to export gas become a gas-importing country? Why were two new fossil fuels, LNG and coal, introduced when these fossil fuels were losing competitiveness as the cost of non-fossil fuel technology like solar declined?

8.3 Existing Explanations

The existing explanations mostly highlighted the techno-economic perspective of the adoption of coal and LNG. The existing literature and policy documents mainly focus on the mechanisms of demand-supply balance, depletion of incumbent energy sources, and availability of cheaper energy sources to explain the causes of the adoption of these new fossil fuels.

Bangladesh needs to secure supply sources to meet the growing demand as it prepares to become a high-income country. (Amin et al., 2023) The policy documents, like PSMP 2005–PSMP 2016, used this perspective to plan the import of LNG and coal. The demand for electricity has increased over the years. However, the installed capacity has grown to such an extent that 40%–60% of it remains underutilized. As a result, the supply-demand mechanism cannot sufficiently explain the cause of this overcapacity. While meeting the demand is consistent with the explanation, the high excess capacity, load shedding, and higher cost of energy are not consistent with the demand-supply balance argument. Therefore, the outcome deserves further explanation than what existing evidence can explain.

To satisfy the industrial demand, it was necessary to identify affordable and accessible sources of energy. Prior to 2010, coal was widely regarded as an inexpensive means to fulfill the electricity demand. The primary rationale behind the adoption of coal in Bangladesh was its cost-effectiveness and the enthusiastic interest of investors in constructing coal-powered plants. Nevertheless, when coal power plant planning and approval began in the 2010s, the cost of solar energy was already declining. Since the beginning of 2010, when the cost of solar energy steadily decreased and there was an influx of new investments in solar deployment worldwide, Bangladesh has prioritized the construction of coal power plants rather than solar power plants. There was also opposition from the public against the construction of coal power stations. In the 2010s, coal's affordability did not explain its adoption. This raises the question of why, even if there were other cheaper alternatives emerging, the government was so determined to complete the coal projects. This needs additional clarification.

Existing explanations stressed the possibility of domestic gas depletion and emphasized the need for coal and LNG to substitute for domestic gas use. (Das et al. 2020, GoB 2017) In the name of diversifying energy sources, LNG and coal were shown as alternatives. (GoB 2010, Islam et al. 2022, GoB 2016a) The explanation fails to acknowledge that gas depletion is not an inevitable occurrence, but rather a result of inadequate investment in gas fields. The existing explanations do not explain the sudden drop in investments, especially since many IOCs were interested in making such an investment. Additionally, they don't explain why, under the prospect of resource depletion, the government's focus on gas exploration capacity development waned, leading to significantly low interest in new gas exploration. Instead, the government pursued expensive LNG based on the Power System Master Plan 2010's suggestions. Therefore, the potential for future gas depletion does not directly drive the adoption of coal and LNG. Rather, gas depletion is a path-dependent outcome that requires further explanation. Furthermore, a more comprehensive understanding is required to explore the reasons behind the rejection of alternative paths and the emergence of coal and LNG as new fuel sources.

In the specific context of Bangladesh, coal and liquefied natural gas (LNG) were considered specialized technologies, whereas natural gas was the dominant and established energy source until 2010. There has been a significant transition in the policy, moving from a domestically sourced energy system to one that relies on imported energy. Both academic literature and public discussions have excessively highlighted the techno-economic aspect of energy security to support this transition. Nevertheless, these theories fail to account for the excessive capacity of coal and LNG, as well as the reasons behind the preference for these solutions over the alternative approach of increasing investment in domestic field exploration and production.

8.4 History of adopting coal and LNG

8.4.1 History of coal adoption

In the 1980s, the power sector in many developing countries was facing challenges, including inadequate infrastructure, insufficient capacity, and a lack of investment. Bangladesh was among the countries grappling with similar issues. The public sector, which traditionally dominated power generation, transmission, and distribution, often struggled to meet the growing demand for electricity for its economic development. When the power sectors were struggling to secure capital and technology for increasing their capacity, the international financial institutions recommended some market-oriented reform. The reform includes vertical unbundling of generation, transmission, and distribution to promote competition and encourage the private sector to increase investment. Chile was one of the first examples of implementing some recommended reforms. (Pollitt 2004) Other developing countries, like Bangladesh, later applied the experiences from Chile.

The power sector reform in Bangladesh led to the establishment of independent power producers (IPPs), allowing private entities to invest in power generation. The addition of electricity to the grid by the IPPs during the 1990s and 2000s was not sufficient to meet the electricity demand. The power outage persisted, and it became so acute that it significantly hampered the social and economic lives of the people. To meet the increasing industrial demand for power, the government permitted captive power plants as an immediate solution. The captive power units allowed the industries to generate their own electricity and reduced the burden on the national grid.

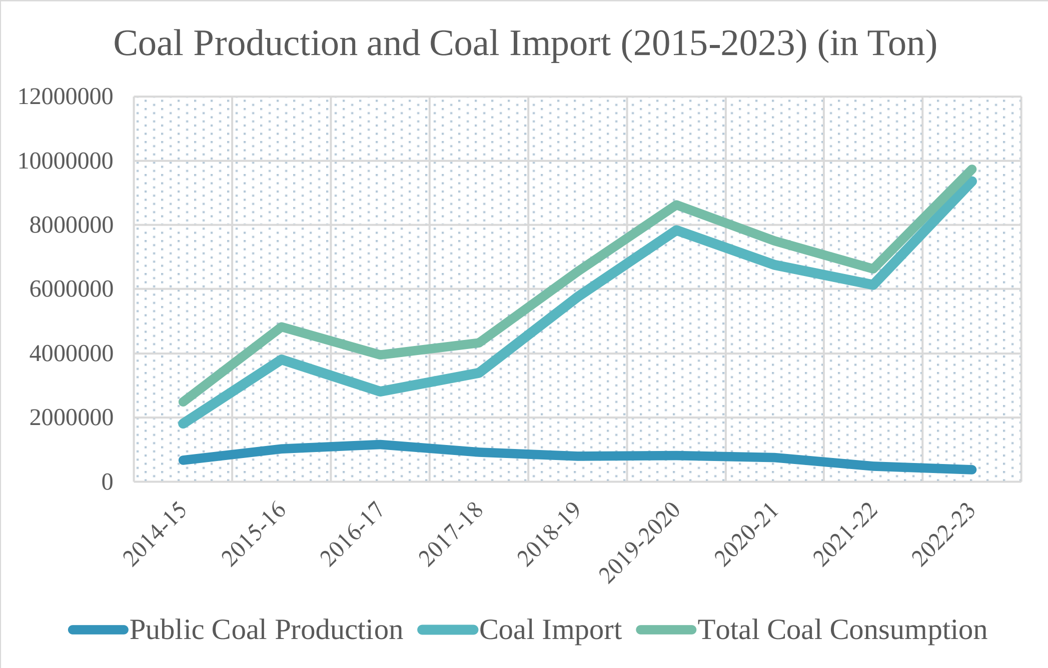
As a result of the growing load-shedding and public disappointment, the power and energy crisis became more politically sensitive towards the end of the 2000s. In 2008, the Awami League-led grand alliance formed the new government, which promptly addressed the issue. As a quick solution to the problem, Bangladesh permitted oil- and gas-based rental and quick rental power plants to generate electricity. As a result, oil imports increased. Although access to electricity increased from 2008 to 2023, the cost of electricity became so high that in some private power plants, the cost was two times higher than the cost of public power plants. (BPDB 2020) A significant portion of the government subsidy was allocated towards providing oil and gas for rentals and quick rentals at a low price, while the remainder was used to purchase electricity at a high price. As a result of unplanned growth or quick rentals, the share of private sector power generation rose so high that the unutilized installed capacity became a burden. The amount of capacity charge payments increased, putting enormous pressure on the government to subsidize the private power plants.

Despite recognizing the need for a reliable and affordable source of energy, the government opted for an immediate solution to increase power capacity without ensuring reliable and affordable energy sources. When electricity costs increased at the start of the 2010s, the government justified the need to use coal as an affordable source. Finally, in 2018, Bangladesh experienced a surge in imports of both, with an increase in the capacity of coal power plants and the start of commercial operation of the first LNG terminals in Bangladesh. However, the government formulated a plan to utilize coal and LNG well in advance of the 2010 cost surge. In order to gain acceptance, the government demonstrated the affordability and reliability of coal and LNG as energy sources.

The power system master plan of 2005 (GoB 2006) emphasized the need to utilize both domestic coal and imported coal as affordable sources of energy. (The plan developed a scenario based on promoting coal. The first draft of the coal policy received approval in the same year. BHP Minerals proposed to develop a coal mine and a coal plant in Phulbari, located in the North West district of Bangladesh, in 1994, much earlier than the development of the plan and policies. The Bangladesh government awarded a coal exploration license to BHP, an Australian company. Another company, Asia Energy, received BHP's licenses in 1999.

When Asia Energy was preparing to develop a coal mine, the local people created strong resistance. To suppress the growing movement, on August 6, 2006, the police shot three people to death and injured about 200 people during the protest. The government had to halt the project and never explore the Phulbari coal mine, as it failed to gain acceptance in that region.

Figure 8-1 Coal Production and Coal Import (2015-2023) in Ton



The government of Bangladesh established Barapukuria Coal Mining Company Limited in August 1998 with financial and technical assistance from China. Later, in 2005, the government established the 250 MW Barapukuria coal power plant, and since then, the plant has used coal from the mine. In 2018, the government expanded the plant's capacity by 275 MW. The BNP-led government constructed the first two units of the power plant. In 2008, when the next government came to power, the Anti-Corruption Commission filed a corruption case against the opposition leader and former Prime Minister Khaleda Zia and 10 former ministers over awarding the Barapukuria contract to the China National Machinery Import and Export Corporation for violating the rule of awarding the lowest bidder, which at that round was Shandong Ludi Consortium. Now the coal power plant is running at half its capacity because of insufficient coal supply, stolen coal supply, technical inefficiency, and corruption.

The Barapukuria coal mining experience exposed the inefficiency in Bangladesh's energy system. The Phulbari experience shows that there is a lack of acceptability for open-pit coal mining in the region. Despite realizing that extracting indigenous coal had been challenging in Bangladesh, policymakers repeatedly advocated for extracting coal and creating a demand for domestic coal by building new coal power plants. Moreover, the Power System Master Plan of 2005, 2010, and 2016 consistently recommended that Bangladesh increase its coal capacity. As a result, with the increasing availability of international finance for coal, Bangladesh planned to build 29 coal-fired power plants with an approximate 32700 MW capacity. Building all the plants would have increased Bangladesh's coal-based installed capacity from 525 MW to 33200 MW. Later, the lack of financial resources led to the cancellation of many power plants. Bangladesh’s installed coal power capacity is now 5300 MW. Some of the power plants are highly controversial projects, including the Rampal coal power plant and the Banshkhali power plant. Both of these power plants faced resistance from local opponents and environmentalists due to their potential risks to biodiversity, air pollution, water contamination, and the displacement of local communities. Despite strong resistance, the Rampal Power Plant and Banshkhali Power Plant started commercial operation in 2022 and 2023, respectively. Both plants rely on imported coal for power. Due to the increase in coal prices on the international market and the devaluation of Bangladesh's currency, the project's initial cost has nearly doubled. Some policymakers are now advocating for the extraction of domestic coal, pointing out the economic benefit while ignoring the needs of the local community as well as environmental activists' concerns.

Since the 1990s, the reason for adopting coal has been to use domestic coal resources for power generation. However, policymakers appeared to underestimate the strength of resistance during that period. Several factors, such as environmental concerns and community displacement, challenged the acceptability of coal extraction in society in the 2000s. However, international cooperation agencies like JICA, through the power system master plans, have continued to recommend the use of both indigenous coal and imported coal for power generation since 2005. The availability of international funds for coal power plants further drove the plan's implementation. Banks and cooperation agencies showed strong financial interests during the 2000 decade, as Bangladesh's credit rating gained a comparatively higher score than before.

Governments, state-owned companies, or public and private entities implemented the majority of the coal power plants through framework agreements or joint ventures. The loans came either in the form of official development assistance or from public or private commercial banks. The common element of these projects has been cooperation between governments, regardless of funding, ownership, or equity. In a situation in which a local private owner, S. Alam, jointly partnered with a Chinese state-owned company, the government of Bangladesh played a key role in supporting land acquisition and facilitating construction. The countries' diversity in energy cooperation (India, Japan, and China) reflects strategic interests in addition to the commercial interests of the companies.

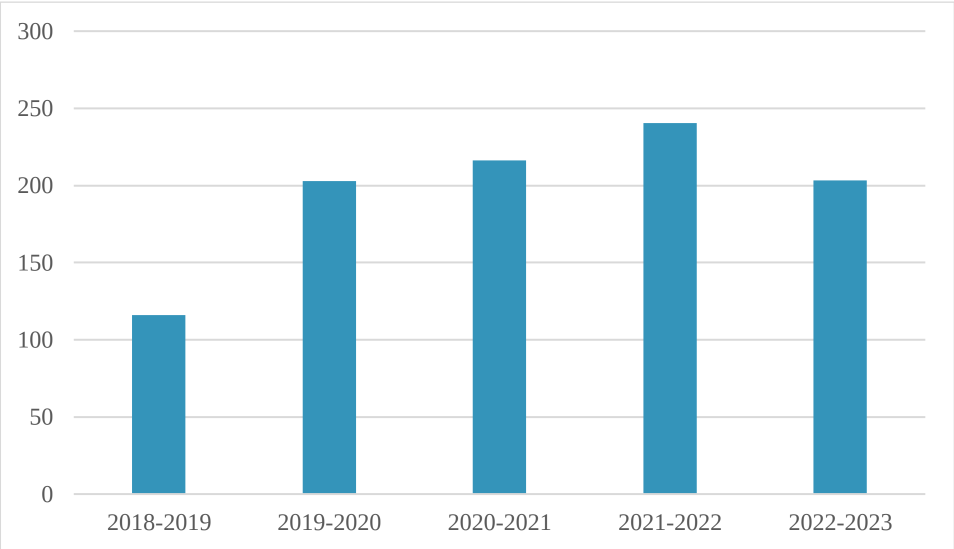
After a failed attempt at open-pit coal mining, Bangladesh seemed to use the "politics of demand" strategy to explore the possibility of gaining acceptance of closed-pit mining. The idea is to gain the consensus of the majority of the interest groups in favor of coal extraction by convincing them that meeting domestic demand from coal extraction is an economically more efficient choice than importing coal, even at the cost of the community's livelihoods. After the construction of coal-fired power plants, when the economic burden of expensive imported coal purchases emerged in the early 2020s, it became easier to garner support from general consumers for the use of cheaper domestic coal, despite ongoing concerns about community displacement and environmental degradation at the newly proposed Dighipara coal mine. However, the local community, through their strong resistance, had by then proved to be a stronger interest group than environmental activists and consumers based in major cities.

Despite the plan's implementation beginning in 2010 indicating a tendency to develop coal power plants using imported coal, the coal lobby continued to advocate for the use of indigenous coal, disregarding the environmental costs and the displacement of local communities. After more than fifteen years of people's movement in Phulbari, in a time of crisis in 2023, the discussion has resurfaced about whether and how to extract domestic coal. People are comparing the cost of expensive LNG and imported coal to the cost of extracting domestic coal solely on the basis of economic logic, without considering the social cost. Since 2005, there has been no change in the community's conviction against Phulbari open-pit coal mining. The repeated revival of the discussion indicates that the coal interest groups are still looking for opportunities to gain acceptability in multiple forms, from community acceptance to civil society consensus on coal mining.

8.4.2 History of LNG adoption

The history of LNG adoption is inseparable from the history of coal adoption. LNG imports grew almost at the same time as coal grew in Bangladesh (from 2018 onwards). Both represent their status as niches in the energy system. The sole distinction lies in the strong connection between LNG imports and existing gas-based power plants, whereas the expansion of coal relies on the creation of new demand through the construction of new power plants. LNG can use the incumbent natural gas distribution network once the terminals re-gasify the LNG and mix it with the natural gas through an existing pipeline. To expand, however, coal must have new coal power plants, coal storage facilities, and port development. Building a new port that can unload both LNG and coal offers a co-benefit. The energy diversification motive appeared to be served by purchasing expensive LNG to meet the demand in existing power plants and acquiring cheap coal to expand new demand. However, both proved to be costly and economically burdensome in 2022, thereby diminishing the anticipated benefits from 2010.

Figure 8-2 LNG import in billion cubic feet (2018-2023)



Source: Hydro Carbon Unit, 2024

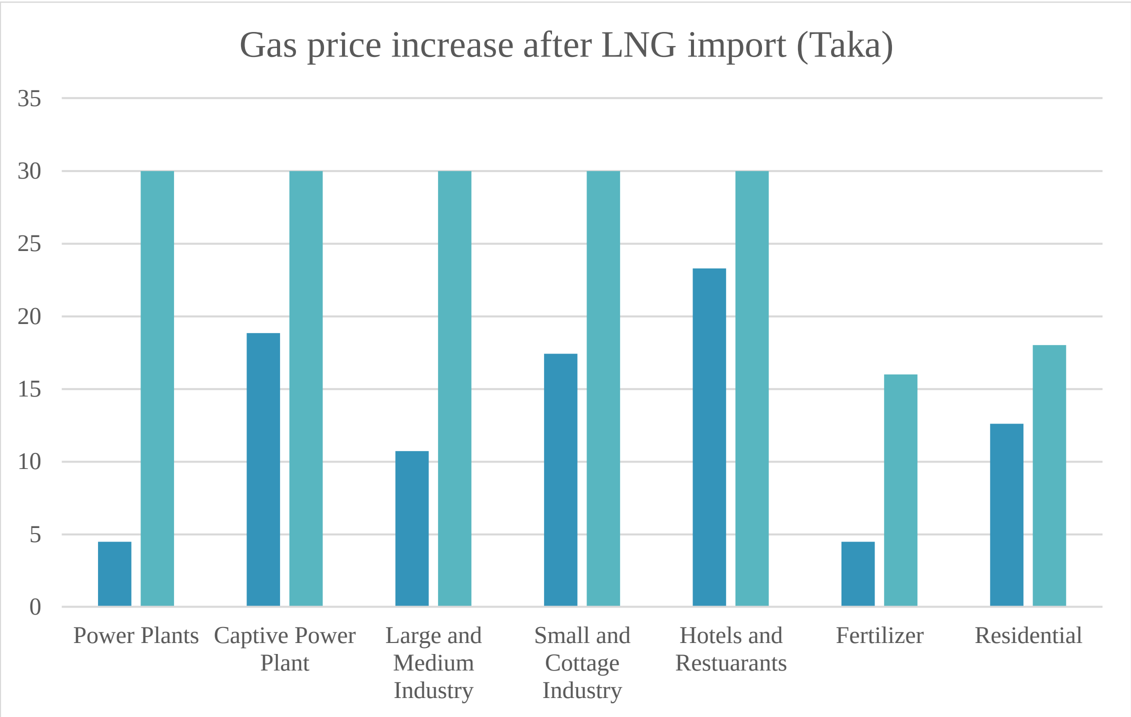
Although In 2010, when the Power System Master Plan recommended the import of LNG as a new source of fuel in Bangladesh, LNG was actually a sixty-year-old technology. With the first commercial shipment from Algeria to the UK and France, this technology has developed gradually since the 1970s with the market expansion to the US and other European markets. The US was initially an LNG importer and later became an LNG exporter. Between 2001 and 2009, the US saw years of increasing natural gas production. (Tusiani 2016) For almost three decades, the United States competed with Russia over gas production before finally overtaking Russia as the world's greatest natural gas producer in 2009. The Shale Revolution, which started in 2000 with only 1 percent of total gas production, ended up with 20% in 2010 and 50% in 2015. US LNG shipment to Asia, Latin and South America, Europe, and the Middle East began in 2016 with the rising demand for gas in those regions. Moreover, Russia's "politics of demand" (Agina) strategy, which made European countries reliant on its piped natural gas, significantly influenced the US's decision to retaliate by implementing a similar strategy among its alliances, thereby fostering dependency on US LNG. Japan, as a close geopolitical ally of the US, shares a common goal of expanding LNG supply to meet the growing demand in response to Russia's dominance in natural gas supply.

Because of climate concerns, gas (natural gas and LNG) is considered a less carbon-emitting fuel source than coal and oil. In some countries, LNG is considered a bridging fuel for its role in bridging the gap between high-fuel-dependent energy systems and more clean energy-dependent energy systems. As long as clean energy diffusion does not take off to a sustained level, LNG can play a bridging role before reaching the clean energy target. However, LNG's role as a transition fuel is not applicable in Bangladesh. Bangladesh was already a highly natural gas-dependent country before it started importing expensive LNG. For Bangladesh, the politics of demand hold greater significance, as the country's long-standing gas-dependent industrial infrastructure and regulations have fostered a demand for LNG.

From the demand side, Bangladesh, as a natural gas-dependent country, didn’t need to import gas if it had explored its own domestic natural gas. From the supply side, there is a strong interest from supplier countries in developing LNG infrastructure in Asian countries and increasing dependency to ensure a high price of LNG. The Japanese strategy of coal and LNG expansion heavily influenced the master plans prepared by JICA. The plans did not focus on increasing the capacity of the national gas exploration company BAPEX but instead encouraged extracting coal and importing LNG. Different local and international rent-seeker groups, including consultants, experts, business groups, and bureaucrats, supported the plan's implementation.

Another compelling factor driving the imperative need for LNG in Bangladesh stems from the historical adoption of captive power using affordable natural gas since the 1990s and the direct use of natural gas for industrial purposes. In the absence of reliable grid-supplied electricity infrastructure, the government granted permission to the industrialists, who over the ensuing decades evolved into a powerful interest group that significantly influenced the country's politics. As industrialists became increasingly reliant on the natural gas supply, the lag in gas exploration prompted the government to propose LNG imports as an alternative solution. Despite their capacity to influence government decisions, the industrialists found themselves constrained by their dependence on low-cost natural gas. (Mridha 2022) Consequently, when the government offered LNG as a more costly substitute, the industrialists had no choice but to accept it as an immediate solution. (FE 2023) This underscores the idea that the creation of demand followed a path-dependent process, rooted in the historical adoption of captive power, the use of natural gas in industries, the failure to explore natural gas, and the subsequent dependency. The eventual provision of more expensive LNG appeared at a time when the forgone opportunity of having an alternative provision could not be availed of in the short term.

Figure 8-3 Gas price increase after LNG import (Taka)



Despite the considerable potential for gas exploration in both the onshore and offshore areas, the government did not take sufficient initiative in this regard. To meet the sustainable development goal (SDG7), Bangladesh prioritized increasing installed capacity and access to electricity over stable energy supply for the power plants. The overemphasis on electricity access, considered an indicator of development, led to a shift in focus toward a more politically persuasive target. Consequently, access to electricity surged from 20% in 2000 to near-universal access by the end of 2022, and installed capacity soared to almost 29,000 MW (including renewable energy and captive power) from under 5000 MW in 2008. This has led to excessive overcapacity, reaching approximately 60% in the winter season and about 40% in the summer season. The government now bears substantial subsidies as capacity charges for the unused capacity, placing a heavier financial burden on citizens. While the government uses tax revenue to subsidize private entities, consumers face higher electricity bills due to a number of price hikes over the past 15 years. The price hike is a result of the country's increasing dependency on expensive energy like coal and LNG, which it adopted in the last decade.

8.5 Mechanisms of transition (empirical analysis)

In this section I propose explanations for the rapid switch to coal and LNG in Bangladesh that are more nuanced than the mainstream explanations based on neoliberal economic theories and the concept of technological lock-in.

First, I argue that both supply and demand are not only ‘objective’ phenomena but are also politically constructed to serve interests of certain political actors. In case of coal and LNG, the main actors capable of constructing the idea of supply and demand categories were (i) government, (ii) international oil companies; (iii) large countries with strong geopolitical interests like China, India, Japan, USA, and Russia. Understanding the motivations and strategies of these actors provides more plausible explanations of adoption of LNG and coal in Bangladesh than traditional neoclassical supply-demand theories.

Second, I explain the role of rent-seeking behavior among different actors involved in adopting LNG and coal. The explanation reveals the causes of adoption of coal and LNG despite their economic inefficiency and social costs. The rent seeking framework provides a more plausible explanation of rapid coal and LNG utilization than a traditional neoclassical efficiency theory that argues for elimination of deadweight inefficiency or the widely used ‘lock-in’ theory that points to technological path dependence. According to the neoclassical efficiency theory a market efficient outcome is characterized by the absence of any deadweight loss when supply meets demand. Despite the justification for the adoption of

LNG and coal was to yield an efficient outcome, in reality the evidence suggests otherwise. The rent seeking framework explains why actors often adopt inefficient policies, such as utilization of expensive imported LNG and coal, resulting in high social cost. It also points out that developing countries like Bangladesh, which depends on external technology, adoption of inefficient technology can be best explained by rent-seeking caused by institutional lock-in that can apply to both old and newly introduced or proposed technologies.

8.5.1 Politics of demand and supply

It is usually assumed that demand and supply are primarily driven by markets. However, in Bangladesh, the states (national and foreign) have played a large role in shaping demand and supply of some energy sources. In particular, the Bangladesh government interacted with foreign state actors to shape demand for LNG and coal.

JICA's Master Plan for Bangladesh introduced a policy to increase the installed capacity of LNG and coal, thereby creating demand for these energy sources. On the supply side, the same plan promoted the development of energy supply infrastructure, but it did not accurately estimate the availability of reliable and affordable energy sources. The mismatch between the extent of demand creation and Bangladesh's lack of real purchasing power to meet the increased demand by providing an affordable energy supply has led to market inefficiency. The demand (installed capacity) has been consciously created way above the actual national demand to create a market for technology supplied by countries like India, China, Japan, and the USA. Actors driven by both geopolitical and economic interests turned Bangladesh into a recipient of energy technology, influencing both the politics of demand and supply.

Besides, the interests of the major power and Bangladesh's government's 'balancing strategy' resulted in a number of partnerships motivated by geopolitical and economic considerations and shaping demand for LNG and coal in Bangladesh. Scholars have argued that Bangladesh should play either a 'balancing act' (Pattnaik, S. 2019) or a 'hedging strategy' when it comes to dealing with great powers. In the following, I explain how the geopolitical and economic interests of the countries worked together to use the politics of demand in both LNG and coal demand creation in Bangladesh.

8.5.1.1 Politics of demand in liquefied natural gas (LNG) market

With respect to LNG, the Bangladesh government has primarily interacted with the US and Japan. From a geopolitical point of view, Bangladesh's interaction with the US and its ally Japan is part of a balancing act. At the global level, Bangladesh plays a balancing role in energy diplomacy by importing LNG technology from the US while also engaging in nuclear cooperation with Russia.

How demand was consciously created can be better explained by the gradual creation of demand and consequent supply of LNG and its technology to the market in Bangladesh. Bangladesh's power system master plan (GoB 2006) focused more on developing LNG import capacity than exploring domestic gas. The 2010 Bangladesh Master Plan suggested that Bangladesh import LNG to meet its demand. Around the same time, the US was planning to expand its LNG market in Asia.

Initially, Bangladesh approved two LNG terminals. The first LNG terminal, the Moheshkhali floating LNG terminal, started commercial operation in 2018. According to the contract, the US company Excelerate, after building the terminal, will own and operate the facility for fifteen years and transfer ownership to Petrobangla. The second terminal, Summit LNG Terminal, started commercial operation in 2019 after receiving a concession from Petrobangla in 2017. Summit Power, a domestic conglomerate, used Excelerate Energy's US technology. Both of the floating storage and regasification units (FSRUs), which re-gasify imported liquefied natural gas and supply it to the national grid, have a combined annual capacity of 7.6 million metric tons (mtpa).

Bangladesh persisted in constructing new gas-fired power plants in early 2020, despite gas shortages and challenges in procuring LNG. The power plants that have finished construction include the 584-MW plant owned by Unique Meghnaghat Power, the 583-MW Summit Meghnaghat-II plant, and the 718-MW power plant jointly owned by Reliance Power of India and JERA of Japan. The public sector is nearing completion on three gas-fired power plants: the 800 MW Rupsha combined cycle power plant, the 416 MW Ghorashal Repowering Unit 3, and the 409 MW Ghorashal Repowering Unit 4. Over the last decade, these new gas-based power plants have increased gas demand and made Bangladesh more reliant on LNG.

In 2019, Japanese business JERA acquired 22% of the outstanding share of the Bangladeshi company Summit Power International Limited. This stands out as an example of the Japanese government's conflict of interest because JICA, a Japanese development agency, suggested LNG capacity development in their master plan for Bangladesh and allowed a Japanese company to acquire a share of the Bangladeshi company, Summit Power. Furthermore, JERA's partnership with Reliance Power is another example of a Japanese company involved in the LNG-based power plant business. While this partnership raises concerns about conflict of interest, JERA has also set an example by starting to resell its surplus LNG to Bangladesh.

Although Bangladesh initially had a long-term LNG supply contract with Qatar and Oman, it has recently started to import LNG from US and Japanese companies as well. Increasing demand for LNG in Bangladesh has been part of the deliberate US policy to increase global demand for LNG as opposed to pipelined natural gas in order to provide a market for US LNG exports following the shale gas revolution. Besides supplying LNG, the US has also adopted a policy to expand its LNG technology supply by building LNG terminals in new locations. As a result, Excelerate, a US company, built the first LNG terminal, indicating US interest in entering both the LNG and LNG technology industries.

During the LNG volatility, half of the existing capacity remained unused. Despite this unused capacity, the government has proposed the development of four additional LNG terminal projects. These include an onshore terminal in Matarbari with the ability to convert 7.6 million metric tons per annum (mtpa) and two Floating Storage Regasification Units (FSRUs) in Moheshkhali and Payra, each with a capacity of 7.6 mtpa. Additional capacity is planned for one of the two FSRUs. BMI research (2024) shows that the planned projects would increase the LNG regasification capacity by an extra 21 mtpa before the end of 2030. In 2023, Petrobangla entered into two new long-term LNG sale and purchase agreements with QatarEnergy and Oman Trading International for 1.8 million mtpa and 1.5 mtpa, respectively. Once the two additional contracts commence LNG deliveries in 2026, BMI projects Petrobangla's contracted liquefied natural gas (LNG) imports to rise to a maximum of 6.8 million metric tons per annum (mtpa). Therefore, Bangladesh is projected to have excess regasification capacity by 2030. According to UK-based BMI Research (BMI 2024), Bangladesh will have excess capacity for re-gasifying liquefied natural gas (LNG) by the end of 2030. This surplus capacity would result in financial costs for the government.

From the supply side, Japan is projected to have excess supply by 2030. According to the IEEFA report (IEEFA 2024), major utilities are investing in projects including regasification terminals and gas power plants, especially in South and Southeast Asia. Four companies—JERA, Tokyo Gas, Kansai Electric, and Osaka Gas—collectively represent over 75% of Japan's historical contracting activity. These companies have secured a larger amount of liquefied natural gas (LNG) supply than necessary for the majority of years between 2019 and 2030. Specifically, there was an excess of around 2 to 3 million tons per year in 2022 and 2023. In 2017, their exports had a significant surge, multiplying several times over. The total volume of liquefied natural gas (LNG) sold by Japanese corporations to foreign countries increased significantly from approximately 15 million tons in 2018 to more than 38 million tons in 2021. JERA and Tokyo Gas are involved in numerous projects related to LNG power plants, import terminals, and supply infrastructure in Southeast Asia, Bangladesh, and Taiwan, as observed by IEEFA. Osaka Gas is involved in the distribution of gas and provides technical services in the region. Kansai Electric possesses a trading corporation in Singapore, in addition to owning minority shares in power facilities within the region.

According to Sam Reynolds, the lead researcher on Asia LNG and Gas at IEEFA, Japan's gas trade activities in Southeast Asia could result in long-term energy insecurity for these developing nations. Reynolds emphasizes the concerns about geopolitics, climate change, and the infrastructure associated with this trade. (Lang 2024)

2015 saw a decrease in domestic gas consumption, prompting Japanese buyers of liquefied natural gas (LNG) to look for ways to sell their surplus supply. They also requested an easing of limits on where they could send the LNG and more flexibility in their contracts. In 2017, Japan experienced a situation where it had too many contracts, which was a first for the country. During the same year, Japan's Fair-Trade Commission (FTC) concluded that certain contracts with restrictions on destinations would violate competition regulations. Although there was a decrease in domestic demand, the government was determined to safeguard Japan's presence in the international LNG market. In 2020, Japan's Ministry of Economy, Trade, and Industry (METI) introduced the New International Resource Strategy for Enhancing LNG Security. This strategy aims to achieve a target of handling 100 million tons per year (mtpa) of LNG by 2030 for Japanese enterprises. The handling goal exceeds the current committed amount of 79 million tons per annum (mtpa) through long-term sale and purchase agreements (SPAs) by Japanese customers, but it is consistent with recent transaction volumes. Although there is a decrease in domestic demand, the policy indicates that Japanese corporations will probably continue to have a significant presence in LNG markets and transactions. Long-term contracts, spot market trading, and/or investments in upstream and LNG export projects can achieve this. Following the Russian invasion of Ukraine in February 2022, worries about excessive contracting were less important as Japan shifted its attention to strengthening its energy security. The Ministry of Economy, Trade, and Industry (METI) has strongly advised Japanese corporations to increase their provision of long-term liquefied natural gas (LNG) contracts. Several Japanese companies are currently in talks to purchase LNG from Qatar as of early 2024. Despite the ongoing contract discussions, it is quite probable that the main Japanese utilities will continue to face a consistent surplus of supply until 2030.

8.5.1.2 Politics of demand in coal

With respect to coal, the Bangladesh government interacted mainly with India, China, and Japan. Among these countries, India and China have large domestic coal resources and expertise in both coal mining and coal power plant technology, whereas Japan has coal power technology to export. The Bangladesh government commissioned India, China, and Japan to conduct various surveys and research on energy resources. Due to their close ties to countries and companies directly interested in supplying coal and coal-related equipment and technology to Bangladesh, these research outputs could not provide impartial advice.

The Bangladesh government commissioned the Japanese development agency JICA to develop the power system master plan for 2010, 2016, and 2023, envisioning a large role for coal. This was a glaring conflict of interest, given that Japanese companies also developed the Matarbari coal power plant, which was supported by a JICA loan for both the plant and a related port development.

Bangladesh plays a balancing act by allowing India to build the Rampal coal power plant, China to build the Payra, Banshkhali, and Barishal coal power plants, and Japan to build the Matarbari coal power plant. This shows how Bangladesh is keeping a balance among these nations with regional power.

While US-China competition at a global level has regional implications for South Asian countries' trade, commerce, finance, energy cooperation, and diplomacy, China-India competition over share of investment and economic expansion in South Asia has added a regional dimension to the region's geopolitics. Although India and China continue to have strategic rivalry, China is India's biggest trading partner, and while India is the largest recipient of loans from the China-sponsored Asian Infrastructure Investment Bank (AIIB), India has continued to be a top borrower of the AIIB since 2017. Therefore, it remains unclear if the coal expansion strategy stems from the saturation of the domestic coal markets in both China and India, or from the geopolitical tension that fuels India-China competition. Both factors may have contributed to the increasing interest of India and China in the coal sector of South Asian countries, such as Pakistan, Nepal, Bhutan, and Sri Lanka. Given their status as coal mining countries and their ongoing efforts to phase out coal, both India and China have adopted a strategy of expanding coal technology into Asian countries with limited technical capacity. Bangladesh is one of the countries that has benefited from coal technology, leveraging both market expansion and geopolitical opportunities.

The Bangladeshi government entered into agreements with India and China to establish coal power plants, supported the development of infrastructure, modernized port facilities, dredged the river, acquired land, obtained environmental clearances, and guaranteed the loans for these power plants. Loans from their respective countries of origin (India from the Export Import Bank of India, China from the Export Import Bank of China) also supported these coal power plants.

The outcome of this engagement with China, Japan, and India yielded a costly, ecologically detrimental, and ineffective supply infrastructure that failed to deliver the promised benefits to local stakeholders. Consumers in Bangladesh are currently paying exorbitant prices for poor and unreliable services due to the underutilization of established electricity capacities. These countries' recognized geopolitical interests serve as motivations for their coal investments in Bangladesh, while economic factors also drive their coal expansion strategy. Despite worldwide pressure for these countries to eliminate coal and discontinue new coal power projects, the coal market has become saturated, prompting these suppliers to seek other markets for coal and coal technologies. These countries constructed coal power stations without taking into account the availability of coal and Bangladesh's affordability in order to establish a new market for their technologies.

Until 2019, these countries had plans to construct 29 coal power stations in Bangladesh. This garnered global attention due to its remarkable potential for expansion, resulting in Bangladesh's rapid ascent from 12th to 6th place in terms of global coal power under development within a mere 3 years. According to a report (Market Forces 2019), if constructed, these power plants had the potential to expand the nation's current coal capacity by a factor of 63, from 525 MW in 2019 to 33,200 MW. The planned capacity exceeded the country's predicted demand. The fervent race to invest in Bangladesh indicates that these nations are expanding their economic and financial stakes. Due to international pressure to divest from fossil fuels, Bangladesh has abandoned its plans to construct certain coal power stations while allowing the development of some already underway coal-fired power facilities to proceed. Despite the cancellation of numerous coal power stations, the operational capacity in 2024, following the construction of six additional coal power plants, remains below its full potential.

To begin with, the cost of imported coal has increased. Furthermore, despite the country's efforts to implement demand management, some units have had to remain inactive in order to maintain a balance between demand and supply. The government's recent actions to capitalize on the coal lock-in situation and extract domestic coal further strengthen the evidence for the demand creation plan. Bangladesh now has 6604 MW of coal-based capacity, mostly relying on imported coal. In order to run the existing power plants, Bangladesh needs 33.6 million tons of coal annually. This imported coal costs $6 billion. Initially, when the projects were undertaken, they were mainly justified on the grounds that coal was cheap and Bangladesh needed cheap sources to meet the rapidly growing electricity demand. However, since the plants began their commercial operations, the price of coal gas has increased significantly in recent years, making production financially unviable. Power China and Asia Energy are currently expressing interest in extracting indigenous coal resources. (Raana 2024)

Bangladesh possesses coal reserves in strategically important economic centers that are home to thriving agricultural, commercial, and residential activity. As a result, open-pit coal mining in these regions incurs significant environmental costs and human suffering. Nevertheless, under the pretext of the existing need for coal in operational coal power plants, there is a push to revive the proposal to mine domestic coal, despite the significant environmental risks involved. China's desire to capitalize on the coal lock-in represents a manifestation of demand-driven politics.

8.5.2 Rent seeking in coal sector

As of 2024, the total capacity of coal-based power plants was 6604 MW, accounting for around 24% of the overall capacity. (BPDB 2024) Half a decade ago, the capacity was a mere 2.76%. By the year 2024, Chinese, Indian, and Japanese corporations are collaborating with both state-owned and private enterprises to manage the power plants. Over the past decade, coal has experienced quicker growth than any other new energy technology. Coal technology encompasses a diverse range of participants, such as coal mining corporations, labor unions, logistics firms, distributors, power plants, and an extensive network of beneficiaries from the spread of coal technology. Due to the extensive network of stakeholders, coal lobbies tend to become more powerful, enabling them to exercise significant influence on decision makers in support of the sector. In Bangladesh, numerous individuals and organizations in the coal sector strategically employed regulatory capture, licensing, lobbying, and opposition management techniques to establish themselves as resilient participants in the market. The subsequent sections will provide a concise analysis of the empirical observations pertaining to different forms of rent seeking.

8.5.2.1 Regulatory capture in coal sector

All the five coal power plants in Bangladesh Rampal, Bashkhali, Barisal, Payra, and Matarbari, in collaboration with India, China, and Japan were built after 2010. These were built either under regulations enacted by the government to bypass competitive bidding, or they were built under government-to-government agreement that also avoided competitive bidding. While this is one example of regulatory capture by rent seeker because they took largely gained from the regulation, there were also instances where violating regulation was observed. For example, the Bangladesh Environment Conservation (Amendment) Act (2010) designates certain areas as "Ecologically Critical Areas" (ECAs), highlighting their unique biodiversity and the necessity for their protection against destructive activities. In 1999, the government of Bangladesh identified the vicinity near the Sundarbans, St Martins Island, and Sonadia Island as ecologically critical areas. Some of the power plants including Rampal Matarbari and Payra power plants have been found to threaten these areas.

Despite the potential environmental and social costs, these coal power plants were constructed to serve the interests of rent seekers. Furthermore, under the Quick Enhancement of Electricity and Energy Supply (Special Provisions) Act, to ensure quick power supply, Bangladesh entered into a contract with the Indian private company Adani to import electricity from a coal-based power plant. The Institute for Energy Economics and Financial Analysis (IEEFA), which deemed the project too expensive, too late, and too risky showed that the implementation of this project primarily aimed to benefit technology suppliers like Adani, an influential conglomerate receiving state support while also charging exorbitant prices for electricity. This cooperation created the opportunity for the coal industry to launch their projects violating the local environmental act. (IEEFA 2023)

8.5.2.2 Resistance capture in coal sector

Originally, in 1994, the Bangladesh government granted a coal exploration license to BHP Minerals, an Australian company, for mining purposes. However, due to various environmental and engineering challenges, BHP Minerals opted out of coal mining operations. Consequently, in 1999, BHP transferred its licenses to Asia Energy. Right from the outset, the local community voiced opposition to the project. On August 26, 2006, during a demonstration against open-pit coal mining, law enforcement authorities opened fire, resulting in the deaths of three protesters. This violent suppression of dissent was supported by a coal lobby that was gaining strength through collaboration with the government. Similarly, there has been significant opposition to the construction of a coal power plant near the Sundarbans, with law enforcement being instructed to crackdown on protestors, leading to numerous injuries.

In 2016, during a protest by local communities, five workers at the Bashkhali power plant were killed. (Rahaman 2021) Throughout these movements, consultants, media outlets, and experts were hired to shape public opinion in favor of the companies and government. Public funds were utilized to run media campaigns highlighting the purported benefits of the coal power plant. These investments aimed at managing resistance and influencing public perception represent the resistance capture costs borne by rent seekers to safeguard their rent-seeking endeavors.

8.5.2.3 License for importing coal

Out of the original 29 planned coal powered projects, 25 of them intended to import coal. If those were adopted, it would be necessary to import coal from Australia, India, Indonesia, and South Africa. The issuance of a license for importing coal serves as a lucrative means of rent seeking, since it effectively eliminates other competitors in the market and grants the licensee the exclusive privilege to supply coal for an extended duration. In order to obtain the license, the providers engage in competitive bidding. The coal power plants in Bangladesh rely on imported coal, which is procured, transported, and delivered to the project site by private enterprises, creating significant opportunities for generating rent in this process.

8.5.2.4 Indirect lobby behind coal adoption

A newly formed interest group comprising industrialists, who are establishing industries within the ecologically critical area around the Sundarbans, intensified lobbying efforts in favor of the Rampal coal power plant. The government granted licenses to 190 industrial and commercial units within the Sundarbans' ecologically critical area (ECA). Experts warn that these industries will pose a significant threat to biodiversity. According to a report by the Department of Environment (DoE) submitted to the High Court, at least 24 of these industries fall under the "red category," indicating they are extremely detrimental to the fragile biodiversity. (Daily Star 2018) Granting authorization to these companies serves as a means of providing advantages to a wide range of stakeholders who, driven by their own self-interest, would persistently advocate for the utilization of the land and the transformation of the ecologically sensitive region into an industrial zone. This facilitates formation of a new lobby group that strengthens the existing coal lobby.

8.5.3 Rent seeking in liquefied natural gas (LNG)

When Bangladesh commenced importing LNG in 2018, it was already a costly alternative compared to domestic natural gas. Initially, Bangladesh utilized approximately 650 to 800 million cubic feet (mmcf) of imported LNG capacity for the national grid. However, since 2022, the global LNG spot market prices have surged. Consequently, LNG quickly became a significant contributor to electricity generation. By 2022 and 2023, imports had dwindled to around half of the previous capacity, ranging from 500 to 553 mmcf. The steep rise in LNG prices on the international market, coupled with the underutilized capacity, has resulted in significant social costs. Businesses have witnessed a contraction in output, residential consumers have endured severe load shedding, and inflation has adversely affected the lives of the poor and middle class. (Rahman 2023) The following sections identify various rent seeking options available to the rent seekers and how government facilitated it in the country.

8.5.3.1 Regulatory capture in LNG adoption

When Bangladesh sought to increase its reliance on LNG, it was already apparent that LNG was more expensive than the domestic natural gas. In view of this reality, the Gas Sector Master Plan of 2017 (GoB 2017) prepared by Danish International Development Agency (DANIDA) recommended that the government prioritize exploration of indigenous gas resources rather than investing in costly LNG imports. The Master plan also pointed out that Bangladesh has a potential gas reserve. Furthermore, Independent experts have consistently advised the government for years to prioritize exploration efforts for onshore and offshore gas reserves. However, driven by the interests of the LNG lobby, the government chose to focus on LNG imports. During this period, the Quick Enhancement of Power and Energy (Special Provision) Act of 2010 provided a legal framework that facilitated such economically inefficient decisions. Consequently, by 2023, the government was burdened with a daily capacity charge of approximately USD 202,500, even without utilizing regasification. This serves as an example of regulatory capture aimed at creating rent-seeking opportunities.

Indian company Reliance built an LNG based power plant under the Quick Enhancement of Power and Energy (Special Provision) Act of 2010. This power plant created another example of regulatory capture through which Reliance is able to earn the capacity charge even when it does not get gas supply.

8.5.3.2 Lobby in LNG industry

According to the estimate of Petrobangla, the cost of LNG import in 2020-21 was 24 times higher than the cost of natural gas production in Bangladesh in 2021-22. (Moazzem et al. 2022) Despite this high cost, Bangladesh started importing LNG in 2018 and by 2020 Bangladesh became the 14th largest importer in the global LNG market. This high share is a reason for the interest groups in LNG industry to actively pursue LNG demand creation in Bangladesh. Besides, between 2022 and 2025 the capacity addition of gas-based power plants (completed and under construction) is more than 6468 MW. (BPDB 2021) Although the government points out to the depleting gas resources as a reason behind LNG adoption, there is evidence of global LNG supplier's lobby (Rahman 2019) in securing higher price of LNG for a long time. Moreover, experts and political parties questioned LNG lobby as a reason behind negligence of domestic gas resources. (Star Business Report 2023, Khan et al. 2023, Moazzem et al. 2023, Mohiuddin 2023)

The LNG lobby's previous intention has become more evident when Bangladesh started to focus on domestic natural gas exploration during the escalating gas crisis in 2022. Upon recognizing the impending crisis that would put significant strain on the foreign exchange reserve, Bangladesh swiftly made the decision to tap into its previously unused domestic gas in order to preserve foreign exchange. Bangladesh observed the political turmoil, mass resistance, and economic instability faced by other South Asian countries such as Pakistan and Sri Lanka due to the foreign exchange crisis and acted immediately. As a response to the crisis, in 2022 Bapex undertook the drilling of nine wells, resulting in savings of at least USD 10.13 billion (Tk 100 billion) on LNG imports, achieved through an expenditure of only USD 85.7 Million (Tk 812 crore). To procure an equivalent amount of LNG via a long-term contract, the government would have had to expend foreign currency totaling USD 10 billion (Tk 96,000 crore). Alternatively, purchasing from the spot market would have necessitated an outlay of USD 17.89 billion (Tk 1,70,000 crore). Notably, between 2018 and 2019, the government had already spent USD 9 billion (Tk 85,000 crore) on importing LNG. (Mustafa 2023, Taher 2023) LNG lobby destabilized the existing gas regime by preventing Bangladesh from exploring its gas resources.

This scenario serves as a compelling illustration of how the lobbying efforts of private and international investors had previously influenced government decisions in energy planning.

The influential lobby group supporting the expansion of liquefied natural gas (LNG) infrastructure hindered the government's resource mobilization for domestic gas utilization. Despite facing challenges such as high import dependency on LNG and struggles with purchasing expensive LNG amidst dwindling foreign reserves, the government has opted to maintain its LNG-dependent policy. Instead of altering course, the government is actively exploring contracts with private operators to construct additional LNG import terminals and LNG based power plants. Most recently, the cabinet committee on Economic Affairs sanctioned the establishment of a third LNG terminal with a capacity of 600 mmcf, to be developed by the Summit Group. (TBS Report 2023)

8.5.3.3 Rent for learning

Located in Maheshkhali, Cox's Bazar, are two floating gas and re-gasification units (FSRUs) with a combined capacity of injecting 1000 million cubic feet of gas per day into the national gas transmission grid. One FSRU, operated by Excelerate Energy from the United States, boasts a capacity of 500 million cubic feet per day, while the other is managed by the national company Summit Group. To facilitate the construction of these terminals, the government has granted exemptions on VAT, duty, and other supplementary charges on materials and services. This reduction in costs for suppliers of new technology has paved the way for the creation of a learning curve for LNG technology and facilitated rent generation. (Mala 2023)

8.6 Discussion

This section discusses how rent seeking mechanism and politics of demand and supply mechanisms identified in section 8.5 reveal that the existing explanations mentioned in section 8.3 are not sufficient to explain the causal mechanisms behind adoption of coal and LNG in Bangladesh. Section 8.5 identified the mechanisms with empirical observations using secondary literature on adoption of LNG and coal. This section summarizes the novel explanations using rent seeking and politics of demand framework.

Existing explanations emphasizes mostly on the techno-economic mechanisms. The focus was on the need for demand supply balance, depletion of incumbent energy source, availability of cheaper energy source, and need for diversifying energy sources.

The following discussion provide three alternative explanations:

1. Demand is not objectively determined. There is politics of demand and rent seeking in the global LNG industry.

2. Gas depletion is not a mere unavoidable consequence of past use, but rather a deliberate strategy aimed at systematically destabilizing existing gas regime.

3. Coal was no longer regarded as a cheap source at the time of building the plants.

8.6.1 Politics of demand

The motivation to use politics of demand to create demand for LNG and coal is geopolitical interest, and suppliers' interest in technology lock-in. The empirical evidence showed most of the coal and LNG projects have linkages to foreign actors. These foreign actors include governments and companies from the US, China, Japan, India and Russia who had strong economic and geopolitical incentives to shape Bangladesh energy system in a particular way. With respect to economic interests, the US has been primarily interested in expanding the global LNG market that would allow it to export its shale gas and also its expertise in constructing LNG facilities. (Sakmar 2013, Goldathu 2020) Japan, that does not have gas resources of its own also has considerable expertise in LNG technology and is interested in exporting it to other countries. Furthermore, Japan, India and China all have large shares of coal in their energy mix and in case of India and China considerable coal mining. Faced by the international pressure they sometimes seek to limit the use of coal in their own countries, but at the same time seek new markets for their industries that manufactured coal mining and power plant equipment. These coal technology supplier countries were therefore interested in creating and expanding demand for coal. Finally, Russia has had an interest in diversifying its predominately fossil fuel exports with advanced technologies such as nuclear reactors and achieving a dominant position on this global market (Vetier, Jewell 2019).

In addition to economic interests, these large countries also have geopolitical interests directly and indirectly related to Bangladesh. India has long been at the center around which the geopolitics of Bangladesh revolved and shaped historically. Due to its geographic proximity, cultural links and above all its intervention as an ally against Pakistan during Bangladesh's liberation war, India has been the major regional geopolitical player for

Bangladesh. Other regional powers, such as China and Japan, had a more peripheral role until China's rise as an economic and military power strengthened its ability and reinforced its willingness to exert influence in South Asia, providing Bangladesh a scope to partner with a country having both regional and global power.

Bangladesh, being surrounded by India in three sides, is under more direct influence of India than China, USA, Russia, and Japan. The location of the Bay of Bengal makes Bangladesh a facilitator and connector between regions and competing powers. Bangladesh's role in regional connectivity makes Bangladesh a key location in shaping the regional geopolitics. For example, India benefits highly from transit facilities through Bangladesh. Access to Bangladesh's seaport opening to the Bay of Bengal is important for trade of goods from North Eastern states of India to the other regions in India and abroad. In return, Bangladesh does not secure any significant benefit compared to what India acquires from Bangladesh.

India has been using energy cooperation as a strategy to develop economic diplomacy through which India is gradually implementing its plan to develop energy dependency relationship. This has become more evident when India had been more interested in bilateral energy cooperation than in regional energy cooperation. When SAARC (South Asian Association of Regional Cooperation) was formed, one of the proposed objectives was to develop a regional grid network through which all South Asian member countries could benefit from shared grid network, based on their own national demand and supply. India, as the most influential country in South Asia, was against South Asia based regional grid and instead consciously built bilateral energy cooperation relationships with neighboring countries like Nepal, Bhutan, Bangladesh, and Sri Lanka. Through this cooperation, India has been able to exercise greater control over the supply and demand of these countries.

India expanded its businesses in energy and technologies according to its own interest, without any obligation to serve common regional goal. As a part of the bigger energy plan of India, both in terms of creating grounds for demand politics and supply politics, India has partnered with Bangladesh to develop a coal power plant, endangering the largest mangrove forest in the world. Reliance, an Indian company, along with JERA, a Japanese company, has also set up an LNG based 750 MW power plant in Bangladesh. The Reliance Bangladesh LNG and Power project was supposed to start commercial operation in 2022, but because of

Bangladesh's reduced capacity to import LNG, the project could not be started. This evidence represents these companies' business interest based on the demand-supply assumption that relied excessively on imported LNG. Additionally, India has recently started to export electricity to Bangladesh from the coal power plant located in India. Beside exporting oil to Bangladesh through pipeline, India has signed a contract with Bangladesh to build second pipeline to export LNG. The growth of power and energy projects based on Indian technology and energy over the last decade shows the growing power of India to have control over the supply by creating demand for their technologies and energy.

China's share of investment in Bangladesh started to increase after Bangladesh joined the China's Belt and Road Initiative (BRI) in 2016. Most of the power and energy sector project in partnership with China started construction after 2016. These include Payra (1320 MW), Patuakhili (1320 MW), SS (1320 MW), Barisal (350 MW). Of the 4 coal power plants (3960 MW capacity) two are still under construction. In developing coal power projects in Bangladesh China is ahead of India.

Beside India and China, Japan is another country that invested in coal power project in Bangladesh. Japan's strategy was driven by its coal technology expansion strategy included in the infrastructure export strategy. The project was planned and undertaken before the financial institutions' coal power divestment started getting momentum following Paris Agreement 2015. Japan planned more coal power plants including phase-2 of Matarbari coal fired power plant, which was later cancelled.

At the global level, there are USA and Russia using their advanced technology and financing abilities to establish strong foothold in Bangladesh. United States is the major global power exercising the greatest economic and political leverage over Bangladesh. Russia's historical support during the 1971 liberation war and its efforts in nuclear cooperation with Bangladesh has made Russia emerge as a major global energy player.

8.6.2 Rent seeking embedded in institutions

When a new energy is adopted, it is generally assumed that the choices are market-efficient, meaning that they are usually cheap or cost-efficient. However, there are many instances when the adoption of a particular energy may be economically inefficient compared to other readily available technologies. Policymakers often tend to adopt inefficient policies, resulting in higher social and environmental costs, even when the higher cost is revealed. In Bangladesh, the adoption of coal and LNG is inefficient as both of these energies are expensive and less affordable than other energy sources. The network of rent seekers in these sectors, which includes technology suppliers, fuel suppliers, and labor suppliers, becomes so powerful that the adoption of these energies is not due to their efficiency, but rather because they generate more opportunities for these interest groups to use various rent-seeking tools to secure their income.

There are various rent-seeking networks involved in various types of energy technologies. The larger the network and the greater the power of the rent seekers involved in the technology, the greater the political feasibility in favor of that technology. While solar power primarily relies on technology suppliers (equipment and infrastructure), coal and LNG-based power rely on both fuel and technology (more expensive equipment and infrastructure) to convert fuel into electricity. However, the network of rent seekers in coal and LNG technology is larger than those in solar technology. The larger the network of rent seekers, the greater their influence on the government's decisions, policies, and regulations. When rent seekers are too influential, governments may often tend to implement policies even when the cost is higher than the benefit. The larger rent-seeking opportunities involved in coal and LNG drove the adoption of these technologies in Bangladesh. I discuss various rent-seeking methods used by the rent seekers in the following section.

8.6.3 Gas depletion: random consequence versus intentional destabilization of incumbent technology

The research shows that gas depletion is not a mere outcome resulting from past use, but rather a deliberate strategy aimed at systematically undermining the need for exploring onshore and offshore gas. Instead of taking gas depletion as a given reality this research further investigates the question why investment in gas exploration has been undermined. In the 2000s, international oil companies were willing to sign PSCs for the domestic gas with the condition of allowing gas exports. However, towards the end of that decade, there was a notable shift in perspective driven by the growing concern about depleting gas resource. The fear of gas resource depletion became a dominant perspective. The transformation of Bangladesh from a gas-abundant to a gas-scarce country within a few years remains a perplexing puzzle. The research brings to light why gas scarcity was an intentionally constructed reality to destabilize incumbent energy sources.

When the decade of 2000 and 2010 was the high time for Bangladesh to explore new gas fields and increase gas production, it was the time when IOCs were insisting on gas export, converting to LNG and selling to the international market at high price. However, the nationalist movement against gas export were seen by IOCs as a barrier to a quick recovery of investment and achieving high profit. The divergent motivations of Bangladesh as a resource owner country and the IOCs as technology owner did not match to create a common understanding of resource sharing. As a result, the international companies who had resources to make such an investment were not interested in supplying Bangladesh's domestic markets, but rather to produce expensive LNG for export. In the meantime, US and Japan were seeking to expand LNG market as a geopolitical strategy against Russia's dominance in piped natural gas market. Inability to export LNG along with global LNG expansion policy shifted focus away from domestic gas resource to reliance on imported LNG. Partially destabilizing the gas regime in Bangladesh was necessary to create market for LNG and coal.

In addition to under investment the unplanned diversification could not ensure stable supply and affordability. One of the previous dominant perspective was that there is a need for energy diversification to avoid the risk of availability and affordability and ensure energy security. (GoB 2010) (Aminul et al 2022 GoB 2016a) After the crisis has started, this notion of energy security has been questioned. Although the goal of diversification is to ensure both the availability and affordability of energy, recent crises have revealed shortcomings in meeting these criteria. The attempt to diversify by adopting coal and LNG fails to adequately justify the adoption of these technologies heavily reliant on imports.

8.6.4 The outdated idea that coal is cheap

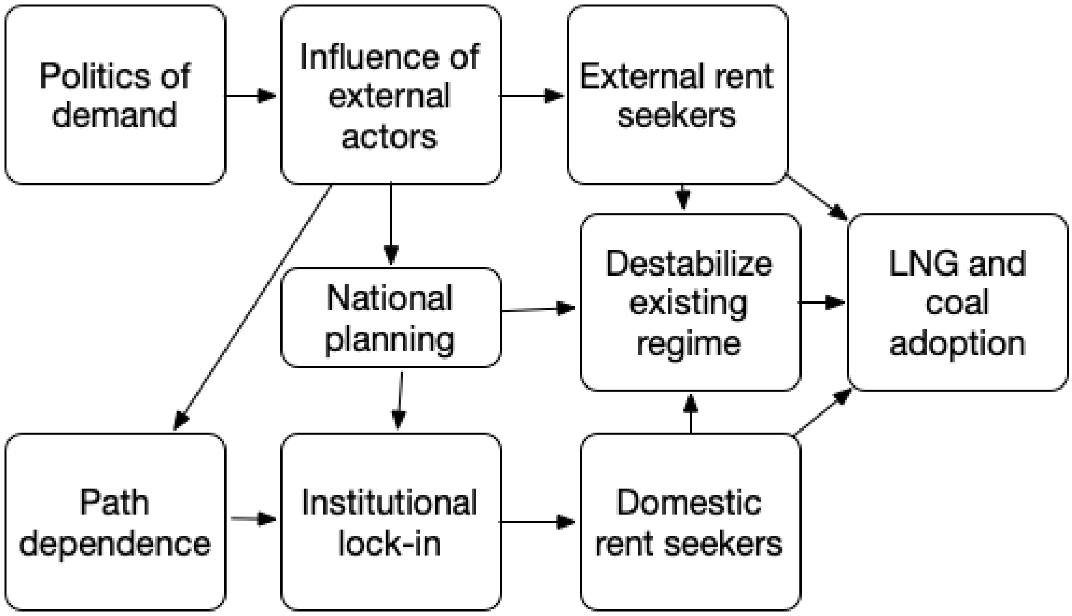
Most of the coal power plants were built during the decade of 2010 and 2020 to implement the master plan of 2005 and 2010. Before 2010 solar was more expensive than coal and was readily available. Countries like China, Japan, and India were searching for coal expansion opportunities overseas. Besides, building coal power plant in Bangladesh did not require strict environmental standard. All these things made Bangladesh a destination of new coal power investment for the companies abroad. However, when the coal power plants were being planned and built after 2015, by that time price of renewable was already declining. Coal as a cheap alternative was already losing social acceptability. All the countries were pledging to phase out coal or cancel construction of coal power plants, expansion of coal technology in new destinations was a decision against the ideology of climate justice. The coal investors were aware of the changing public acceptability and was desperately taking the last advantages they could take.

Table 8-1 Major Rent Seekers and Strategies Employed

	Geopolitical Strategy used by countries.	Rent Seekers	Rent Seeking Strategies Employed
Excelerate (LNG)	US and Japan	Technology Suppliers	1.Regulatory Capture 2.Lobby 3.Rent from Learning
Summit (LNG)	US and Japan	Private Owner and Technology Supplier	1.Regulatory Capture 2.Lobby 3.Rent from
Rampal	India	Technology Suppliers and Coal Suppliers	1.Regulatory Capture 2.Lobby 3.Rent from Learning 4.License 5.Resistance Capture
Matarbari	Japan	Technology Suppliers and Coal Suppliers	1.Regulatory Capture 2.Lobby 3.Rent from Learning 4.License 5.Resistance Capture
Payra	China	Technology Suppliers and Coal Suppliers	1.Regulatory Capture 2.Lobby 3.Rent from Learning 4.License 5.Resistance Capture
Banshkhali	China	Technology Suppliers and Coal Suppliers	1.Regulatory Capture 2.Lobby 3.Rent from Learning 4.License 5.Resistance Capture

Although there was a rush to build 33 GW, a large portion of it had to be cancelled. The research shows that rent seeking and geopolitical motivation played the most significant role behind coal adoption.

Figure 8-4 Causal Chain of Coal and LNG Adoption



8.7 Summary

The existing explanations for the adoption of coal and LNG in Bangladesh are not sufficient to fully understand the causal mechanisms behind these decisions. This chapter provides four alternative explanations: the politics of demand, presence of external and domestic rent seekers, intentional destabilization of incumbent technology, and the outdated belief that coal is cheap.

The politics of demand suggests that the motivation to create demand for LNG and coal is driven by geopolitical interests and the desire of foreign actors to lock in their technology. The empirical evidence shows that many of the coal and LNG projects in Bangladesh have linkages to governments and companies from the US, China, Japan, India, and Russia. These countries have economic and geopolitical incentives to shape Bangladesh's energy system in a particular way. For example, the US is interested in expanding the global LNG market to export its shale gas and expertise in constructing LNG facilities. (Goldthau and Sitter 2020) Japan, India, and China, all with significant coal resources, seek new markets for their coal mining and power plant equipment industries. Russia aims to diversify its fossil fuel exports with advanced technologies like nuclear reactors.

Furthermore, gas depletion in Bangladesh is not simply a random consequence of past use, but rather a deliberate strategy to undermine the need for exploring onshore and offshore gas. The research reveals that international oil companies were initially willing to sign production sharing contracts for domestic gas with the condition of allowing gas exports. However, a shift in perspective occurred in the late 2000s due to concerns about depleting gas resources. This fear of depletion was intentionally constructed to destabilize incumbent energy sources and create a market for LNG and coal. The strong lobby in the global coal and LNG industry and the culture of facilitating the rent seeking embedded in the domestic institutions contributed to the destabilization of the existing natural gas industry's development and this eventually reinforced the adoption of LNG and coal.

Lastly, the belief that coal is cheap was a dominant perspective when the coal power plants were being planned and built in Bangladesh. At that time, renewable energy was more expensive than coal, and countries like China, Japan, and India were searching for coal expansion opportunities overseas. However, by the time these coal power plants were being constructed after 2015, the price of renewable energy had already declined, and coal was losing social acceptability due to concerns about climate change. Despite this changing landscape, rent-seeking behavior and geopolitical motivations played a significant role in the adoption of coal.

In conclusion, the adoption of coal and LNG in Bangladesh cannot be fully explained by the existing explanations of demand-supply balance, depletion of incumbent energy sources, availability of cheaper energy sources, and the need for diversification. The alternative explanations of politics of demand, intentional destabilization of incumbent technology, and the outdated belief that coal is cheap provide a more comprehensive understanding of the causal mechanisms behind these decisions.

9 Comparing Electricity Transition of Bangladesh and Vietnam

9.1 Introduction

Energy transition requires introduction of new low carbon technologies to mitigate the effect of climate change. Much of these technologies need to be introduced in developing and emerging economies, which are increasingly important for the future of global energy because of their rising demand for energy for economic development. There is therefore a need to understand energy choices or outcomes of developing countries. However, at the moment there are competing theories and expectations. On the one hand, developing countries are expected to grow renewables faster than developed countries. In part, this expectation is based on the 80% decline in the cost of solar PV throughout the decade of 2010. However, indefinite cost decline is not a given phenomenon.

There are arguments that due to technology learning, technology would diffuse faster in periphery than it does in core. (Grübler 2016) These arguments are especially powerful with respect to distributed energy technologies such as wind and solar power that are readily transferrable across the globe (Binz et al and Wilson et al. 2020) There is also a leapfrogging hypothesis where developing countries are often expected to leapfrog up to low carbon energy technology without considering their limits to leapfrog. (Gallagher 2006) On the other hand, there is limited evidence for faster growth of low-carbon technologies in developing countries.

Cherp et al (2021) and Brutschin et al. (2021) show that solar, wind and nuclear power are not introduced faster in developing and emerging economies. Some of the developing countries cling to old options or even keep expanding fossil fuels. Furthermore, there are conceptual arguments against the feasibility of leapfrogging (Gallagher)

The empirical evidence here is however not unambiguous. Some developing countries adopt renewables very fast, whereas some lag behind. The literature does not give clear clues to why it is so because in contrast to comparative studies of developed countries, comparative studies of developing countries, are relatively rare (Vinichenko 2019). Furthermore, there are no widely agreed frameworks for explaining energy transitions. Many of the studies focus only on one perspective be it technology diffusion, supply-demand balance, technology cost and competitiveness, vested interests or policy analysis.

Vietnam and Bangladesh are two emerging lower middle-income economies with aspirations to become high income countries in next twenty years. Both have export-oriented economies with a potential of manufacturing and service sector growth and projections of high electricity demand. The rapid growth of demand and depletion of indigenous resources has led both countries to undertake an energy transition. However, in spite of their relatively similar energy paths from the 1980s through the 2000s, with electricity market reforms starting in the 90s, and similar energy challenges, the energy transitions of Vietnam and Bangladesh have unfolded differently since 2010. While Vietnam is rapidly growing solar power (26% of installed capacity by 2020), the country cancelled its nuclear power plant (NPP) in 2016. In contrast, in Bangladesh installed solar power capacity is still below 2% and the country has started construction of a large-scale NPP in 2017.

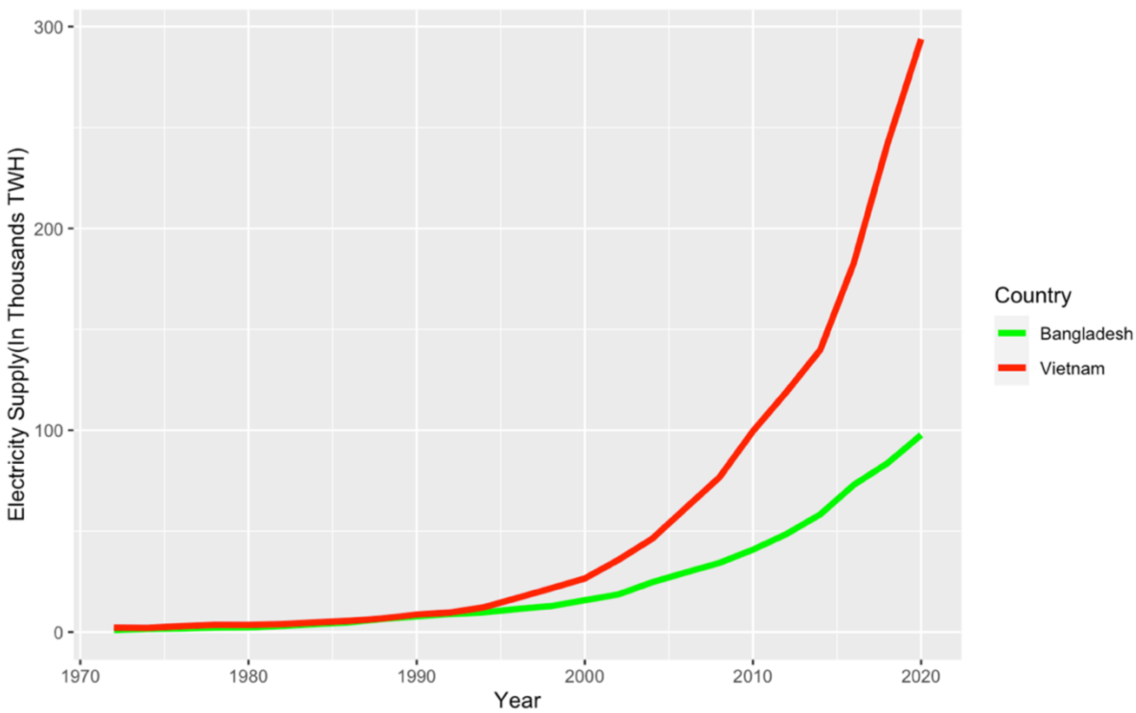
Here I seek to explain why Vietnam is adopting solar power while Bangladesh is adopting nuclear power. Using a most similar case study design and qualitative analysis we show that the deviating outcome is a result of combination of political, techno-economic and socio-technical mechanisms.

This paper contributes to enhancing conceptual and empirical understanding of energy transitions in developing countries through systematically exploring the difference in energy transitions in Bangladesh and Vietnam. These two countries present one of the most puzzling cases of different outcomes. They are similar in many aspects, including low-middle income status, rapid growth of energy use, size and geographic location in South – South-East Asia. Until recently these countries also had similar electricity systems dominated by fossil fuels and hydro power. However, within the last 5-10 year their paths rapidly diverged. While both keep expanding coal power, Bangladesh focuses on nuclear while lagging behind in solar while Vietnam rejected the nuclear option and rapidly developing solar. We aim to explain this difference in an integrated manner using three perspectives framework (Cherp et al. 2018) to identify relevant causal mechanisms that lead to different outcomes.

9.2 Brief context of new energy adoption in Bangladesh and Vietnam

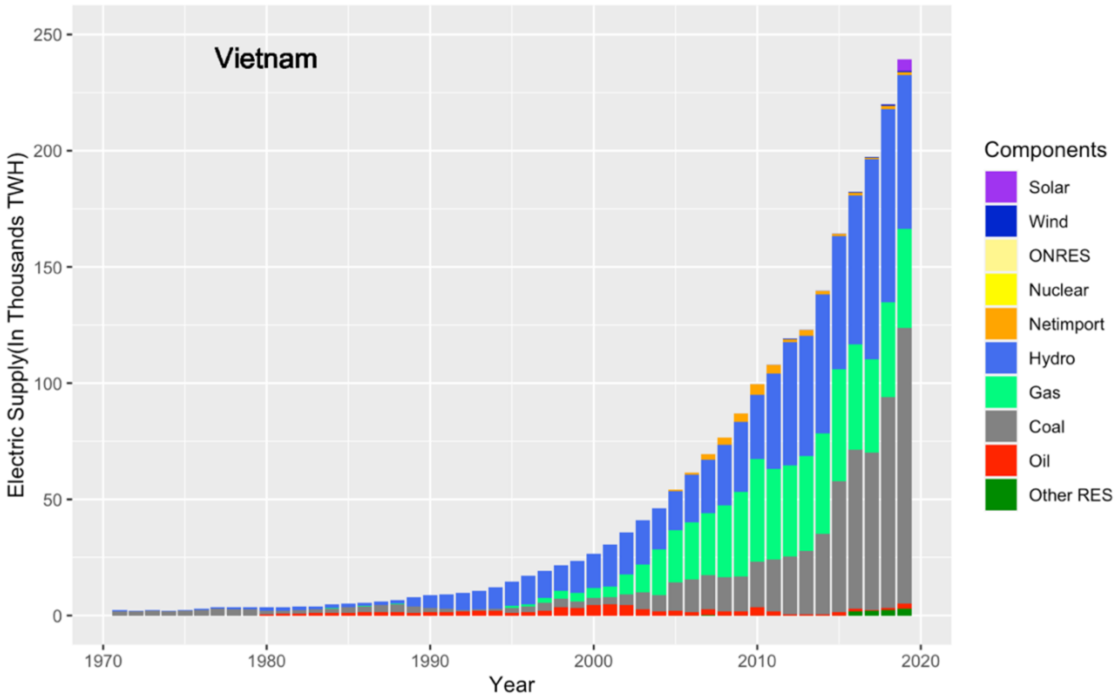
Since 1970s the electricity supply of Vietnam and Bangladesh were almost same until 1995. The growth electricity supply started to increase faster in Vietnam from 1995 as the grid infrastructure connecting North and South enabled Vietnam to distribute the surplus power produced in the north to the south. Although Bangladesh had plenty of gas resources to use in electricity generation Bangladesh fell behind because of under developed grid across the country. Vietnam's electricity growth in 1990s was mostly driven by more hydropower addition. Bangladesh's growth in electricity supply since 1990s mostly relied on indigenous gas resources. Although Vietnam's source of electricity was highly coal dependent in 1970s, the growth of use of coal has started to increase faster after 2010 than before 2010. The growth of coal was highest from 2015-2020.

Figure 9-1 Electricity supply in Bangladesh and Vietnam



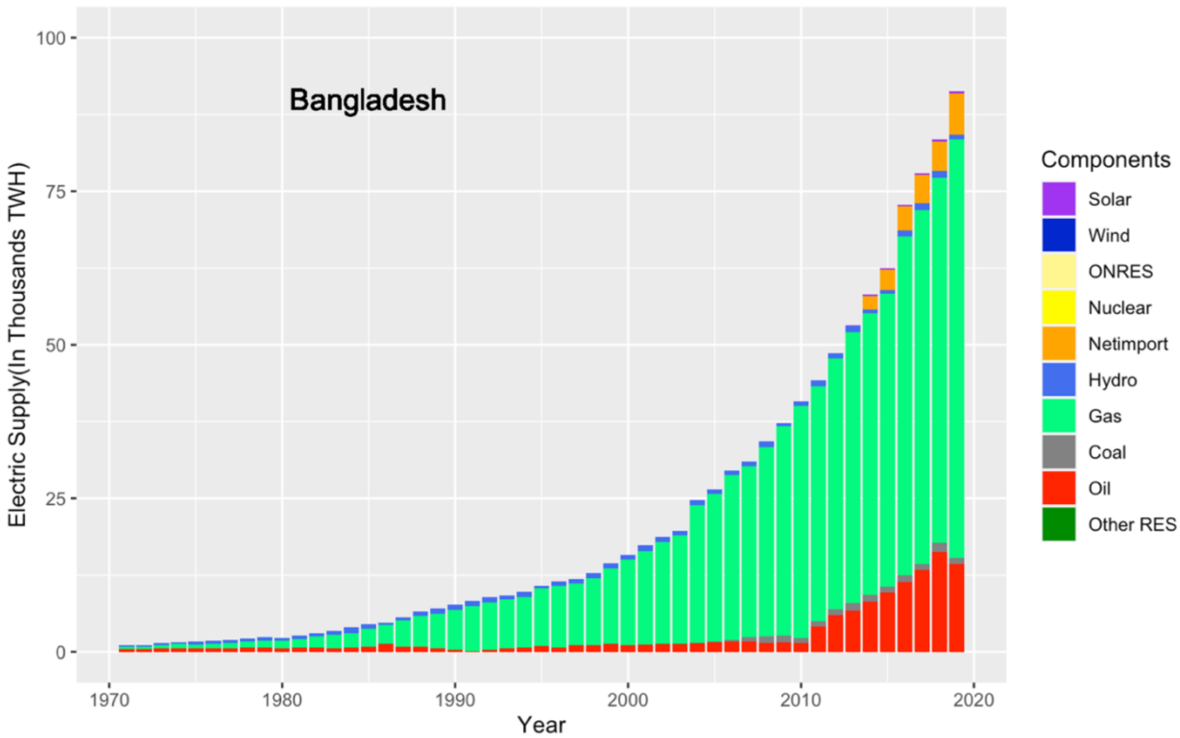
Source: IEA 2022

Figure 9-2 Electricity supply by fuel source in Vietnam



Source: IEA 2022

Figure 9-3 Electricity supply by fuel source in Bangladesh



Source: IEA 2022

9.2.1 History of oil use

During the 70's oil crisis Bangladesh's dependency on imported oil for electricity generation was very high. (51% in 1973 to 33% in 1980). The oil bill became 80% of the total import. International oil companies started to find oil from 1970s and by 1980s. In 1985 Bangladesh started oil production in a limited scale. Total reserve of oil in Bangladesh is less than a single year of oil consumption. The oil consumption of Bangladesh increased gradually from 1990s to 2000s. In the decade of 2010, the use of oil in electricity generation increased drastically as the private sector started to develop oil-based power plants for which the government gave high subsidy.

In Vietnam, imported oil was mostly used in bunker and transportation in the 1970s. In North Vietnam Petrovietnam started oil and gas exploration and production activities in 1961, mainly with the help of the Soviet Union. Before the reunification in 1976, multinational companies including Shell, Caltex, Texaco, Exon, Mobil Oil Corporation, Cities Service Company and Marathon Oil Company were present in South Vietnam. Vietnamese and Russian entity Vietsovpetro first started oil production in 1988. Since then Vietnam has started to export all of the crude oil until it has developed its own refinery that started operation in 2009. Throughout the decade of 1990s Vietnam's export of crude oil was a strategic policy to earn foreign exchange. 25% of the crude oil was exported to Japan in 1998. Oil export in Vietnam continued to grow until 2009, when the refinery was established. Vietnam started to consume its own oil after 2010 and gradually decreased oil export.

9.2.2 History of natural gas and LNG adoption in Bangladesh and Vietnam

After facing economic challenges from the oil crisis when nationalization of oil fields was a global trend, Bangladesh was one of those countries nationalizing and focusing on developing its own capacity too. Soviet Union provided assistance to Bangladesh to develop the national capacity particularly in gas sector. Since then, the World Bank actively tried to create investment environment for international oil companies in Bangladesh. Despite their strong interest Bangladesh's national company PetroBangla started to dig some prospective oil by themselves. By 1990s a gas regime was formed. IOCs interest grew more. In 1990s

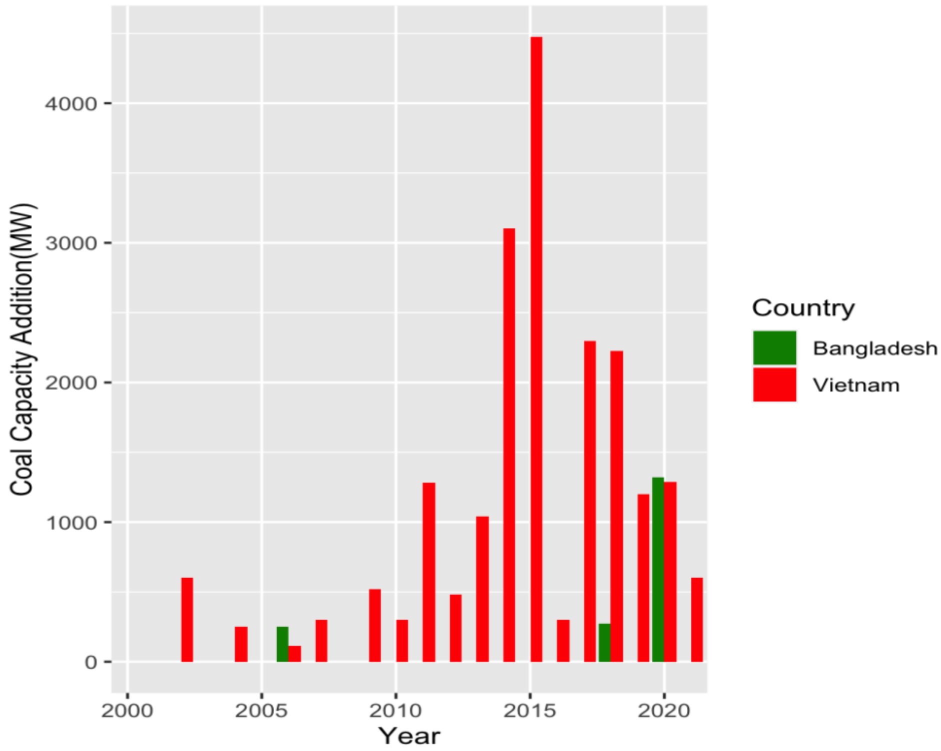
Bangladesh signed highest number of PSCS with oil companies to extract gas. Bangladesh reduced its dependency on oil and gradually increased its dependency on indigenous gas. By 2010 share of gas in electricity production was almost 90%. However, in the decade of 2010 and 2020 there was not much effort given to discovering new gas. To meet the growing need Bangladesh has started to look for other alternatives including importing LNG. From 2018 Bangladesh started to import LNG and its share is gradually increasing since then.

Vietnam's gas sector has a different timing of regime formation than Bangladesh. After Doi Moi reform in 1986 the share of gas increased to 23% from 7% before reform. For Vietnam, the decade of 2000 was the decade of formation of a gas regime. By the end of this decade contribution of gas in electricity generation increased from 23% to 48%. However, dependency on natural gas decreased in the decade of 2010 both in absolute term (7. 63 mtoe to 6.88 mtoe) and in percentage (48% - 19%). Vietnam has a plan to import LNG from 2025.

9.2.3 History of coal adoption in Bangladesh and Vietnam

Bangladesh has coal resources but since the potential fields are located in agriculture area there was strong protest from the local people against coal mining. With the coal available in the only active coal mine (Barapukuria) in Bangladesh can produce only 250 MW power. Bangladesh has started to build coal power plants in the decade of 2010 in joint venture with Chinese, Indian, and Japanese firms. The share of coal in electricity production has increased in last decade and it will increase more when the under-construction coal power plants will start operation in next 2-3 years. Before and during the Vietnam war, the electricity generation heavily relied on coal (93%). The share of coal started to decrease and became 33% in 1995. Coal capacity started to increase again in the decade of 2010. The contribution of coal in electricity generation increased to 61% by the end of 2018.

Figure 9-4 Coal Capacity Addition in Bangladesh and Vietnam



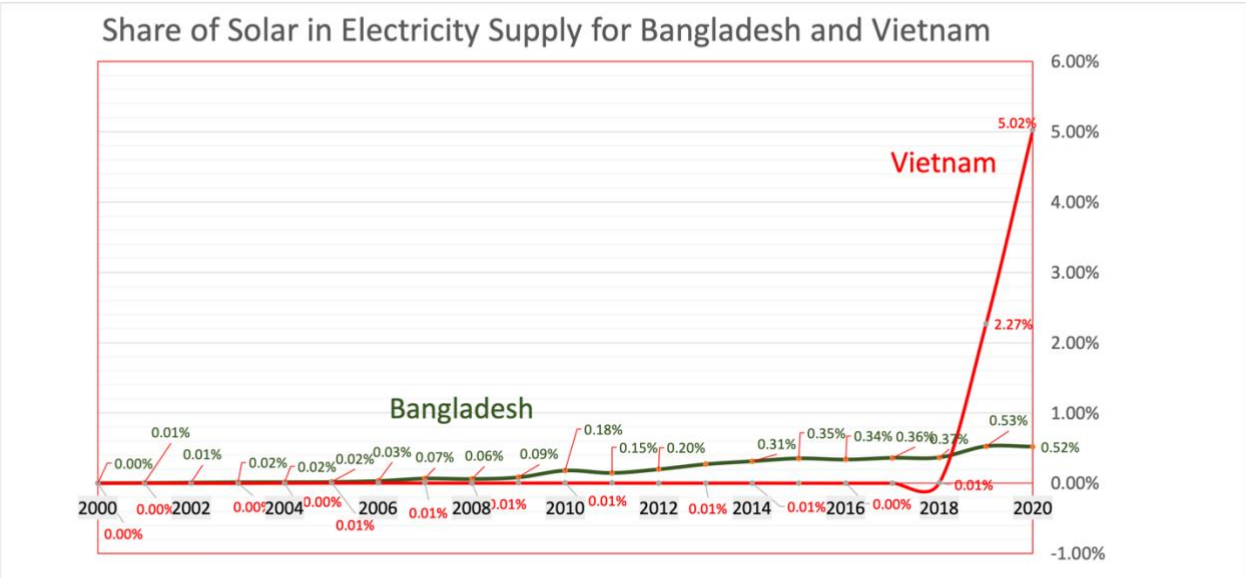
9.2.4 Hydropower use in Bangladesh and Vietnam

In Vietnam, the contribution of hydro in electricity production was about 7% in 1973. In the 4 years following the Doi Moi (1986-1990) reform, electricity generation from hydro increased from 7% to 27%. In 1990s the share became 42%. The contribution of hydro in electricity production gradually decreased and became 12% by the end of 2019. Bangladesh has one hydropower plant with a capacity of 230 MW. It was built in 1960s and is still operating. Currently Bangladesh does not have any specific plan to expand hydropower because of the potential social movement against it.

9.2.5 Solar adoption in Bangladesh and Vietnam

Both Bangladesh and Vietnam started installation of solar home system in the 1990s. It was expensive in the beginning and installations were limited to remote off-grid areas. As cost declined 80% in the last decade and more efficient on-grid technologies were developed, the adoption of both roof-top solar and utility scale solar developed differently in these two countries. The difference in the speed of growth became visible when after 2017 Vietnam experienced a solar boom and its share in total electricity supply became 5% by the end of 2020, while Bangladesh's share of solar in electricity supply remained well below 1%. This has raised question about difference in the speed of solar growth in these two countries. Bangladesh has the largest solar home system program in the world, with installation of about 6 million SHS. Since 2000 the growth of solar in Bangladesh was faster than Vietnam. In the beginning of the decade of 2010 when Vietnam's solar share was 0.01%, Bangladesh's share was 0.18%. Vietnam's solar share exceeded after 2018 and in just 2 years the share increased to 5%.

Figure 9-5 Share of Electricity Supply for Bangladesh and Vietnam



9.2.6 Nuclear adoption in Bangladesh and Vietnam

Bangladesh and Russia had a history of cooperation since the 1971 liberation war when West Pakistan was backed by the US to establish economic dominance over East Pakistan, currently Bangladesh. After independence Soviet Union provided technical support to Bangladesh for developing national capacity to explore indigenous gas. Vietnam also had strong economic ties with Soviet Union even before 1970s. Coal mines in Vietnam before 70s were built by Soviet Union. Before the collapse, Soviet Union was so involved with the Vietnamese energy sector that the country even made the energy master plan for Vietnam.

Soviet Union provided financial and technical assistance to coal mining, gas exploration, refinery development, and hydropower development.

For Russia, both Vietnam and Bangladesh are equally potential market for nuclear power expansion as both are going through a development phase that demands high energy for manufacturing sector growth. Rosatom, the state-owned company of Russia was moving forward with its objective to construct nuclear power in both countries from late 2000. In 2009, Vietnam government approved building two units of nuclear power unit, one with the support from Russia and one with Japan. In the same year Bangladesh Atomic Energy Cooperation signed an MOU with ROSATOM on peaceful use of nuclear energy. By March 2024, 80% of the construction has been completed. Because of delay in loan disbursement, construction of grid infrastructure, as well as Ukraine war, sanction of West against Russia the project has been delayed by two years, from 2024 to 2026. The delay will increase the cost further, making this a more challenging for Bangladesh to repay the loan. which is about two third of the external debt. Bangladesh's external debt GDP ratio has already become 42% because of the mega project.

9.3 Method

This research is a comparative case study using explaining outcome process tracing (PT). The objective of an explaining outcome PT is to find out an explanation for why an outcome has been produced in a specific case. (Beach and Pederson 2012). In many instances, a single theorized mechanism cannot sufficiently explain the outcome, and it needs other theories in order to achieve a "minimally sufficient explanation" as explained by Mackie in an article on causes and conditions published in 1965 in American Philosophical Quarterly. (Mackie 1965) This allows diversity, interdisciplinarity, and pragmatism in explanations, which is case centric, and not theory centric.

In explaining outcome PT, a selected case may not represent a set of similar countries having most similar characteristics. The selected cases can resemble extreme cases, or puzzling cases, or cases revealing complex and deviating outcomes that cannot be explained with single theory. Energy transition worldwide has always been complex and perplexing because of the variation of contexts in the countries, rapidly changing global relations, multi directional movement of technology actors, financial actors, and eclectic resource formation. A meta theoretical framework known as the three perspectives on national energy transitions (Cherp et al. 2018) attempted to encompass three different co-evolving systems integrating techno-economic, socio-technical, and political perspectives on energy transition. This research uses this metatheoretical framework to minimize the missing explanation of a puzzling outcome.

In this research the cases are similar with complex and unfolding deviating outcomes. Bangladesh and Vietnam, historically more integrated to Soviet bloc during cold war era, following similar neoliberal development path during post-cold war era, reforming electricity sector in response to crisis, depending on external technology and financial resources, are now two lower middle-income countries aspiring to become high income countries in the global north. The deviating energy outcomes of these two countries were discussed in section 1.2 in detail. The appendix (i) also provides detail information about the similarities and differences between the two countries.

The findings from the comparative case study cannot be generalized for all developing countries but at least it can provide explanations of causal mechanisms that may be commonly identified with different combinations in other developing countries having higher level of dependency on external technology and finances.

The aim of most of the PT studies is to explain a particular historical outcome, working backward from the known outcome to reveal the causal mechanisms that establishes sufficient explanation of the outcome. (Beach and Pederson 2012) In this research, outcome means energy transition using substantially two different technologies of two different scales, complexity, financing, duration, and sustainability implication.

9.4 Existing explanations in literature

There are several groups of explanations of the deviating outcomes in Bangladesh and Vietnam but they're all unsatisfactory on some level. This section reveals some existing explanation and discusses why no theory alone can explain the outcome and why three perspective frameworks can help establish sufficient explanation of the puzzle.

9.4.1 Technology diffusion

According to Grübler (2016) technology diffuses faster in the periphery than it does in the core. "Diffusion in innovating core markets takes considerably longer than in later adopting markets that benefit from learning externalities like "spillovers" of knowledge and improved, cheaper technologies developed and tested in core markets."(Grübler 2016, p. 20) In periphery like Vietnam and Bangladesh, the speed of growth of solar are substantially different. The existing explanation of periphery's faster growth is not sufficient to explain why despite being technology receiving countries one country's solar grow faster than the other. Faced with similar financial resource and capacity constraints for diffusion of nuclear, why Bangladesh opted for nuclear and Vietnam cancelled it remained a puzzle to be explored.

9.4.2 Cost decline

The unprecedented growth of 35% for solar PV over the period 1996–2019, has been largely explained by the consequent 80% decline in cost in ten years. According to IRENA renewable power generation is becoming the default economic choice for new capacity. (IRENA, 2020) The existing explanation also recognizes that "the combination of targeted policy support and industry drive has seen renewable electricity from solar and wind power go from an expensive niche, to head-to-head competition with fossil fuels for new capacity. (IRENA, 2020, P. 14) Besides, Fouquet (2016) argued that the price of energy services played a crucial role in creating the incentives to stimulate energy transitions. However, this explanation cannot fully explain why and how despite global declining cost of solar some countries targeted policies and industry drive could grow solar deployment in one country and could not grow in other countries.

9.4.3 Technology characteristic

For faster clean energy transition nuclear power (lumpy) is often considered as a substitute of solar (granular). Wilson et al (2020) suggested number of potential advantages of more-granular energy technologies for accelerating progress toward climate targets and the conditions on which such progress depends. However, in Wilson's paper (2020) on granular versus lumpy technology, Wilson considered nuclear as an outlier when impact of granularity and lumpiness on speed of diffusion was studied. According to Sovacool "It is well recognized that a grid structure optimized for larger scale centralized power production (like much conventional nuclear power) will tend on balance to make it more difficult, time-consuming and costly to introduce small-scale distributed power (like many renewables). The same is true of the associated norms, protocols, contracts, and operating codes and expert cultures necessary to make these structures work." (Sovacool et al 2020). The technology characteristic explanation does not explain why a country like Bangladesh adopted a lumpy technology like nuclear despite being aware about the complexity of technology, high expense, and risks. Why and when advantages are subjective and who are ideologically maneuvering the public perceptions and the decision making remain largely ignored in the existing literature.

9.4.4 Configuration of global innovation system on diffusion

According to Binz and Truffer (2017) not all technologies diffuse in the same way. There are four GIS configurations based on varying valuation (standardized versus customized) and innovation system (Science and Technology innovation (STI) versus Doing, Using, and Interaction based innovation (DUI)). According to the innovation-valuation framework nuclear falls in the market anchored GIS (customized and STI mode) and PV falls in the footloose GIS (Standardized and STI mode). According to Binz et al (2017) policy interventions in footloose GIS types, because of their global innovation and valuation subsytems, strong spatial spillover of knowledge, could apply a 'free trade zone'-type policy rationale. For example, supports like tax credits, low interest loans, liberal trade policies and the creation of local centers of excellence in R & D may incentivize local firms to succeed in the fierce international price and technology competition. (p.1295) Despite having strong spillover of knowledge, and global character in its innovation and valuation, solar PV did not equally diffuse in Bangladesh and Vietnam. The case of Bangladesh and Vietnam cannot be fully explained by the footloose global innovation system framework.

According to Sovacool et al (2020) two of the most widely emphasized contenders for carbon emissions reduction in the electricity sector are nuclear power and renewable energy. "Larger-scale national nuclear attachments do not tend to associate with significantly lower carbon emissions while renewables do. There is a negative association between the scales of national nuclear and renewables attachments. This suggests nuclear and renewables attachments tend to crowd each other out." Jin & Kim (2018) performed the long-run cointegrating vector and Granger causality tests and found that nuclear energy does not contribute to carbon reduction unlike renewable energy. Thus, the development and expansion of renewable, not nuclear, energy are essential to prevent global warming. Using a different method, Fell et al (2020) argued that both renewable energy and nuclear power are associated with national decarbonization. (Sovacool et al 2020) There are also scientific studies on emission reduction impact of nuclear and renewables. In 2018 Jin & Kim (2018) found "The results of the long-run cointegrating vector and Granger causality tests indicate that nuclear energy does not contribute to carbon reduction unlike renewable energy. Thus, the development and expansion of renewable, not nuclear, energy are essential to prevent global warming." (Jin & Kim, 2018, p.464)

These literatures are quantitative evidence based and are largely contentious because they ignore the qualitative explanations of past adoption of different technologies by different countries. These explanations ignore the historical context in which nuclear expanded in the developed economies with higher technology capacity. They also did not take into account the existing different context in developing countries because of their dependency on external technology, finance, and institutional resources. The "crowding out between renewable and nuclear" which is simplistically explained by "investing in one technology suppressing the other" is not a straight forward tendency as explained by Sovacool et al. These literatures ignore the combination of techno-economic, socio-technical, and political mechanisms through which a country adopt nuclear or renewable technology.

9.4.5 State action: securing supply-demand balance

Based on the expert interviews, Do et al (2021) found that the government's commitment to energy availability was the most important motivation for Vietnam's solar and wind policies. This is consistent with a previous finding of Dang and La (2019) where they showed that Prime Minister's consistent message has been to not let electricity shortages happen given the importance of electricity to socioeconomic development (Dang & La, 2019). Besides, for the communist government of Vietnam historically electricity supply infrastructure was an area where a number of important political economy dynamics were being played out, between considerations of the delivery of public goods, ideological commitment and vested interest.[1]

After the solar boom in Vietnam from 2019 to 2020, in early 2022 Vietnam has decided not to make significant addition to solar capacity due to a lack of infrastructural facilities to transmit the electricity to the national grid. (Le 2022) It indicates that solar is no longer an option to meet the demand-supply balance for Vietnam.

According to the official estimate 99% of the population has access to electricity. It was only 32% 22 years ago, in 2000. The government had a target to achievement high access to electricity. However, it does not mean that the increase in installed capacity could ensure uninterrupted supply of electricity for all. Although power generation capacity became 25,514 megawatts in 2022, the maximum power production rose to 13,792 MW. Bangladesh had a maximum 53.8% capacity utilization in fiscal year 2021-2022. (BPDB 2022) The interruptions are mainly caused by the under capacity of age-old power infrastructure to carry the load needed to meet the current demand.

Although according to the existing explanations both governments show the need to secure supply-demand balance as one of the main drivers of solar and nuclear, the explanations are not sufficient because Bangladesh already has overcapacity and Vietnam is trying to slow down solar expansion.

9.4.6 Climate policy diffusion

Both in Bangladesh and Vietnam there are perceptions that climate considerations rank high among the drivers of adoption of both nuclear and solar. (Do et al 2021, Md.V Anam eta al

2022) Do et al found that one of the drivers of solar was the government's commitment to international climate change treaties. As a result of international policy diffusion, in 2020, Vietnam targeted to adjust its nationally determined contribution (NDC) by reducing greenhouse gas emissions from the energy sector by 5.5% (unconditional) and 11.2% (conditional) below business as usual, (GoV, 2020). However, in both countries there are contradictory policy actions observed. For example, although in June 2021 Bangladesh's State Minister for Power, Energy and Mineral Resources informed that the government has decided to produce 40% of the electricity from renewable energy in the future. This oral declaration did not confirm any year by which the target could be achieved. Besides, although the Minister mentioned solar as the most important potential energy resources, the declared target did not clarify the share of solar by 2041. The revisited PSMP 2018 set a target to increase share of coal in electricity generation to be 32%, there is no clear indication about growth of solar. (GOB 2018). Similarly, the September 2021 draft of the PDP8 policy in Vietnam proposes to increase coal-fired power capacity by 3 GW by 2030, seeing a further 10 GW installed by 2035. If implemented this plan will sacrifice 8 GW of renewables for coal. (Energy Tracker Asia 2022) The existing explanation is not consistent with the future climate target and therefore requires further analysis.

9.4.7 Economic incentives

Feed in tariff was one of the very important techno-economic incentives found in the study of Do et al (2021). Besides, there are a number of literatures on economic incentives of solar and wind development policies. Some of the previously identified economic incentives are feed-in tariffs (FITs), tax exemptions, and investment subsidies in the initial stages of solar and wind power development (Bechberger & Reiche, 2004; Kilinc-Ata, 2016; Best & Burke, 2018; Thapar, Sharma, & Verma, 2018; Burke et al., 2019; Do, Burke, Baldwin, & Nguyen, 2020) In case of Vietnam, Lee et al. (2019) estimated that the average levelised cost of electricity (LCOE) for solar PV in Vietnam – when excluding protected areas, water bodies, forested areas, agricultural areas, urban areas, and areas with a slope greater than 5% – was around US$0.875/kwh in 2018. Using an annual reduction rate of 13% (International Renewable Energy Agency, 2019), these LCOEs would roughly be about US$0.76/kwh in 2019 and US$0.66 in 2020. Therefore, the FITs of US$0.935/kwh before June 2019 and

US$0.70–0.83 per kwh thereafter have been attractive to project developers, especially given that they have focused on the best available sites in the southern part of the country. Gallagher estimated that solar was $0.12/kwh and coal was 6–8c/kWh in 2020. (Gallagher, 2021) In another study (NK Das et al 20) the LCOE of solar PV ranges from $0.35 to $0.92 in 2020. The net metering guideline considers the net metering system in solar system as a potential driver of solar. The logic put forward by the net metering guideline is "the rising cost of power and decreasing cost of solar technology are excellent incentives for net-metering." (SREDA 2018) However, since the 2018 when net metering policy was rolled out, there has not been significant response from the potential investors. It questions the efficacy of such economic incentive.

The existing explanation that economic incentives like net metering and feed in tariff can incentivize solar is not a sufficient explanation to understand why solar growth was rapid in Vietnam and slower in Bangladesh.

9.4.8 Public demand for reducing environmental pollution

In the study of Do et al (2020) public demand for clean air was identified by the interviewees as the second-most important driver. They pointed out that advanced monitoring technologies have helped to facilitate growing public awareness about air pollution, as one can now easily check air pollution levels in real-time using widely available smart phone applications. Civil society has also played a growing role in voicing concerns about worsening air pollution. This has contributed to rising resistance to new coal power projects, particularly at the provincial level (Do et al., 2020). While the fossil fuel industry remains powerful (Dorband, Jakob, & Steckel, 2020), its influence has begun to wane because of public concerns about its negative environmental and health impacts and the government's anti-corruption campaigns targeting the industry (Do et al., 2020).

Bangladesh has a public demand for pollution reduction. There were past resistances against coal mining, and building of coal-fired power plant in agricultural land (Bashkhali coal power plant) and ecologically critical area (Rampal power plant near the largest mangrove forest). In case of Bangladesh there is no evidence of public demand for nuclear power. Although a section of the government believes that nuclear power generation has become more environment friendly compared to generating electricity from fossil fuels, there is a negative public perception related to the safety of the nuclear materials. (Karim et al, 2018)

The logic of public demand for pollution reduction is not equally applicable in Bangladesh and Vietnam. This requires an extensive analysis of combination of other mechanisms that can explain the deviating energy outcome.

9.4.9 Summary of the gaps in existing explanations

Table 9-1 Summary of the gaps in existing explanations

1	Technology Diffusion	Technology diffusion theory alone cannot explain why ready-to-diffuse technologies grow faster in one periphery country and grow slower in another periphery country. (i.e. Nuclear in Bangladesh, Solar in Vietnam)
2.	Techno-economic Perspective	The studies of techno-economic factors cannot alone explain the puzzle of deviation of energy technology outcome in Vietnam and Bangladesh.
3.	Technology Characteristics	The studies on technology characteristics (Wilson et al.) considered nuclear as an outlier when advantages of granular and lumpy technologies were compared. The centrality of actors involved in technology diffusion and context specific power dynamics in international cooperation are not focused.
4.	Global Innovation System Framework	The innovation-valuation framework does not recognize the speed of technology change on diffusion. This framework puts science and technology innovation in one end of spectrum and doing, using, and interacting in the other end. Science and technological innovation have impact on efficiency improvement, cost decline, and risk. Therefore, the speed at which technological innovation takes place also affects diffusion pattern. This pattern is not reflected only in variation in valuation (customized vs. standardized). Spatial stickiness also results from the difficulty in replacement of older technology by the new one. Innovation-valuation framework does not address the conditions of transition to new technology, rather it focuses only on the GIS configuration and its implication to the governance of institution in a dynamically evolving GIS.
5.	Decarbonization Investment	The “crowding out between renewable and nuclear” which is simplistically explained by “investing in one technology suppressing the other” is not a straight forward tendency as explained by the researchers driven by the assumptions that climate considerations could potentially affect the future decisions of choosing one technology over the other.
6.	State Action	State action to secure demand-supply, mitigate climate, and incentivize solar deployment through economic incentive cannot sufficiently explain why the outcome is different in Bangladesh and Vietnam.
7.	Public Interest	The logic of public demand to reduce pollution creates a puzzle when Vietnam’s solar boom is explained by public demand whereas Bangladesh’s nuclear adoption is clearly not associated with public demand for pollution reduction.

9.5 Energy transition mechanisms and observations from cases

The following chart shows the observations based on process tracing and illustrate how observations obtained from process tracing can be categorized under ten main transition mechanisms.

Table 9-2 Energy transition mechanisms

	Mechanisms	Observations
M1	Demand supply balance	Securing demand supply balance
M2	Public Interest	Demand for clean energy and environment, Public demand for protecting national interest in limiting the use of indigenous resources within the country and reducing import dependency
M3	Rent seeking	Rent seeking interest of incumbent energy suppliers (gas, coal) Rent seeking interest of niche energy suppliers (nuclear, solar, LNG)
M4	Technology Diffusion	National, regional, and global spillover of knowledge. Capacity building. Ease of diffusion based on technology characteristics National, regional, global innovation system
M5	Policy diffusion	Climate policy diffusion, Neoliberal idea of electricity liberalization Formation of institutions and evolution of actors in the process of globalization
M6	Political Mechanism	State apparatus influencing the idea of development Energy security – availability, affordability, and sustainability State action in crisis Government business nexus Strategic cooperation with international actors Economic incentive and other supporting policies for political gain Regulatory policy to facilitate selected interest groups and strengthen political position Empowering and disempowering evolving actors in the process of marketization
M7	State support to incumbent energy regime	In the period of transition when state support already established regime
M8	State support to emerging niche	In the period of transition when state support niche
M9	International actors' strategic interests	International actors cooperate with state to support key energy sector to secure supply and demand
M10	Sociotechnical dynamics within the niche	Character of innovation network, Financial risk sharing among actors within the niche – nuclear, solar. Regional advantage in innovation system

9.6 Historical energy transition in Bangladesh and Vietnam

The following table summarizes the mechanisms of historical electricity transition in Bangladesh and Vietnam. To get sufficient explanation of the puzzling outcome this research goes backward to find out the causal mechanisms that shaped the context in which different combination of mechanisms led to different outcome in Bangladesh and Vietnam.

Table 9-3 Historical energy transition of Bangladesh and Vietnam

	Mechanisms **Bangladesh**	Outcome **Bangladesh**	Mechanisms **Vietnam**	Outcome **Vietnam**
1970s	**M1:** Nationalization of oil companies. **M5:** International Oil Companies were present to explore oil **M4:** Diffusion of gas technology **M9:** Assistance from USSR for gas technology capacity development.	High oil dependency throughout the decade. No domestic oil production Gas use increased	**M1:** Nationalization of oil companies. **M5:** International Oil Companies were present to explore oil **M4:** Diffusion of hydro technology from USSR **M9:** Assistance from USSR	Coal regime was formed before 1970s. No oil production in the 1970s. Start oil Importing by the end of 1980s.
1980s	**M1:** To ensure energy security gas dependency increased. **M5:** Gradually embracing market policies **M8:** State support to emerging niche, gas sector. **M7:** State Support to incumbent gas.	Dependency on domestic gas resources increased further. Gas sector capacity development. Institution and human resource development.	**M1:** domestic gas production started. **M5:** Gradually embracing market policies. **M8:** State support to emerging niche: gas sector. **M7:** State support to incumbent - coal.	After Doi Moi reform, more hydropower into the energy system. Coal lobby getting stronger.
1990s	**M5:** Market led electricity liberalization initiated **M5:** IOCs signed highest number of PSCs in this decade. **M6:** State action in response to crisis was to liberalize faster. Private actors were encouraged to participate in power generation.	Private power plants (IPP) came into operation. The share of private power generation increased faster. Rent seekers gradually ascending higher in the hierarchy of power.	**M7, M8:** Support to both incumbent (coal) and niche(gas). **M6:** State action in response to crisis was to liberalize slowly. **M5:** State controlled electricity liberalization **M4:** Growth of hydropower in this decade symbolizes communist legacy of national capacity development and	High voltage grid connecting North and South allowed surplus of North to reach South. Dependency on hydro increased to 42% Share of coal decreased but coal use increased 4 times.

	M9: Production Sharing Contract (PSC) signed with IOCs to explore gas. M3: Rent seeking interests and opportunities increased with more international investments.	Gas regime formed	dependency on domestic resources. M3: Incentives to immediate rent seeking reduced and long-term benefits got prioritized with more international investments.	The state continued to control IPPs and private entities. The rise of the state-owned conglomerates playing greater role in influencing policy decisions
2000s	M2: Public interest against gas export. Public interest against environmental pollution and local livelihood. M9: Government supported IOCs' operation to ensure supply of gas, neglecting national gas exploration capacity. M5: Influenced by international climate mitigation policies national renewable energy policy, Climate change strategy and action plan were developed. M6: Government supported private sectors heavily.	Gas export was stopped. Open pit coal mining was postponed. IOCs share in gas production became 50%. Electricity price raised to subsidize private sectors.	M9: Gas regime was formed with state playing key role in regime formation. M6: Government showed establishment of refinery in 2009 as a legacy of communism and an achievement towards ensuring energy security. State led the marketization policy in energy sector.	By the end of this decade contribution of gas in electricity generation increased from 23% to 48%. Oil import started to decrease after refinery came into operation. Greater state control balanced public demand and rent seeking interests.
2010	M3: State apparatus influencing the idea of development in favor of rent seeking. Nuclear, LNG, coal adoption got momentum. M9: Implementation of JICA developed Master plan that increases coal dependency in the future. M6: Strategic decision on nuclear, Speedy power supply act 2010 M7: State support to oil-based electricity production.	Nuclear project neglecting public interest. The share of private power generation reached 50%. Oil and LNG import increased. State subsidy to oil based quick rental projects to quickly meet electricity demand.	M2: Public interest against pollution has driven solar. M3: Rent seeking in coal worked against nuclear. M6: Economic incentive and other supporting policies for solar. M8: State support to emerging solar. M8: State support to emerging niche, LNG, Solar. M10: Financial risk burden taken by the government.	Fastest growth of solar (2019-2020) Nuclear project was cancelled. Construction of LNG terminal started. Under construction coal project continued. Coal import increased fast in the second half of 2010s.

	M8: State support to emerging LNG, nuclear, and coal. **M8:** No sufficient state support to solar. **M10:** Financial risk burden heavy on solar investors. Financial risk burden heavy on government revenue and people.	Coal plant construction continued despite strong public resistance. Slow growth of solar. Financial risk burden of nuclear on public.		
2021-2024	**M5:** Influenced by international policy to not build new coal-based power plants. **M8:** State support to LNG, coal, and nuclear continued. Solar is left to the market to grow.	Declaration to not build new coal power plants. Under construction coal projects continued. LNG dependency increased. No significant growth is solar.	**M5:** Influenced by international policy to not build new coal-based power plants. **M8:** State support to LNG expansion. Solar, and wind receive moderate support.	Declaration to not build new coal power plants. Under construction coal projects continued. Solar growth stalled. LNG import will start in 2025.

9.7 Discussion

9.7.1 Why solar growth is faster in Vietnam than in Bangladesh?

9.7.1.1 Policy design

Before 2018, the growth of off-grid solar in Bangladesh was faster than that of Vietnam. As Vietnam government instituted policies to offer lucrative feed in tariff to overcome the barrier of high capital cost of on-grid solar, in two years Vietnam's solar grew so fast that by the end of 2020 the installed capacity of solar increased to 24% of the total supply. However, after the FIT expired the growth of solar in Vietnam stalled. On the other hand, Bangladesh with market rate based net metering system did not have a high growth of solar because of the limitations in the policy design. For example, underestimation of risk, lack of special income tax waiver for solar investors, and no land lease payment exemptions. When technology changes fast enough causing cost to decline rapidly, investment becomes more lucrative in the future than present. In the absence of any time bound economic incentive to invest the solar developers did not respond to the benefit offered by net metering. Uncertainties in the cost of solar equipment, high risk, and alternative investment options did not attract the investors.

9.7.1.2 Presence of actors

The communist government state led marketization policy in Vietnam has historically created a group of conglomerates and local entrepreneurs working closely with the government. These actors facilitated the implementation of the projects undertaken by expediting the process of project development by the international developers. The Foreign investors expanded their investments in the Vietnamese solar power sector via mergers and acquisitions deals or by establishing joint ventures with local players in order to save time as the FIT deadline expired in 2019 and 2020. These local actors also used their ability to access credit from local banks to facilitate financing to new solar projects. On the other hand, although in Bangladesh the government business nexus has become stronger in last two decades, the private sector's participation has become limited in lucrative fossil fuel-based electricity supply projects. These private actors could not mobilize the government to subsidize solar development, neither could they develop a strong independent position to advocate for clean energy. Rather, they are more prone to take advantage of the liberalized electricity system by benefitting from the subsidized rental and quick rental fossil fuel-based electricity generation.

In Vietnam, an economic crisis led to international trade integration and internal decentralization, which created pluralistic interest group competition. This contestation helps Vietnam's key interest groups align their interests, so all players are better off collaborating than defying the new power structure. Competition for capital and labor globally and in the new quasi-federalist domestic realm encourages players to decrease rent seeking for long-term gains. (Jandl 2011) In contrast to Vietnam, in Bangladesh, rent seeking became embedded in the institutions with elite groups ascending in the top hierarchy, from where the rent seekers became resistant to any reform that brings them down in the hierarchy. Thus, in Bangladesh the actors have incentives of immediate rent seeking at the cost of long-term benefits.

9.7.1.3 Support of interest groups

Both Bangladesh and Vietnam have strong interest groups demanding clean energy development and carbon neutral investments. In Vietnam, this public demand was taken seriously at the policy level because of Vietnam's direct historical experience of using coal, depleting indigenous coal resources, and growing dependency on imported coal. Whereas, Bangladesh did not have a direct experience of using huge coal resources in electricity generation. When the under-construction coal power projects were opposed by various interest groups, the government responded by developing ultra-critical coal-based power plants rather than investing more in on-grid solar technology. Besides, although having negligible contribution in electricity supply, Bangladesh used its world's largest solar home system project as an example of solar development.

9.7.1.4 Regional innovation system

In the ASEAN region, China and Thailand had similar FIT that drove their solar deployment. The learning, experience, and resources were already formed in the region waiting to be exploited. The solar technology along with the learnings of the developers and investors was readily transferrable in the region having similar FIT experience. As soon as the FIT was announced in Vietnam, Investors immediately took the opportunity to move to the new market. When China and Vietnam let similar FITs expire, Vietnam acted in a timely manner to attract the solar investors to the country by offering a lucrative feed-in tariff (FITs). Geographical proximity to China gave Vietnam additional advantages to make panels and cells available for solar growth. Vietnam has solar manufacturing (99% imported and assembled from China) To avoid trade barriers (antidumping/countervailing duties) imposed by the US, China moved the end of the production process (that requires minor processing) for crystalline silicon solar products. Vietnam can get cost advantage of the subsidized supply chain and labor in China and low cost of assembling in Vietnam. Although there is no strong evidence that the solar boom in Vietnam is directly linked to its manufacturing capacity, but it can be said that the regional innovation system had substantially contributed to developing an innovation network, that has more of a regional character than a global one. On the other hand, Bangladesh being located in South Asia has a closer neighbor India, a country that also experienced solar growth. However, India's solar growth drivers are different from that of China and Thailand. India did not have any spillover effect of its knowledge regionally to attract investors and minimize risks. India's policy focused more on government support in infrastructure development that drove down the cost, minimized risk through direct and indirect subsidies in certain regions. India had high political motivation to develop solar in certain region. Regional advantages clearly differentiated the case of Bangladesh from Vietnam.

9.7.2 Why nuclear power plant was cancelled in Vietnam and adopted in Bangladesh?

9.7.2.1 NPP's contribution to the electricity supply

In 2009, when the plan of nuclear power plant was adopted in both Bangladesh and Vietnam, Vietnam's annual power demand growth was estimated to be 17-20 percent, and Bangladesh's demand was estimated to be 10%. It was assumed that the capacity of the Rooppur nuclear power plant would be approximately 7% of the installed capacity (34000 MW) in 2024 when the projects would start operation. For Vietnam the planned nuclear power capacity (4000 MW) was supposed to be 3.25% of the total supply (123 GW) by 2030. This shows that the planned NPP's contribution in electricity supply was lower in Vietnam than that of Bangladesh. Although demand was rising faster in Vietnam than in Bangladesh, NPP's contribution to total electricity supply in Bangladesh indicates Bangladesh's greater motivation to meet electricity demand by nuclear. When Vietnam cancelled its nuclear power plant in 2016, Vietnam's annual forecasted growth of electricity between 2016 and 2020 was 11 percent, and 7-8 percent through 2030.

9.7.2.2 Cost escalation

The government of Vietnam cancelled the nuclear power project because of the cost escalation since the planning stage. In 2009 estimated cost was 9 billion-dollar, and in 2016 cost was estimated to be $19-27 billion. In Bangladesh, initially the estimated cost was $4 billion, in 2015 the estimate became $12.5 billion and in 2020 the cost escalated to $13.65 dollars. Across countries, it is a commonly observed phenomenon that construction cost escalates during construction. Without finishing the project, most of the time it is difficult to predict the total cost. It shows that although cost increased in both countries Bangladesh didn't change its decision where Vietnam did.

9.7.2.3 Lack of foreign reserve

When Vietnam cancelled the plan to build nuclear power plant in 2016, beside high expense, the other commonly identified reasons were Vietnam's shortage of revenue to undertake a costly project, already existing high public debt GDP ratio (65% in 2016), high percentage of external debt (47.1%), not enough capacity to ensure safety and security issues, insufficient human resources, and insufficient grid infrastructure. The same reasons were also valid for a country like Bangladesh. Bangladesh's public debt is around 39% of the GDP, external debt increased from 22% in 2017 to 42% in 2022, and the nuclear power plant cost was about two third of the external debt.

9.7.2.4 Governance index and capacity

Bangladesh ranks lower in governance index compared to Vietnam. The technology capacity and human resources were not developed at the time NPP was undertaken by Bangladesh and cancelled in Vietnam. Bangladesh's peak generation is now around 13,000 MW. By the time the nuclear plant will start operation the nuclear power share in total electricity supply could be around 18%, although share of installed capacity is estimated to be 7%. Bangladesh's electricity distribution is already suffering from age old grid network. All the disadvantages Vietnam government recognized for cancelling nuclear power plant are equally applicable for Bangladesh. Still, Bangladesh decided to continue with the construction of the project.

9.7.2.5 Public acceptance

Vietnam government has always pointed out that public acceptance of the nuclear power plant is very important. However, although there were sporadic public opposition, the government officials used to share a common sentiment that it enjoys substantive public support and acceptance. (Ogilvie-White2 014) A very similar situation has also been observed in case of Bangladesh. Initially when local people were concerned about the risk and were ready to protest, the local government intimidated the anti-nuclear activists by threatening and stopped human chain against nuclear power plant. Besides, the experts, civil society, and expatriate nuclear experts also opposed the nuclear power plant but the government officials largely ignored the opposing views and claimed that there is public support for it. While propagating public acceptance is there, the government ran massive campaign to gain the public acceptance. The government developed nuclear information center to provide biased information, organized educational bus tours, produced video contents, and distributed leaflets containing partial information about safety, risk, and nuclear waste. This shows that although public support is often considered as a reason behind the decision of nuclear adoption, in reality the so-called public acceptance in Bangladesh was manufactured by the state using educational tools, controlling media, ignoring opposing views, subjectively designing surveys, selecting biased sample for evaluating public acceptance and disseminating partially true information.

9.7.2.6 Regional geopolitical context

Russia had a policy to expand its economic relationship in the South Asia region through nuclear cooperation. Russia has particular strategic interest in developing energy relationships with India and Bangladesh in South Asia region. Pakistan has a history of building nuclear power plant with the support of China. Having a long-standing nuclear cooperation relationship with India, Russia has always been keen on developing nuclear cooperation with the neighboring countries. Bangladesh was a suitable country as its demand for energy has been rapidly growing and the neighboring countries in the region have nuclear power. For Bangladesh, energy relationship with Russia is a strategic step. Bangladesh had already committed with China, Japan, and India to build coal power plant. Bangladesh received technical assistance from the USA to build LNG terminal. Russia's special sector for energy relationship has been nuclear recently. Therefore, for a small country like Bangladesh to have a balanced energy relationship, Bangladesh made a strategic decision to build cooperation relationship with Russia.

Vietnam had a longstanding energy relationship even before collapse of Soviet Union. Abandonment of the nuclear power plant projects did not obstruct bilateral cooperation with Russia. First, the Russian Federation signed an agreement with Russia for constructing Nuclear Science and Technology Center. Second, Russia is now the third largest coal supplier to Vietnam, after Indonesia and Australia. Vietnam import 2 or 3 million tons of coal every year to meet the domestic demand. "It is anticipated that Vietnam still remains a client of Russian's coal companies in future. Additionally, Russian mining-technology companies find opportunities of cooperation with Vietnam's National Industries Group (Vinacomin) in provision of technology packages for improving efficiency and effectiveness of the Vietnam's coal industry which is now under tense competitive pressures." (Jour 2018 P. 16)

When Vietnam government cancelled the nuclear power plant, the government also declared that its future electricity would come from coal and renewables, the cheaper sources for Vietnam to keep the price low without spending government revenue and increasing external debt, indicating Vietnam's strategic position coal growth and nuclear cancellation. , it is important to note that Vietnam's neighbors in the Asean region also have previous record of cancelling nuclear power plants. ASEAN neighboring member states like Thailand, Philippines, Indonesia and Malaysia have the experience of operating nuclear research reactors. But after the Fukushima nuclear power accident in 2011, most of the ASEAN states who have previously expressed their ambitious nuclear plans decided to reevaluate their decision to build nuclear power.

9.7.2.7 Political value

The popular notion that nuclear power is a symbol of advanced economy, drives Bangladesh to launch nuclear program. Most people in the developed countries gladly accept the fruits of technological advances, and people in less prosperous countries aspire to catch up. (Bodansky, 2004) Often, developing countries perceive having nuclear power more as a status symbolizing advanced economy than as a source of energy. For example, on the day the construction began the Prime Minister addressed to the nation, "Bangladesh enters the world of nuclear energy with the beginning of the construction work of the main structure. It's a pride and joy for us as a nation." And the Minister of Science and Technology said, "we have stepped in the nuclear age". Nuclear project is one kind of prestige project for Bangladesh. Bangladesh aspires to emerge as a middle-income country by 2021, and a developed country by 2041. Any visible development that can be associated with the progress towards being advanced economy gives the government a sense of achievement in its political term. Thus, a nuclear power plant has a lucrative political value, achievement of which works as a motivation for launching nuclear program. Current government also sees new membership to nuclear club as a new national identity which is prestigious to the international community.

In case of Vietnam, nuclear project does not add additional political gain to the communist government, when it has a very well-defined communist legacy in the past while developing its hydro regime with the technical assistance of Russia. Besides, there is already a well-established coal regime in Vietnam. The communist government of Vietnam has always used mega projects like hydropower, oil refinery as symbol of self-reliance and national identity that rely on indigenous resources and increases national capacity. They associated those developments with the communist legacy in the past. The marginal impact of nuclear power to the already built image is low when there is strong opposition among various interest groups against NPP.

9.8 Conclusion

The contribution speaks to the under-researched question of energy transitions in the global south and on the technological periphery. Although Vietnam and Bangladesh faced similar challenges, relied on domestic energy in the past, and had similar energy strategies until recently, they have radically diverged since 2010. The regional context and the role of international actors in shaping their energy transitions largely explain this divergence.

Developing and emerging countries are often expected to leapfrog to adopt clean energy before capacity is developed. Bangladesh lacked the technical capacity, economic capacity, regulatory capacity, and institutional capacity to be able to adopt nuclear when it started construction of the NPP in 2017. Vietnam's grid infrastructure was not well developed to support the fast growth of solar. Neither is Vietnam ready to continue the feed-in tariff scheme to subsidize solar to maintain consistent growth. Despite having insufficient capacity in both countries, both countries were expected to leapfrog to meet the climate goal.

The findings indicate that the divergence between the energy paths of the two countries is not the result of intentional crowding out driven solely by the state but rather a combination of causal mechanisms in which external actors played important roles. Vietnam attracted solar investors to the country by offering a lucrative feed-in tariff (FIT) after China and Thailand had let similar FITs expire. The FIT success in Vietnam followed the Communist government's state-led marketization. In contrast, Bangladesh, which supplies 50% of its electricity from the private sector and has a market-oriented economy, failed to reap the benefits of the market-led net-metering policy, despite demonstrating its ability to implement the largest off-grid solar power program globally. This is because it lacked infrastructural support and incentives for regional solar investors and, as of yet, could not transfer the long experience of installing off-grid solar technologies to on-grid technologies. Rather, the early negative experiences led to low trust in society in terms of adopting solar. This negative experience served as a demotivating factor even when the cost of solar declined significantly.

Part of the explanation for the divergence in nuclear adoption stems from unique relationships with international actors. Bangladesh adopted a highly expensive NPP, not because of its economic advantages but because of strategic cooperation between the government of Bangladesh and Russia, its aspiration to be a nuclear country, its symbolic value of development, and its regional history of being adopted by neighboring countries like India and Pakistan. In contrast, Vietnam, a neighboring country in Southeast Asia, has a history of not embracing nuclear power. Vietnam could cancel the NPP even after investing millions of dollars because of its conglomerates' stronger coal connections and growing potential to import coal from Russia.

The findings contribute to our understanding of the leapfrogging needed to adopt a clean energy transition. It finds that leapfrogging to nuclear in Bangladesh is a strategic decision influenced by external actors and the ideological preference of the country to serve special interest groups rather than national interests. Bangladesh ignored high upfront investment, and potential debt traps and risks, high electricity costs, and a lack of capacity to operate nuclear power plants and prioritized national identity, prestige, and development visibility. Whereas in Vietnam, the context of leapfrogging to solar was set by favorable state action and the regional spillover of knowledge already formed in Southeast Asia.

Another contribution to this chapter is that the solar innovation system is not based on global innovation and validation subsystems but rather on regional innovation and validation subsystems. Solar technology can be readily available globally, but its innovation subsystem is sticky globally. It tends to grow in a regional innovation system, where some essential spillover of knowledge takes place regionally.

Finally, this chapter concludes that the decision to invest in nuclear power does not take into account the potential future crowding-out effect of solar investment. Strategic decisions to adopt nuclear ignore the future crowding-out effect. The regional geopolitical context, the influence of external actors on decision-making, the political value nuclear adoption brings to the nation, and the capacity of interest groups to shape policy choices significantly impact these decisions.

10 Discussion

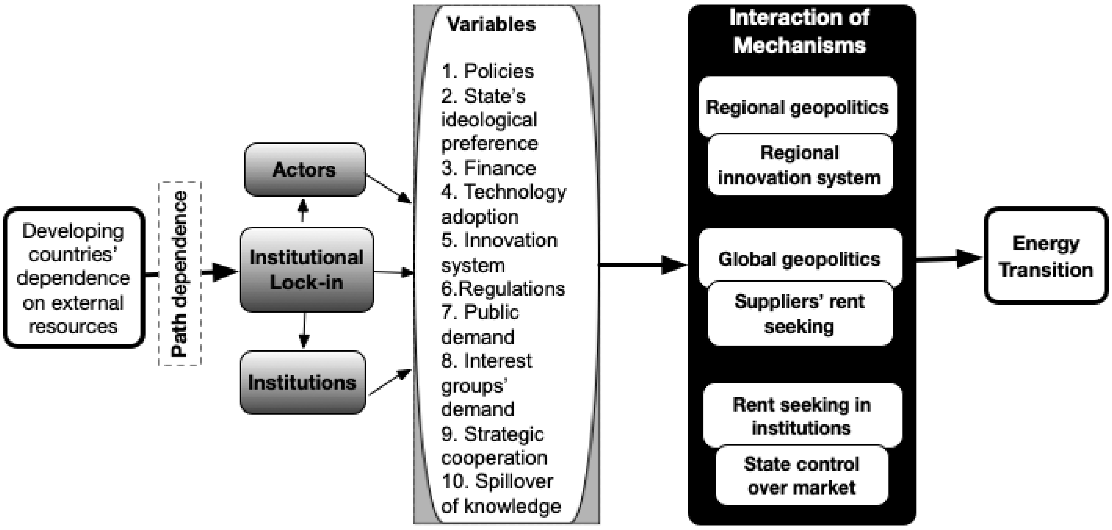
This chapter discusses the findings of chapter 5, 6, 7, 8, and 9 to reflect on the ongoing debate and shows that Bangladesh's adoption of coal, LNG, and nuclear in the decade of 2010s is a result of path dependent institutional lock-in as well as interaction of other mechanisms in an institutionally locked-in country. Chapter five identifies the critical juncture when certain policies altered the system in such a way that it has become increasingly difficult to reverse the policies. Chapter 6 shows why solar as a new clean technology could not grow fast despite its cost advantage. Chapter 7 shows why Bangladesh adopted nuclear despite being expensive. Chapter 8 shows why Bangladesh adopted coal and LNG despite its high cost to the society. Lastly, chapter 9 compares the case of Bangladesh and Vietnam to explore why at different critical juncture two countries adopted policies differently so that growth of solar, nuclear, coal, and LNG differed.

While the first chapter finds that over the fifty years an institutional lock-in has been created. 6,7, and 8 chapters discusses detail energy transition mechanism involving actors and institutions characterized by institutional lock-in. The last chapter (chapter 8) reveals the factors beyond institutional lock-in by comparing the divergent energy outcome of two countries and infer the most significant mechanisms of energy transition using process tracing.

After discussing the path dependence and interaction of multiple variables, section 10.3 summarizes the contribution of the findings in the major on-going debates.

The discussion can be summarized as follows with figure 10-1, that brings together the path dependent institutional lock-in created over 50 years and the interactions of mechanisms afterword contributing to the current energy transition outcome. The figure also shows that actors and institutions, through dialectic relationship, impact the economic, technological, social, and political variables in a locked-in institutional context. These variables lead to energy transition outcome through interaction of multiple mechanisms. This thesis identifies these causal mechanisms leading to the observable energy transition in Bangladesh.

Figure 10-1 Mechanisms of path dependence and interaction of multiple mechanisms



10.1 Mechanism of path dependence

The on-going debate on path dependency and lock-in centers around two key questions: how do we identify the presence of lock-in, and what are the underlying factors that contribute to lock-in. Goldstein et al (2023) draws the classic example of fossil fuel carbon lock-in and pointed out that it is fair to characterize the fossil fuel dependency as “locked” because multiple sources for lock-in exist across spatial and temporal scales as well as across structural unevenness (Unruh 2000). Goldstein et al (2023) questions whether “all cases are equally locked-in, in the same ways?” (Goldstein et al 2023, p. 161) This debate is relevant in understanding why despite the universal understanding of being locked-in in fossil fuel-based energy system, countries are still adopting policies that deepens the lock-in by making it increasingly state centered and more costly to reverse the outcome. Does the source of lock-in vary across countries and time?

Since gaining independence, Bangladesh's energy sector has followed a typical pattern of actions, as evidenced by its historical context. The pattern can be characterized by a tendency to respond to crises rather than taking proactive measures to prevent them, to prioritize short term solution rather a sustainable one, to passively embrace policies offered by external players rather than actively adopting policies to safeguard national interests, and a focus on state structuralism (reconciling competing interest) rather than a state-centric approach (national interest driven).

The sources of lock-in include: 1) habit of choosing crisis driven short term solution in different time of crises (1970s, 1990s, 2010, 2022), 2) Dependence on external actors, (from 1970s to 2024) 3) Creating rent seeking opportunities embedded in the institutional structure, (1990s onwards) 4) Regulatory capture (2010 onwards). These factors have collectively led to the establishment of an entrenched institutional system that is increasingly resistant to change over time. This has been theoretically defined as institutional lock-in. Institutional lock-in refers to a theoretical concept that describes a self-perpetuating cycle of interconnected factors that are challenging to overcome.

10.1.1 Crisis driven short term solutions

Chapter 5 detailed how institutional lock-in developed over time as a result of adopting strategies to rapidly handle crises from the 1970s to the 2010s. As a result of favoring short-term solutions over long term sustainable solutions, crises were never resolved; instead, Bangladesh became more vulnerable to external shocks. Despite the state's repeated attempts to address energy security challenges, each solution has inadvertently given rise to new problems.

10.1.2 Incremental planning

Following the 1970s oil crisis, Bangladesh followed the global trend of nationalizing the power and energy sectors by nationalizing its electricity and energy establishments. Since then, Russia has provided technical help in the electricity industry, while Norway has assisted Bangladesh in developing its capacity for gas exploration. For Bangladesh, the 1980s and 1990s were decades of gas regime formation, with natural gas becoming the country's primary source of electricity. Bangladesh had plenty of energy at the time, but its power infrastructure, which included generation, transmission, and distribution, was inadequate for supplying electricity to meet the growing demand. The first three decades of Bangladesh's energy system saw an abundance of domestic gas supplies, but installed capacity and transmission lagged behind. To address this crisis, in 1990s Bangladesh followed the global trend of liberalization advocated by international financial institutions. Bangladesh has also opened up its energy sector to investment from IOCs. Most PSCs were signed around that time.

10.1.3 Electricity liberalization

Since the 1990s, Bangladesh has rapidly liberalized its power sector. Over the course of next three decades, the proportion of private electricity generation has surged from nearly nonexistent to 50%. As a result of liberalization and private sector participation the cost of generation has started to increase after 2010. The government also increased the price of electricity. However, the crisis was not resolved. Although installed capacity has increased almost fourfold from 2010 to 2020, after the power system has become import dependent, supply of energy became uncertain due to increase in international energy price, dollar crisis, and reserve crisis.

10.1.4 External influence in comprehensive plan

In the decade of 2000, while some rural remote areas were being partially served by solar home system in the absence of grid electricity, most of the urban and rural energy system was so inefficient that intermittent power delivery and load shedding were common occurrences. The crisis in the decade of 2000 led to grid expansion in 2010. In late 2010 when grid capacity was expanded, the installed solar home system created new problems. People started to prefer grid electricity to solar home system and the past experience of solar home system impeded the adoption of rooftop solar as the people lost trust to the society. Thus, the short-term solution of the past created new problem later. The recurring crisis was a result of lack of long-term vision about balancing the demand for energy with the supply of energy for electricity generation. This is partly due to a lack of foresight and a failure to develop a long-term vision.

10.1.5 Institutional lock-in and evolution of actors

The institutional lock-in pattern demonstrates Bangladesh's inclination to implement solutions to resolve crises quickly without considering the long-term costs. Bangladeshi institutions are not well-equipped to collaborate with a large number of decentralized bodies in order to carry out initiatives. Dealing with many specialists, consultants, and possible businesses to outsource work, as well as monitoring progress and evaluating various agents, necessitates multiple managerial and monitoring capacities. Partnering with an organization that can be assigned to single handedly deal with these many actors is an easy solution for institutions that do not want to deal with multiple decentralized actors.

For example, Bangladesh government got away with avoiding full responsibility of building coal power plants by hiring multiple actors. As a result, we see China, India, Japan are engaged in planning, technical assistance, infrastructure building, and managing the projects. In case of LNG the same can be observed as the US providing technology and supplying LNG, while Japan has been involved in planning and supplying LNG. For the same reason, in case of offshore gas exploration Bangladesh has chosen the easiest option between signing contract with a foreign country and taking the responsibility on its own to oversee. Instead of building capacity of Bapex (Bangladesh Petroleum Exploration Company), the state-owned company, by giving it the authority to control offshore gas exploration, Bangladesh is more eager to sign PSCs with the international oil companies. When International oil companies sign contract, they also employ other companies to outsource tasks. If Bangladesh takes the control of offshore exploration it has to interact with multiple contractors whom they could outsource. In that way Bangladesh could build its own capacity. Instead, Bangladesh signed agreement with ONGC to explore in two offshore blocks. ONGC outsources its activities to various companies. Bangladesh signed PSC with ONGC to do the same tasks Bangladesh could do by hiring other contractors.

To foster solar growth, however, new institutional structures, rules, regulatory enforcement, and a well-designed pricing policy are required. Bangladesh was unable to increase its solar rooftop capacity at a faster rate due to ineffective incentives, pricing mechanisms, and law enforcement. Energy technologies that require strong regulatory enforcement, accountability, consumer incentives, and stiff competition are less likely to be preferred over other technologies that do not require these.

While electricity liberalization and competitive pricing (auctions, net metering) are thought to be beneficial to renewable energy growth, the case of Bangladesh demonstrates that they did not work in Bangladesh. The reason for this is because market-based pricing policies do not offer investors with enough motivation to see a quick return on their investment. Rather, alternative investments appeal to them because of the potential for a speedy return. Furthermore, another reason why electricity liberalization is unfavorable to solar expansion is that the gain from rent seeking opportunities in fossil fuels outweighs the benefit from rent seeking in solar. This is covered in full in chapters 6 and 9 of the dissertations. The failure of solar power to gain traction in Bangladesh is due to factors other than the deregulation of power. Investors' previous adoption experiences have contributed to a general lack of social trust. Possible dangers associated with lax law enforcement and unanticipated risk load were another factor.

The dependency on foreign actors led to adoption of coal and LNG. The foreign actors created demand for their own energy technologies and related fuels (coal and LNG) through a variety of techniques. This was done either to satisfy geostrategic interests or to assure market in the long run by locking in to that technology. Rent-seeking possibilities are pursued by the suppliers and the related network of actors in order to guarantee access into the market, maintain a presence in the market, and discourage competition in order keep a foothold in the market. Rent seekers in the coal and LNG industries have a greater capacity to utilize a variety of tactics to secure rent than rent seekers in the solar and wind industries do. This is because the coal and LNG involve license to import, logistics, distribution, gasification and regasification facilities in case of LNG, treatment in case of coal, and other procedures involving long term contract and spot market sale. Solar technology does not require all these technologies, logistics, and capital-intensive investments because it does not involve reliable and affordable source of fuel supply.

The vicious cycle of institutional entrenchment also affected the incumbent gas regime's destabilization. This is evident as foreign companies' share in total production increased as new gas field exploration initiatives declined overtime. The incumbent gas regime in Bangladesh has not been destabilized naturally because of gas resource depletion as has been depicted in the current literature. The gas resource depletion is a path dependent process which was deliberately engineered by not exploring the potential natural gas. To create market for coal and LNG and sustain the opportunity of these sectors was necessary to destabilize the gas regime by creating a scarcity situation. The recent attempt to explore gas after facing the crisis shows that gas exploration was possible before. It is also evident that Bangladesh did not need to learn that gas exploration is necessary after paying the price for technology lock-in.

10.1.6 Rent seeking mechanism in the institutional structure (1990 onwards)

In addition to foreign dependence, another existing institutional entrenchment fueled the functioning of vicious cycle of recurring crisis. Rent-seeking became established in Bangladesh's institutional culture as a technique for transferring public resources to private hands. Since independence, the commonly recognized tacit cooperation between businesses and government has developed a network of entities who have formed informal coalitions to prevent competition. Although this was conducted on a small scale before 1990s liberalization, following the liberalization when private participation flourished, the scope of rent seeking increased to the point that the linkages became impossible to dissolve. This precise range of rent-seeking choices, carved into the institutional structure, aggravated the cyclical effect in which crisis, external dependency, immediate solution, rent-seeking, transfer of public resources to private entities, and additional crisis followed each other to develop a vicious cycle with the institutional structure. National capacity building and governmental control over certain markets could help to break the cycle of such institutional lock-in. However, the practice of rent seeking in institutional framework made the web of entrenched interests impenetrable for any single actor to break through.

Various rent seeking opportunities have been created since the onset of electricity liberalization. At first, independent power producers started to absorb the rent in the form of making profit from the government incentive in power sector. Throughout the decade of 2010 the energy system has become reliant on extensive infrastructure and non-state entities who are not typically concerned with achieving long-term energy objectives. Chinese, Indian, US, and Russian corporations entered the energy industry by negotiating deals directly with governments. The government-to-government agreements facilitated the rent seeking of both state-owned companies (Rosatam, Power China) and other corporate entities (Sumitomo, Toshiba, IHI, Sepko, Excelerate Energy etc). These agreements excluded domestic private enterprises from competition. However, in certain cases, these agreements benefited the domestic private enterprises. Several instances of local-international collaboration can be observed in the fields of coal-based generation and LNG terminal expansions. The involvement of big business groups like S Alam group in the Banshkhali coal-based power plant and Summit group in the LNG terminal align with the electricity and energy objectives established by external entities.

In the debate over path-dependence-led lock-in, researchers often claimed that lock-in is caused by unavoidable actions taken to resolve a crisis promptly. However, in the case of Bangladesh, the lock-in was a consequence of deliberate policies rather than adopting only available policy to the crisis. The availability of various alternatives options and Bangladesh's preference for one policy over the other called into doubt the obligation to implement a specific policy in crisis (ie; subsidizing private power producers, prioritizing imported fuel dependence over domestic resources, preferring fossil fuel over renewable etc.). Thus, the causes of previous policy adoptions can best be stated as conscious policy choices driven by external actors and domestic and external rent seekers during the 1970s, 1990s, and 2010s crises.

10.1.7 Regulatory capture (2010 onwards)

The 1990s liberalization has gradually created new opportunities for private entrants in the electricity market. In the decade of 2000, there were opportunities for private producers to enter the market. However, the new addition of independent power producers was not sufficient to solve the demand supply gap because of inefficiency of the old power plants were getting worse. Instead of making those existing power plants more efficient, the government decided to take a new strategy to solve the problem. Bangladesh targeted to increase installed capacity in the quickest possible time to immediately solve the problems. In a bid to do that Bangladesh passed Quick Enhancement of Electricity and Energy Supply (Special Provisions) Act, 2010. According to the Act, the Bangladesh Power Development Board entered into several contracts to procure electricity from private sources, including rental and quick rental power plants. It allowed the private suppliers to bypass bidding process and supply electricity with the subsidized energy like oil and diesel. The Indemnity provision of the Special Provision Act provides legal protection to state agencies, allowing them to promptly initiate and execute electricity projects without facing legal consequences. The Act supersedes all other laws, including the Public Procurement Act, 2006 (Act No. XXIV of 2006), and any other currently applicable legislation. By granting the government the authority to bypass the Public Procurement Act 2006, which was implemented to promote transparency in government procurement, the act has allowed for rent-seeking opportunities to be limited to a selected group of entities, chosen not for their competence, efficiency, or cost-effectiveness, but rather for their political affiliations.

Initially, the government declared it to be valid for only two years to solve the problem. However, after two years, when the price of electricity increased as a result of absence of competitive bidding, the 2010 Act was criticized. By that time, it has become convenient to use this Act to justify any project without being under jurisdiction. In August 2014, the Cabinet granted approval for the continuation of the Special Provision Act for a further four years, until October 11, 2018. (GoB 2016b) And later in 2019 and 2021, till 2026. It is important to mention that the Bangladesh Power Development Board undertook more than 30 rental/quick rental power plant projects under this specific act. Beside quick rentals gradually all other coal, LNG, and nuclear projects were implemented using this particular regulation.

The fact that the effectiveness of the Act was first extended in 2012, in 2018 once, in 2019 once, and in 2021 once shows how the energy system has become dependent on the special provision Act. The institutional lock-in has been created in this process as the institutions became accustomed to unsolicited bidding process, avoiding accountability and transparency, and created a space for elite capture. This is an important regulation that created path dependency, altered the institutional behavior and eventually locked-in the institutions to display a stable character for fourteen years in a row.

10.1.8 Continuous dependence on external actors

Since gaining independence, Bangladesh's power and energy sector planning has always been shaped by international financial institutions. External consultants and specialists have consistently provided assistance in the development of power and energy policies, roadmaps, plans, strategies, and numerous recommendations. Bangladesh continuously sought technical and financial investment from other entities such as international financial institutions, bilateral cooperation agencies, and international oil companies. From the decade of 1970s to the decade of 1990s, Bangladesh’s power and energy plans were mostly influenced by the World Bank, ADB, and IMF because these institutions provided loans to Bangladesh for its power sector reform. Bangladesh’s first power system master plan was prepared by ADB in 2005. Later, direct consultation of Japan has become visible with the first power system master plan 2010 prepared by JICA.

Following the year 2000, when the electricity crisis reached a critical level, Bangladesh did not involve local experts in the formulation of a long-term strategy despite the country's urgent need for one. The domestic private entities that entered the electricity market following liberalization were unable to establish a role for themselves in actively contributing to the development of policies and plans that encompass a wider perspective on the future of energy. Rather, the private electricity producers were content with the advantages they gained from the government's economic and regulatory assistance. Their activity was predominantly focused on safeguarding their own interests, such as securing subsidized fuel, tax exemption, and capacity payments.

After Bangladesh has turned to Japan to formulate both its short-term and long-term strategies, Bangladesh became more dependent on the foreign consultation and advices. Since then, the dependency led to more dependency. As a result, Japanese International Cooperation Agency has been updated Bangladesh’s master plan in various intervals (2010, 2016, 2018, 2023). This has presented Japan with a chance to advance its own agenda and pursue its interests within the plan.

Although Bangladesh has gradually increased its capacity for onshore gas exploration since the 1990s, after 2000, the emphasis has started to change to negotiating with international corporations to explore offshore gas. However, the offshore agreement collapsed due to a mismatch of expectations on both sides. The attention then moved to coal and LNG. The state did not prioritize establishing national ability to secure domestic energy, instead focusing on the short-term political goal of increasing coverage. By the end of the 2010s, as installed capacity rose, Bangladesh had become increasingly reliant on expensive imported fuels, leading to facing the risk of fossil fuel debt trap as well as reserve crisis.

While the 2010 and 2016 master plan emphasized an increase in coal, nuclear, LNG, and electricity imports from India, these plans undercut the potential of solar and wind. The most recent 2023 integrated master plan classified renewable, nuclear, ammonia, and hydrogen as clean energy and advocated for the use of ammonia and hydrogen technology, in which Japan hopes to establish itself as a leader. Despite the fact that previously committed projects (LNG, coal, and nuclear) have already resulted in overcapacity, creating the possibility of lock-in and leaving little room for future solar expansion, Bangladesh continues to implement new LNG projects and plans domestic coal mining.

As a result of depending on external actors' solution to solve immediate crisis the crisis tended to recur. The external actors' advice created a vicious cycle of dependency. Eventually, the energy crisis led to a bigger economic crisis. After facing the crisis government did not stop planning more LNG terminals. While inviting offshore bid to explore offshore gas, Bangladesh is still planning to increase its LNG terminal capacity. At the same time, to address the crisis Bangladesh is also focusing on developing utility scale solar. However, the recent trend shows that the costs of these newly permitted utility scale solar is very high, and in some cases as costly as coal-based power.

The prevailing trend can be attributable mostly to a lack of willingness to develop domestic capabilities rather than a deficiency in the ability to commence the process of enhancing those capabilities. The national capacity building in onshore gas exploration in the 1990s and 2000 is an example of Bangladesh's potential ability to develop its capacity. However, at the later stage when Bangladesh signed PSCs with the international oil companies and contracted out the largest gas field, the focus on enhancing the capability shifted. This foreign dependency exemplifies the long-fostered attitude of foreign dependence despite having potential of enhancing its own capacity.

10.2 Interaction of multiple causal mechanisms in an institutionally locked-in energy system

While the institutional lock-in typically results from developing countries' resource constraints, lack of institutional and technical capacities, social, cultural, and historical experiences, there are also other multiple mechanisms interacting to create causal chain leading to condition of energy transition. These multiple mechanisms have robust explanatory power behind Bangladesh's reasons for fast adoption of lumpy technology like coal, LNG, and nuclear and slow adoption of granular technology like solar.

In order to explore the other causal mechanisms, I do a comparative case study between Bangladesh and Vietnam. I chose Vietnam because of its similarities and dissimilarities with Bangladesh. The similarities include close connection with Soviet blocks after the war, similar resource constraint, dependency on external technology and finance, phase of development for being lower middle-income country, economic structure with growing service and manufacturing sector, and rapid growth of electricity demand. There are dissimilarities in geographical location and ideological preferences. Vietnam is located in East Asia and Bangladesh is located in South Asia. Bangladesh adhered to market led economic development and Vietnam pursued state led marketization.

10.2.1 Technological regionalism

10.2.1.1 Regional innovation system

Being located in East Asia Vietnam is a neighbor of China, one of the leaders in solar manufacturing and deployment. Most of the East Asian countries like Thailand, Korea, Malaysia, and Philippines benefitted from spillover of knowledge of solar technology from China as well as replicating policies supporting solar growth in China. One of the primary reasons for China's success in the solar business is unwavering government support. The Chinese government has provided significant subsidies, tax breaks, and favorable regulations to promote the expansion of solar power.

The pattern of diffusion of solar technology in East Asia is region specific. First, these countries benefitted from the solar equipment import from China. Second, China's policy to use feed in tariff and other infrastructural support were replicated by countries like Thailand, Indonesia, and the Philippines. When Vietnam experimented with the time-bound feed in tariff, the investors and developer who previously entered the market in East Asia already had the knowledge about how to use the opportunity of feed in tariff in the quickest way. Vietnam government's policy of feed in tariff had a great response in Vietnam due to the past common pattern elsewhere in East Asia.

On the other hand, Bangladesh's neighbor India is also a solar leader but it has very specific diffusion pattern driven by specific political motivation in the country. Only some regions of India had high solar growth and that also happened as a result of political support and incentives provided to certain regions. Bangladesh's neighbor India did not have a long-term vision to establish itself as a solar leader in the South Asia region, until recently when some private companies have been trying to expand solar market regionally. Instead, we have seen India trying to build coal power plant in Sri Lanka, Bhutan, Nepal, and Bangladesh. The regional spillover of knowledge and the reginal network of actors did not work in case of Bangladesh as it did in Vietnam. The policies of the region from where technology diffuses mattered in case of Bangladesh and Vietnam. Bangladesh could not benefit from regional spillover of knowledge as Vietnam did.

10.2.1.2 Regional geopolitical motivation

Bangladesh's location close to two nuclear countries like India and Pakistan is one of the reasons why Bangladesh found it strategically important to invest in nuclear. Bangladesh is also important for Russia to establish a cooperation agreement for a number or reasons. While India and China have long fostered rivalry and cooperation history, India is also a strategic partner of USA for their common competitor China. In a complex geopolitical context, Russia needed to develop a long-term relationship with Bangladesh. Building nuclear power plant is an excellent opportunity for Russia to establish a long-lasting dependency relationship, whereas for Bangladesh it is also an opportunity to enter the nuclear club and make the megaproject visible as a symbol of development.

10.2.2 Role of state

10.2.2.1 State-led marketization vs. state supported liberalization

Vietnam and Bangladesh both were facing electricity crises in the 1990s when the existing power plants were not sufficient to meet the demand. Moreover, the old power plants lost efficiency in both countries during that time. There was financial constraint in modernizing the electricity sector to be able to meet the demand. In both countries' electricity crisis appeared as an obstacle to economic development. When in the whole world electricity liberalization through unbundling of generation, transmission, and distribution were taking place and there were attempts to encourage private participation in electricity generation, both Bangladesh and Vietnam underwent some reforms in the electricity sector. However, the patterns were different. While Bangladesh allowed independent power producers to take part in electricity generation without much control of the state, Vietnam, with its adherence to communist ideology, were cautious about abrupt privatization. Rather, Vietnam took it as an experiment by gradually allowing private participation while having full control of the operation of the newly built power plants with private initiatives.

Under the influence of communist ideology, the government of Vietnam has consistently adhered to the ideological position that electricity should be made available at prices that are affordable to all of society. The provision of inexpensive utility services was Vietnam's only essential ideological position without any opposition from this viewpoint. On the other hand, Bangladesh did not have a strong ideological preference that would have prevented it from the implementation of liberalization and price increases. In contrast to Vietnam, which permitted private participation while maintaining a certain degree of state control over the market, Bangladesh not only allowed unrestricted liberalization, but it also provided financial assistance to the private sector by providing subsidies and purchasing electricity at a higher price. Because of this, private producers have been encouraged to benefit from power generation that rely on fossil fuels.

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10.2.2.2 State centrism versus state structuralism

State centrism refers to the state's tendency to adopt policies based on the national interest. State structuralism refers to the tendency of the state to let contending interest groups to influence the policies and regulations in favor of them. Although both of these definitions represent two extreme ideological positions, in reality there exists a spectrum in between two positions. In this spectrum some countries are closer to practicing state structuralism while others are closer to state centrism. The case of Bangladesh and Vietnam can be distinguished by their ideological preference for these two approaches. As Vietnam's practice of policy adoption is quasi-federalist, meaning that it is closer to central planning than to decentralized planning, Vietnam's ideological position is closer to state centrism than to state structuralism. The interest groups are in harmony so that long term benefits are prioritized over immediate rent seeking. Bangladesh's policy making, on the other hand, is state structuralism where different interest groups contend to prevail. The most dominant interest groups develop nexus with the government to implement their preferred policies in their interest. The rent seekers in top of hierarchy of power structure are against any reform and can contend to direct policies in favor of them.

Vietnam's Power Development Planning is an example of how state has higher control over the planning process by involving different experts from inside and outside the country. Despite external resource dependency like any other emerging economies, in Vietnam, their planning reflects alignment with well-defined national objectives. Whereas, Bangladesh allowed a foreign development agency to make the power system master plan for Bangladesh. Here, the state did not have a vision of its own national interest. Rather, it allowed another country having conflict of interest and a plan to serve its own interest.

Bangladesh, as a state, lost its original ideological position regarding using domestic energy and fell into the fossil fuel debt trap by following the advice of external actors. Bangladesh did not learn from the repeated mistakes and is planning to develop new LNG terminals with the help of Japan and USA and are in the process of engaging with China in domestic coal mining. The state structuralist approach, although it may sound democratic, is actually a result of institutional lock-in driven by both domestic and foreign interest.

10.2.3 Politics of demand

10.2.3.1 Global geopolitical motivation

The politics of demand is a mechanism through which countries create demand for certain energy as a strategy to increase foreign countries' dependency on that energy. The objective of such a strategy is to establish control over countries where their competitors have already established monopoly control or where there is a potential for the competitor to establish control in the absence of substitute energy sources. The mechanism of demand creation can be used to diversify the energy mix of some nations so that these countries do not remain dependent on any particular country. The strategy to use this mechanism is often driven by geopolitical interest and, at the same time, to expand the market for domestic energy. Russia has long been using Europe's natural gas dependency as a weapon against Ukraine and NATO. After the 21st century shale gas revolution, which increased the volume of US natural gas production, the United States planned a retaliatory action aimed at reducing the dependency of its allies on Russian natural gas. The United States used LNG demand creation as a geopolitical strategy. (Cunningham 2013) As a result, LNG business expansion was prioritized to create a long-term demand for LNG. (Tusiani 2016) As part of its policy, the US actively promoted the construction of LNG terminals to enhance the reliance on US LNG in Asia and Europe. As part of the overseas energy policy, Accelerate Energy provided technical support to build an LNG terminal in Bangladesh.

Bangladesh is a natural gas-abundant country. Bangladesh’s domestic gas exploration effort has stalled for the last two decades. Even when some IOCs were interested in exploring gas, they did not sign contracts as Bangladesh refused to export gas. Exporting gas in the form of LNG was one of the most lucrative incentives for IOCs to explore gas in Bangladesh. Meeting domestic demand was not their priority. It is the expansion of LNG trade that they are interested in. As a result, Bangladesh developed its LNG import capacity. Despite having gas resources, Bangladesh gradually turned into an LNG-importing country.

While the US's geopolitical interest is to increase LNG business worldwide in order to diversify the world's energy dependency, Russia's demand strategy for Bangladesh has been nuclear power-centered. Russia pursued nuclear power plant construction in Bangladesh as part of its nuclear technology expansionist policy. Historically, Russia has been involved in natural gas-based power plant development in Bangladesh. The Russian company Gazprom is still involved in digging wells in Bangladesh. Although Bangladesh has the technical capacity to dig well at one-third the cost of Gazprom, Bangladesh is still hiring Gazprom for gas exploration. The mechanisms of demand creation and geopolitical competition of both of these countries are evident in their presence in the energy sector.

10.2.3.2 *Global energy technology suppliers' rent seeking motivations*

While the technologically advanced countries use the politics of demand driven by their geopolitical motivations, they also provide incentives to both state-owned energy technology suppliers and private technology suppliers. To implement their plans, these countries engage in cooperation agreements with developing countries, either through government-to-government agreements or joint ventures. The governments establish rent-seeking opportunities for global power and energy technology suppliers in foreign countries. For example, in Bangladesh, Japan created opportunities for one of its important energy technology suppliers and traders, JERA. The US facilitated Excelerate Energy to build LNG terminals in Bangladesh and later created opportunities for US traders to export trade. Similarly, the Russian government facilitated the rent-seeking activities of Gazprom and Rosatom through their energy diplomacy, while the Indian government facilitated the access of state-owned entities such as ONGC India for offshore gas exploration, NTPC India for the construction of coal power plants, and the private company Adani for the export of electricity to Bangladesh. The Chinese government, with their diplomatic arrangements, facilitated access for Chinese state-owned companies to build coal power plants in Bangladesh. The construction of all of these power and energy projects is in line with these countries' greater geopolitical goals and the rent-seeking motivations of technology suppliers.

10.3 The major debates

10.3.1 Diffusion speed and spillover of knowledge

The *first* debate centers on the speed of technology adoption on the periphery. Much of the literature argues that this speed should be faster because late-comer countries benefit from technological learning and cost decline in front-runners. However, my research shows that these benefits are not automatic. In case of solar power, I show that learning about modern rooftop systems was swiftly conveyed to Vietnam by transnational actors, but was not conveyed to Bangladesh despite its prior experience with solar home systems. I show that for solar, a policy driven technology, policy diffusion matters as much as narrowly understood 'technology diffusion'. Due to its lack of capacity to introduce effective policies supporting solar growth, Bangladesh failed to expand this technology despite globally accumulated knowledge and cost declines. In contrast, more effective policies such as feed-in-tariffs have diffused to Vietnam through a regional innovation system of South-East Asia, resulting in faster growth of solar. In summary, technology diffusion on the periphery can be faster or slower depending on the socio-political capacity and the effectiveness of the concurrent policy diffusion.

This conclusion is further strengthened by my observations of coal and LNG diffusion. These technologies also required policy intervention, however, Bangladesh had propensity for rent-seeking to facilitate such interventions and, as a result coal and LNG diffused relatively fast despite their rising costs.

10.3.2 Technological characteristics and the speed of diffusion

The same empirical observations about diffusion of the four technologies also contribute to the **second debate about technological characteristics and the speed of diffusion**. The literature argued that granular technologies expand faster because of the faster learning and cost decline. However, this argument does not fully work in case of policy-driven technologies in emerging economies. In this case most of the learning occurs globally, not nationally and policy capacity matters as much if not more than costs. Granular capacities require complex and novel policy interventions involving many actors, whereas lumpy technologies may require interventions that are, if not simpler, at least more familiar to established rent-seeking bureaucracies of emerging economies. As a result, lumpty technologies like nuclear, coal and LNG could diffuse faster in emerging economies than granular technologies like solar.

10.3.3 Technological innovation systems

The *third* **debate on the technological innovation systems**, has a specific focus on whether the diffusion of technologies in emerging economies is better explained by the global innovation or national innovation systems. The global innovation system literature identified solar as a standard technology that is globally available and therefore diffuses in a global innovation network where learning by doing rather than science and technology innovation plays a greater role. The thesis shows otherwise. It shows that it is neither national, nor global innovation system that can explain the diffusion of solar, rather it is the regional innovation subsystem within which resources and actors were mobilized to utilize the national incentive to promote solar. Vietnam developed solar faster because of the strength of the regional innovation system in South-East Asia, whereas Bangladesh could not similarly benefit from the regional innovation system in South Asia. However, in case of nuclear the situation was the opposite. Although both countries had the major actor of the global innovation system, Russian Rosatom, involved, Bangladesh also benefited from regional actors such as India, whereas Vietnam had no such support.

10.3.4 The role of electricity liberalization in solar growth

The *fourth* **debate is about the role of electricity liberalization in facilitating solar growth**. Does the cost recovery pricing as a result of electricity liberalization make solar electricity more profitable? The debate began when heavy solar subsidies burdened Germany's electricity sector. As a result, Germany began to shift to auctions and competitive pricing policies, reflecting the move towards a more liberalized electricity market. Does the degree of electricity liberalization have a positive impact on the expansion of solar energy, particularly in emerging countries? (Lee 2020, William et al. 2021) The conventional literature assumes that electricity liberalization opens up new opportunities for new investments in low carbon energy. Besides, electricity liberalization allows competitive pricing in electricity market so that countries can benefit from the global cost decline of solar, creating profitability in the solar market. The thesis did not find any concrete causal mechanism that could establish the fact that solar has become more competitive because of electricity liberalization. Rather, the thesis shows that Vietnam had to use subsidy dependent pricing mechanism like feed in tariff to promote solar growth. Vietnam has been historically critical to electricity liberalization because of its ideological preference skewed to ensure public utility provision. The degree of electricity liberalization is different in Bangladesh and Vietnam. Bangladesh has drastically adopted liberal reform and became increasingly dependent on private sector financed by foreign actors for electricity supply. The higher degree of electricity liberalization did not ensure competitive pricing for solar in Bangladesh.

11 Conclusion

11.1 Achieving the research objectives

11.1.1 Development of conceptual framework

The first objective was to develop a conceptual framework to reveal the causal mechanisms of the energy transition in developing countries. In this thesis, I develop a conceptual framework for explaining energy transition mechanisms in developing countries. I used three-perspective theory and worked on the conceptual framework developed by Vinichenko et al. in 2018. This new framework is different from the previous framework in four different ways.

1. This new framework, in the context of developing countries, defines the energy system as a co-evolving system consisting of techno-economic, socio-technical, and political mechanisms. Rather than defining the energy system solely as physical infrastructure and a system for energy flow in a techno-economic framework, I approach the energy system holistically, incorporating elements of both socio-technical and political systems.
2. In this framework, the energy systems of developing countries are characterized by their reliance on external actors and institutions due to their technical, financial, and institutional dependencies.
3. This new framework is different from the previous conceptual framework developed by Vinichenko (2018), as this framework does not define capacity as a given variable as a function of income. Rather, in this framework, capacity development is an evolving phenomenon that changes over time and is an integral part of the political system as well. As a result, capacity, which was previously defined as technical, regulatory, and financial capacity at a given time, is now defined as the ability of the state to develop its own national innovation system in a co-evolving system. External actors influence the country's capacity as institutions become entrenched as a result of long historical dependency.
4. This new framework differs from the previous one in another aspect. The new framework characterizes actors and institutions in a dialectic relationship where actors

(both internal and external) and institutions continuously interact with each other, confront each other, and reconcile with each other based on the relative power of interest groups.

11.1.2 Identifying the mechanisms and contributions to literature and ongoing debates

The second objective was to do national case studies that aim to enhance the current body of literature on mechanisms of energy transition by providing insights into the reasons for the adoption of expensive technologies such as coal, LNG, and nuclear, while simultaneously exploring the factors that delay the adoption of solar technology.

I fulfilled the above-mentioned objective as I identified mechanisms in each chapter, made contributions to the existing literature, and position the research in the existing ongoing debate. The following figure 11-1 summarizes the mechanism-based explanation by using a causal chain. Table 11-1 summarizes the relative strength of mechanism using process tracing. Table 11-2 summarizes the specific contributions to the ongoing debates. Table 11-3 summarizes the primary and secondary contributions to the literature.

Figure 11-1 Causal chain: mechanisms-based explanation

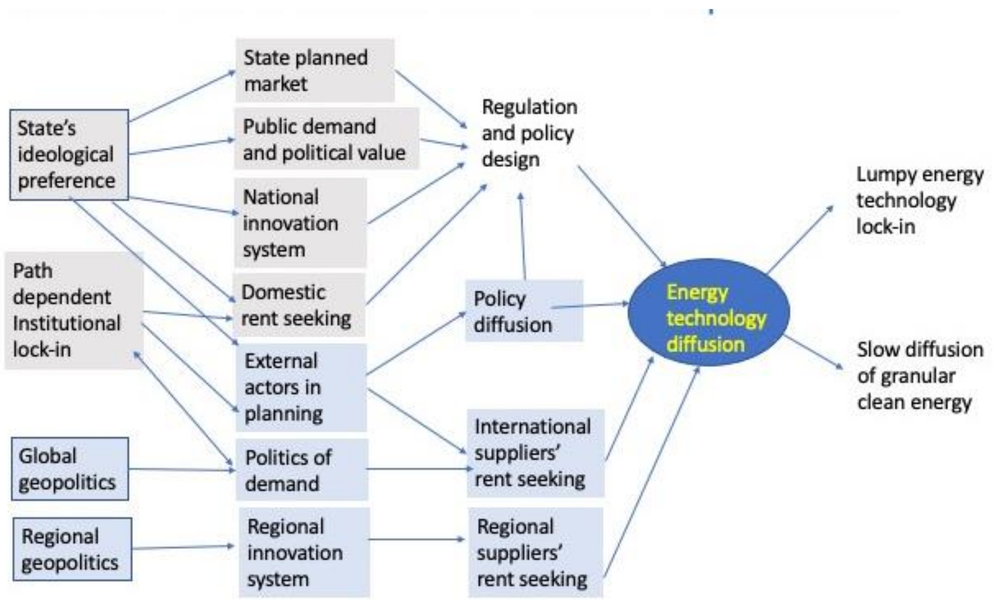


Table 11-1 Relative strength of causal mechanisms

	Chapter 5	Chapter 6	Chapter 7	Chapter 8	Chapter 9
Relative strength of Mechanisms	History of Power and Energy	Solar Adoption	Nuclear Adoption	LNG and Coal Adoption	Bangladesh-Vietnam Comparison
Most significant mechanisms	Path dependence	1.Low social trust 2. Lesser opportunity for rent seeking. 3. Poor policy design 4. Institutional lock-in	1. Regional and global geopolitics 2. Regional innovation system 3. Rent seeking 4. National identity politics	1.Rent seeking 2.Regulatory capture 3. Politics of demand	1. Regional innovation system 2. Regional geopolitics 3. State's ideological preference 4. Policy design 5. State led liberalization
Weaker mechanisms	State's ideological preference: development	Techno-economic mechanisms	Techno-economic mechanisms	Techno-economic mechanisms	1. Learning by doing. 2. Public demand
Outcome	Institutional lock-in Poor energy planning system	Slow growth of solar	Prioritizing nuclear power	Adoption of more fossil fuel technologies	Vietnam: granular technology Bangladesh: lumpy technology

Table 11-2 Specific contribution to major ongoing debates

Subject	**Debates**	**Key Contribution**
Diffusion speed and spillover of knowledge	Is the rate of diffusion of solar technology from the core similar in all periphery countries? Do mature energy technologies such as liquefied natural gas (LNG) and coal spread more rapidly in peripheral areas compared to core areas?	Solar did not grow in Bangladesh not because of the lack of scope of spillover of knowledge, rather because of the absence of actors, poor policy designs, and state's ideological preference. Vietnam had a faster growth of solar without long prior experience from learning, and with implementing effective policy design. LNG and coal grew faster not because these are matured technologies, but because of demand creation driven by geopolitical and rent seeking interest.
Technological characteristics and the speed of diffusion	Is granular technology or lumpy technology is more advantageous in achieving fast decarbonization?	The motivation of adoption of granular (solar) and lumpy technologies (nuclear) cannot be compared with each other because the underlying causes of adoption of these two are intrinsically different. While nuclear adoption is a strategic decision that largely depends on geopolitics as well as national and regional identity of the country, solar adoption is more of a national goal driven policy,

		relatively less dependent on geopolitical position of the countries. Therefore, despite having lot of advantages, including simplicity, cost effectiveness, shorter implementation duration, solar did not grow in Bangladesh. On the other hand, Vietnam cancelled its plan to build nuclear because it did not have capacity to adopt a complex technology, as well as lack of regional geopolitical motivation to adopt nuclear. Advantages of granularity is not a necessary condition for a low carbon granular technology to grow.
Technological Innovation System	Is diffusion of solar power in small emerging countries more significant in the global innovation system or the national innovation system?	Neither national innovation subsystem, and nor global innovation system were relevant in explaining the diffusion of solar, rather it was the regional innovation subsystem within which resources and actors were mobilized to utilize the national incentive to promote solar.
The role of electricity liberalization in solar growth	Does market-based pricing under more liberalized electricity sector increase profitability and encourage investment and accelerate the solar growth? Or developing countries need more government interventions to incentivize solar in the formative phase?	Competitive pricing, and profitability resulting from electricity liberalization does not contribute to solar growth in developing countries in formative phase. With more liberalized electricity sector Bangladesh could not benefit from solar cost decline. Vietnam, with less liberalized electricity sector, exceeded its solar target using economic incentive like feed-in-tariff.

Table 11-3 Additional contributions to literature

Literature Section	The main use in Energy Transition	Key Contribution	Secondary Contribution
Co-evolving System	To define the relationship between different systems that co-evolve and energy transition takes place in the co-evolving system		Energy System consists of techno-economic system, socio-technical system, and political system. Energy system is not merely physical infrastructure and the flow of supply. In an evolving system capacity also evolves. Holding capacity as a variable dependent on only income contradicts with the idea of co-evolution.
Neo-classical economics	Explaining techno-economic behavior of suppliers, consumers, and government.		Demand and supply are not objectively determined in the market. Politics of demand and politics of supply explain the behavior of suppliers, consumers, and responses of government.

Technology Diffusion			Readily available technologies at global level does not ensure that it will be adopted. For developing countries technological regionalism is more important than technological globalism for both lumpy and granular energy technology
Rent Seeking Theories		Social resistance suppression is one form of rent seeking.	
Pricing and Policy Design			Electricity liberalization and market-based pricing policy does not accelerate clean energy adoption
Energy Geopolitics			Nuclear power adoption in lower middle-income country is a geopolitical outcome based on both strategic and economic cooperation.
Policy Diffusion			Power and energy policies diffuse to developing countries as experts and consultants use hegemonic ideas to influence policies of developing countries.
Path Dependence		Path dependence due to dependence on core for technical, financial, and institutional resources causes institutional lock-in	
Innovation System and Capacity			There is a difference between capacities between developed and developing countries. However, capacity is an evolving process and needs to be understood from a historical perspective.

11.1.3 Validation of the findings using comparative case study

The fourth objective was to use the findings from an extensive analysis of a specific case in Bangladesh involving four energy technologies and validate the findings from single case study by conducting a comparative study between Bangladesh and Vietnam. The purpose of this study is to investigate the reasons behind the different energy outcomes in these two countries, despite their shared goal of transitioning from a lower middle-income country to a high-income country.

In this section I summarize the findings from each case study (chapter 5, 6, and 7) and use the findings to compare with another similar country's outcome to validate the findings.

11.1.2.1 Findings from empirical chapters

Chapter 5 identifies sources of path dependence and institutional lock-in that has been created in fifty years. Bangladesh has historically provided electricity through a state monopoly, largely drawing from domestic natural gas. Bangladesh had abundant gas reserves from the decade of 1970s to the decade of 2000s to meet the demand for electricity. During that time the reason of power crisis was not domestic energy reserve, but poor electricity infrastructure including generation, transmission, and distribution. However, after 2010 when Bangladesh started to increase its installed capacity, it has started to implement oil, coal, nuclear, and LNG based power plant projects. During that decade solar cost decline 80%, making solar cheaper than oil, coal, LNG, and nuclear. As a result, of building new power plants and expanding grid, Bangladesh has achieved universal access to electricity. Although electricity reached the remote areas that were not covered before, the problem of interrupted supply persisted. Part of the reason of poor electricity supply was import dependent electricity sector, increase in price of coal, LNG, oil, dollar crisis, and foreign reserve depletion. As a result, the country witnessed overcapacity of installed power plants while at the same time declining economic capacity to buy imported fuels to meet the demand of the installed power plants.

Chapter 6 explores why solar adoption has been slow in Bangladesh, despite Bangladesh's long experience of installing solar home system. It finds out the mechanisms through which solar home system could not contribute to learning and instead the experience almost worked as a social deterrent to new grid-connected solar power. The chapter finds that liberalized electricity market failed to attract actors to invest in solar even after market-based pricing policies to incentivize solar adoption. Even unsolicited proposal bypassing competitive bidding could not generate sufficient capacity of solar.

Chapter 7 uses process tracing to explore why Bangladesh has engaged in nuclear cooperation agreement with Russia. In contrast to solar the nuclear adoption is based on state-to-state agreements. There is a limited number of actors involved and few domestic actors have capacity in this area. The chapter finds that the project is driven by strategic rather than economic interests. Geopolitical interests of Russia and strategic imperatives of Bangladesh government was the main driving force behind the adoption. Although economically, the project is expensive and Bangladesh does not have the capacity operate, Bangladesh still developed the project. The reason for which Bangladesh has adopted nuclear has been traced back and found global and regional geopolitical mechanisms behind building this project.

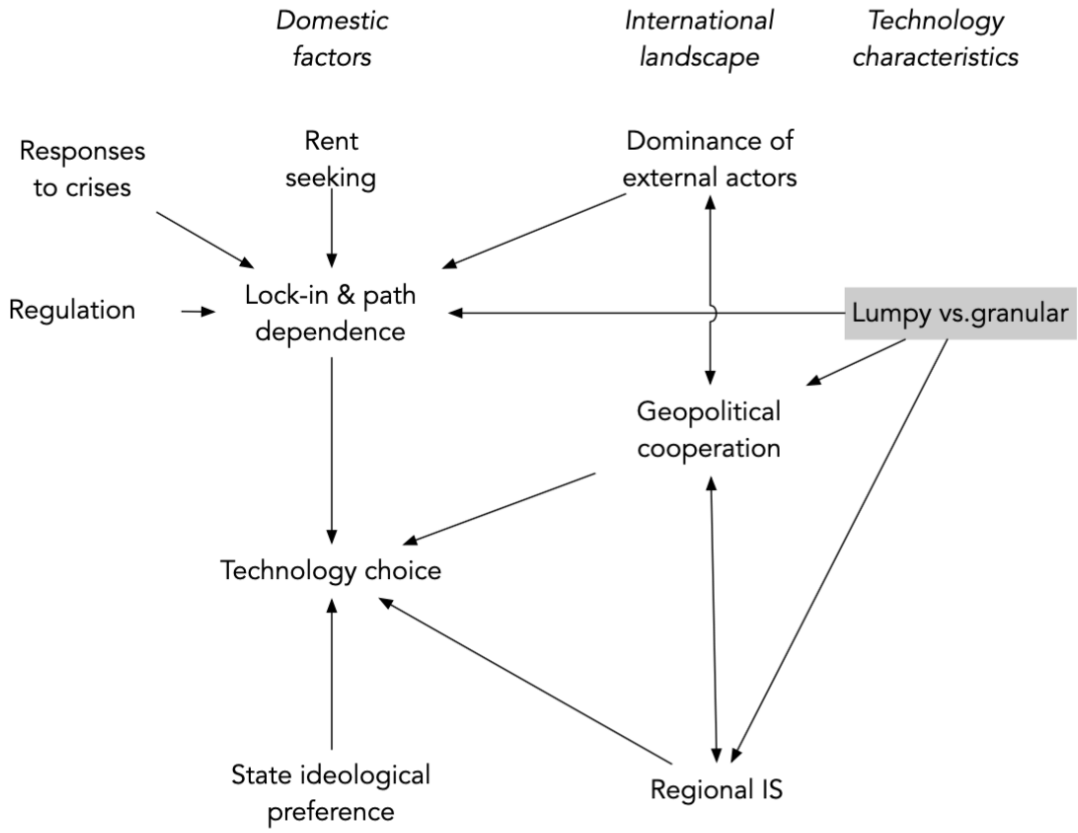
Chapter 8 focused on Bangladesh's new fossil fuel adoption, specifically coal and LNG in the decade of 2010. This chapter uses the politics of demand and supply and rent seeking framework to explore the mechanisms of adoption of these new technologies. The study reveals that while the cost of solar was declining, the adoption of coal and LNG was already being regarded as environmentally costly and socially inefficient. Therefore, the techno-economic argument that coal and LNG were cheaper at the time of adoption is not a suitable explanation. Rather, the adoption was triggered by the geopolitical motivation of demand creation as well as the rent seeking motive of suppliers. The finding of the chapter goes back to the discussion of institutional lock-in that was created over the five decades in Bangladesh. The past dependency on external technology and finance to address the past crises made the institutions dependent on external actors. This chapter shows how the repeated pattern of external dependency created path dependence and locked in the institutions to such an extent that the institutions became increasingly resistant to change over the time. The adoption of coal and LNG is the result of lack of long-term vision due to institutional lock-in as well as evolving geopolitical priorities at the particular time.

11.1.2.2 Findings from comparative case study

Chapter 9 compares Bangladesh and Vietnam to validate the mechanisms identified in the previous chapters. It also finds regional dynamics and differences in ideological preference of these two countries as mechanisms of adoption of solar by Vietnam and nuclear by Bangladesh. The developments and choices in Bangladesh can be traced to several key factors and mechanisms. Domestically, the state claims to believe in liberalized market but lacks capacity to make such markets work as illustrated by the failure to enact a workable support scheme for solar in the liberalized markets. As a result, the state is primarily able to deal with other states, as in case of nuclear - Russia, coal - Japan and China and India. These other states usually engage with Bangladesh to pursue their geopolitical or commercial interests. Engagement of Bangladesh state with other states is supported by large actors who see rent-seeking opportunities for themselves. All these works better for lumpy project adoption like coal, LNG and nuclear.

The findings of the comparative case study between Bangladesh and Vietnam are summarized in the following figure.

Figure 11-2 Comparing energy transition mechanisms in Bangladesh and Vietnam



11.2 Policy implications

Research on energy transition in the global south is crucial for several reasons: The demand for power in the global south is expected to experience significant growth. (Source: IRENA, 2020.) (ii) It is imperative for the globe to harness the sustainable natural resources in the region in order to implement renewable energy. (iii) The fundamental question is how the global south can obtain the necessary technology and financial resources to decarbonize and attain the net zero aim.

The thesis concludes that the reliance of developing and emerging economies on external sources leads to a situation where their future development is determined by their past choices, and this dependence also hinders the ability to change existing institutions. This has important implications for policy-making in the context of global power and energy transition. Excessive reliance on external sources can have negative consequences for developing and growing economies, including increased dependence on imports, a heavy load of foreign debt, costly projects with high initial expenses, reliance on subsidies for adopting fossil fuels, a burden of debt related to fossil fuels, and rising prices. The implication of this conclusion is that developing countries must establish institutional mechanisms to enhance their ability to develop national planning systems. This will enable them to formulate long-term plans that are focused on achieving specific goals, rather than implementing incremental solutions that primarily benefit a selected few interest groups.

The finding that the liberalization of electricity results in an increase in the market price of electricity and a decrease in the cost of solar power may indicate potential profitability. Nevertheless, the presence of profitability does not guarantee that this techno-economic condition alone is enough to achieve significant solar expansion. The expansion of solar energy is contingent upon various socio-technical elements such as the dissemination of information across regions, political will to offer incentives, societal trust, and the potential for future technological entrenchment. Pricing plans in numerous developing nations are formulated according to profitability indicators. Policy makers frequently assert that further electricity liberalization and a rise in market prices of electricity can enhance the viability of solar energy. This thesis presents a finding that questions the commonly believed influence of liberalization on the expansion of solar energy in emerging nations.

The actors, particularly consultants, engineers, and planners, in both emerging and developing countries frequently encounter difficulties in formulating their own perspectives that are in line with the national interest. External actors frequently employ diverse techniques to disseminate hegemonic ideas during the process of knowledge transfer. These countries must not solely rely on their own national programs developed by domestic actors who are significantly influenced by external educational institutions. Universities can enhance their research capabilities by fostering an interdisciplinary approach to problem-solving, which allows for the inclusion of diverse perspectives, exploration of alternative strategies, and engagement of multiple stakeholders. This technique allows for a more comprehensive understanding of the socio-technical hurdles. The results from the solar chapter (chapter 6) indicate that the process of learning by doing did not provide any beneficial effects on the expansion of solar energy in Bangladesh. Furthermore, it demonstrates that developing nations with limited prior experience can attain rapid economic growth in a relatively brief timeframe. This finding suggests that a specific outcome is not solely influenced by one strategy, but rather by a combination of various mechanisms. To effectively replicate policies in diverse contexts or in similar developing and emerging countries, it is crucial to comprehend the causal mapping rather than just the impact of a specific policy.

Ultimately, the allocation and utilization of climate funding across various sectors is a policy determination that involves both the international community and national policy actors in developing nations. The results of the thesis will be particularly valuable for allocating resources to tackle the climate catastrophe. Gaining a comprehensive understanding of the processes by which energy transition occurs is crucial in order to identify the most effective and efficient methods of allocating financial resources for climate mitigation.

11.3 Limitations and further scope of research

Many national case studies suffer from a lack of generalizability. This dissertation attempted to overcome the limitations by comparing two similar developing countries. However, some gaps remain due to the differences in the depth of case studies on the adoption of energy technology in both countries. While I examined fifty years of data for Bangladesh to identify institutional lock-in, I did not apply the same methodology for Vietnam. Rather, I relied on some literature, especially the previous in-depth case study of Vietnam's political economy (Jandl 2014) and electricity sector (Sawdon 2014), and used some of their findings as a ground for my analysis. Due to the extensive scope of the research and the depth of analysis it required, it is not feasible to compare four energy technologies across nations, especially when the contexts of external dependency vary across developing countries.

Some of the concepts, like national capacity and patterns of external influence, are vague, evolving, and, in most cases, subjective. Being in Bangladesh, I have been able to cross-check secondary data and existing perceptions and explanations in more detail. It was not possible to do the same for Vietnam. Therefore, it was not possible to rely on vague concepts without sufficient cross-checking. In my analysis, I relied mostly on evidence that was actual, reliable, and free of human perceptions. Nevertheless, the study has identified several potential areas for future research that could improve our understanding of energy outcomes in developing countries.

There are several areas that need further research to understand energy transition mechanisms in developing countries. One of the issues that requires additional investigation is the global expansion of LNG. LNG is commonly referred to be a transitional fuel due to its use in diversifying the energy mix, phasing out coal, and satisfying electricity demand during the transitional period when clean energy sources are projected to expand and supplant fossil fuel-based energy. Does the utilization of LNG in emerging nations and the expansion of global trade, logistics, and businesses suggest that LNG is effectively fulfilling its role as a transitional fuel? The research holds equal importance for both developed and developing nations. The future of Hydrogen technology and co-firing of Hydrogen with LNG is expected to contribute to decarbonization. However, we do not have predictive capacity when the technology is still in the experimental stage. This dissertation findings show that the previous decisions of adoption of new technologies are driven by the geopolitical and commercial motivations of external actors. This finding created a premise from which the future study on LNG's transitional role can be studied further.

While rich nations have been strategizing to gradually eliminate the use of coal, emerging nations have commenced the operational activities of coal-powered facilities that were initiated in the 2010s. Developing and emerging countries are anticipated to bypass intermediate stages and directly adopt more sophisticated and environmentally friendly technology, as suggested by the energy ladder and leapfrogging hypothesis. Nevertheless, there are instances, such as in Bangladesh, where coal capacity has been incorporated into the energy mix. Additional investigation might be conducted to examine whether the coal technology suppliers generated the demand for coal during a period when the coal market began to reach its maximum capacity in industrialized nations. Both quantitative and qualitative studies of selected emerging country situations where coal expansion has been documented may be necessary for this analysis. Co-firing of coal and Ammonia is another technology that is being widely discussed now-a-days as a method to reduce carbon emission. Whether this kind of technology is cost effective in case of developing countries, or whether this is another way of expanding coal business, needs to be understood with specific case study.

In order to overcome the issue of generalizability of the thesis findings to other developing and emerging countries, it will be useful to conduct additional comprehensive case studies using the same method. Conducting a thorough case study to examine the mechanisms and subsequently comparing additional cases might enhance our understanding of the mechanisms and their applicability in developing countries. This will also aid in formulating more effective policy measures to reduce carbon emissions in developing countries where a significant increase in electricity demand is an unavoidable reality.

The findings indicate that despite increasing installed capacity, Bangladesh's energy crisis remains unresolved. We can conduct further research to scrutinize the current demand prediction method, particularly in light of the country's ongoing structural transformation. We need to assess the industrial development plan and demand estimation based on it to gain a comprehensive historical overview of the development phases of emerging countries and their demand growth.

We could also conduct further research to compare two or three developing countries where the national innovation system either developed, did not develop, or developed differently. This could aid in comprehending the relationship between the national innovation system and regional and global innovation systems, as well as whether and how the development of the national innovation system could sustainably contribute to the adoption of clean energy.

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