



THE ENERGY AND RESOURCES INSTITUTE
Creating Innovative Solutions for a Sustainable Future



CTCN
CLIMATE TECHNOLOGY
CENTRE & NETWORK



Implementation of Fast Technical Assistance – **Study on Renewable Energy Grid Integration in Cambodia**

Implementation of Fast Technical Assistance – Study on Renewable Energy Grid Integration in Cambodia

Suggested Format for Citation

Meghana Jayakumar, Narayankumar. Sreekumar. 2021. Implementation of Fast Technical Assistance – Study on Renewable Energy Grid Integration in Cambodia. New Delhi: The Energy and Resources Institute.

Team

Project Experts & Lead Authors

Ms Meghana Jayakumar, Associate Fellow, TERI

Mr Narayankumar Sreekumar, Associate Director, TERI

Advisor

Mr Girish Sethi, Senior Fellow & Senior Director, TERI

CTCN Focal support Team

Ms Clara Landerio, Regional Manager for Asia and Pacific, CTCN

Mr Sambit Nayak, Climate Change Specialist, CTCN

Mr Sovanchandara Heng, Local consultant, CTCN

For more information

TERI Press
The Energy and Resources Institute
Darbari Seth Block
IHC Complex,
Lodhi Road New Delhi-110 003
India

Tel. 2468 2100 or 2468 2111
E-mail pmc@teri.res.in
Fax 2468 2144 or 2468 2145
Web www.teriin.org
India +91 • Delhi (0)11

Preface

This report has been prepared as part of the Climate Technology Centre & Network's (CTCN's) 'The Fast Technical Assistance (FTA)' Program. FTA is CTCN's short time response to requests referring to technology prioritization, endogenous technologies assessment, policies and measures that are immediate priorities for Cambodia. The study was carried out by experts from The Energy and Resources Institute (TERI) through an in-depth analysis of the Cambodian Power sector and renewable energy scenarios in Cambodia.

The objective of FTA was to enhance capacity to transition to renewable energy and energy efficiency by providing a better understanding of the achievable levels of renewable energy integration; developing the capacity to conduct grid stability assessment; developing a comprehensive methodology for the grid stability assessment; and providing technological options for grid stability and renewable energy integration.

One of the major impediments to Cambodia's economy is the limitation of electricity coverage, especially in rural areas. One-third of rural households in Cambodia must rely on off-grid sources of electricity. Issues also remain concerning unreliability and high costs of off-grid/ distributed sources of electricity. On the other hand, Cambodia has plans to expand the national grid and strengthen the energy mix with the integration of more Renewable Energy (RE) such as solar and biomass, and the government has also introduced RE to promote access to electricity for people in remote rural areas. This report focuses on studying the grid stability with the renewable energy integration at the proposed level and identifying the gaps and opportunities for increasing the share of renewable energy in Cambodia.



Acknowledgement

Study on Renewable Energy Grid Integration under the Implementation of Fast Technical Assistance (FTA) for Cambodia is a collective effort put in by The Energy and Resources Institute (TERI) team as well as the members of the Climate Technology Centre & Network (CTCN) amidst the Covid-19 pandemic.

TERI places on record its sincere gratitude to all the key stakeholders in Cambodia, members of The Ministry of Mines and Energy (MME), Electricity Authority of Cambodia (EAC) and Electricité du Cambodge (EDC), who extended their full support all throughout the study. We are grateful to Dr Hak Mao, Director of Department of Climate Change, Ministry of Environment, Royal Government of Cambodia, for his guidance at every stage of the study. The interactions and deliberations with various officers from different stakeholder organizations were constructive, and their cooperation throughout the study was exemplary.

TERI would also like to thank members of CTCN for their support and perseverance in helping complete this research.



Table of Contents

Preface	iii
Acknowledgement	v
Executive Summary	1
Introduction	5
Approach & Methodology	9
2.1 Diagnostic Review of the Power Sector	10
2.2 Gap Analysis and Development of Pragmatic Approach to Address the Gaps Identified	11
Diagnostic Review of the Cambodian Power Sector	13
3.1 Overview of Cambodia	14
3.1.1 Geography	14
3.1.2 Climate	14
3.1.3 Economy	15
3.1.4 Population	16
3.2 Diagnostic Overview of the Power Sector of Cambodia	17
3.2.1 Institutional Mapping	17
3.2.2 Role of EDC	19
3.3 Electricity Demand and Supply Mix	20
3.3.1 Supply Mix	21
3.3.2 Electrification	21
3.3.3 Electricity Demand	22
3.4 Tariff	23
3.5 Losses	24
3.6 Cambodia's Energy Resources	24
3.6.1 Fossil Fuel	24
3.6.2 Hydro Energy	25
3.6.3 Renewable Energy	25



Growing Electricity Demand in Cambodia	27
4.1 Peak Demand	29
4.2 Losses	30
4.3 Future Demand Projections	31
4.3.1 Supply-side Analysis	32
4.4 Why does Cambodia need to trap its Sunshine?	33
Identifying the GAPS and Opportunities for Renewable Energy Grid Integration through PESTLE Framework and Case Studies	35
5.1 Political	37
5.1.1 Strengthening Regional ties in the ASEAN Region or Greater Mekong Region through Cross-border Power Exchange for RE-balancing and Load Management	37
5.2 Economic	39
5.2.1 Green Recovery of Cambodian Economy	40
5.2.2 Curbing the Electricity Prices	41
5.2.3 Financial Incentives to Promote Clean Energy	42
5.2.4 Concessional Climate Finance through Soft Loans, Green Bonds, Guarantees, and Blended Finance	43
5.2.5 Promotion of Global Competitive Bidding in Renewable Energy Development and Balancing Mechanisms	44
5.3 Social	45
5.3.1 Creating an enabling Environment to Boost Employment with Renewables	46
5.3.2 Nurturing Social Entrepreneurship and Women Empowerment through Clean Energy Applications	48
5.3.3 Catalyzing Adoption of Renewable-based Microgrid Systems for Rural Electrification	49
5.4 Technological	50
5.4.1 Utility-Centric Solar Rooftop Programmes	50
5.4.2 Sustainable Hydro Power	51
5.4.3 Adoption of Grid-scale Energy Storage to Mitigate Intermittency in Large-scale Grid Integration of Renewable Energy	51
5.4.4 Large-scale Deployment of Distributed Energy Resources (DERS) and Intelligent Microgrids near Load Centres	56

5.4.5 Embracing Blockchain Technologies to Foster peer-to- peer Trading	60
5.4.6 Developing an Integrated Re-forecasting and Balancing Mechanism	62
5.4.7 Establishment of Renewable Energy Management Centers (REMCs) for Renewable Forecasting & Scheduling	63
5.4.8 Increase Grid Flexibility and Improve the Integration of Renewable Resources through Demand-Side Management (DSM)	64
5.5 Legal	64
5.5.1 Modifications in the Existing Renewable Energy Grid Integration Regulations	65
5.5.2 Enforcement of Renewable Purchase Obligations and Must-Run Status	65
5.5.3 Applying Blockchain Technologies in REC Market Mechanisms	67
5.5.4 One nation-one grid	68
5.5.5 Upgradation of Grid Code and Coordinated Grid Planning & Strengthening	69
5.6 Environmental	74
5.6.1 Cambodia Climate Change Strategic Plan 2014–2023	74
5.6.2 Air Pollution Impacts	75
5.6.3 Role of Biomass	76
5.6.4 Carbon Markets Development to Enhance Emission Trading Schemes	77
Way Forward	79



List of Figures

FIGURE 1:	Challenges Faced By Cambodia	2
FIGURE 2:	Approach And Methodology	10
FIGURE 3:	GDP Growth Rate of Cambodia	16
FIGURE 4:	Distribution of the Population and Households by Provinces in Cambodia	16
FIGURE 5:	Institutional Structure of the Power Sector of Cambodia	18
FIGURE 6:	Electricity Generation Mix of Cambodia	20
FIGURE 7:	Electricity Supply Mix	20
FIGURE 8:	Installed Capacity as per Generation	21
FIGURE 9:	Progress of Electrification	21
FIGURE 10:	Status of Electrification by Provinces	22
FIGURE 11:	Electricity Demand Growth in terms of Number of Consumers and Energy Sold	22
FIGURE 12:	Power Tariffs in Major Southeast Asian Economies (2019)	24
FIGURE 13:	Electricity Demand Pattern of EDC	28
FIGURE 14:	Average Distribution Loss in Cambodia as Opposed to that in Phnom Penh from 2012-2017	30
FIGURE 15:	Growth Peak Demand for the Next 10 Years Under Three Scenarios	31
FIGURE 16:	EDC Projections on Energy Demand and Supply Mix Upto 2030	32
FIGURE 17:	Solar Energy Generation Vs Average Demand of Cambodia	34
FIGURE (I):	Schematic diagram of factors considered for PESTLE analysis	36
FIGURE 18:	Application Potential of Energy Storage Technologies (ESTS)	52
FIGURE 19:	Global Installed Capacity Mix of Energy Storage	53
FIGURE 20:	Usages of Advanced Technologies in Hybrid-renewable Energy Systems (HRES)	60
FIGURE 21:	Thematic Diagram of REMC Mechanism in India	64

List of Tables

TABLE 1:	Retail electricity tariffs (\$/kWh)	23
TABLE 2:	Province Wise Annual Peak Demand of EDC	29
TABLE 3:	Grid side role of various energy storage systems	54





EXECUTIVE SUMMARY

Human activity has warmed the planet at an unprecedented rate in at least the last 2000 years. In 2015, the international community achieved a genuinely historic milestone with the Paris climate accord. To significantly decrease the dangers and consequences of climate change, it was agreed that it is necessary to keep global warming to far below 2 degrees Celsius, ideally 1.5 degrees Celsius, relative to pre-industrial levels. Countries prescribed steps they will take to decrease greenhouse gas emissions to meet the Paris Agreement's targets in their Nationally Determined Contributions (NDCs). Countries also describe activities they will take to enhance resilience in order to adapt to the effects of rising temperatures in their NDCs.

Cambodia has always been a staunch supporter of multinational climate action. As a country particularly vulnerable to the effects of climate change, Cambodia has prioritized comprehending the importance of aggressive climate action. It aims to set an example in accordance with its capacities and duties under the United Nations Framework Convention on Climate Change (UNFCCC).

Cambodia's economy has grown rapidly in recent decades. Like other developing nations Cambodia also struggles to balance the aspirations for economic growth on one arm and its climate commitments on the other. However, the country still lacks the infrastructure needed for the energy industry to keep up with the country's rapid expansion. With expanding cost benefits and the growth of renewable energy, the coming decade is poised to have a profound transformation in the global electricity market.

The key challenges confronting Cambodia's energy sector that hinder its aspirational growth are heavy reliance on imported fossil fuels and power, regular power outages and shortages, the significant environmental impact of hydropower and coal-fired power plants, high cost of electricity, lack of a free economy for attracting investments, etc. Cambodia faces three principal challenges in the current scenario while meeting its growing demand at the same time protecting its people from the growing challenges of climate change; viz-a-viz Energy Access, Integration of Renewable Energy, and Emission Reduction as shown in Figure 1. Large scale integration of renewable energy using its abundant inland resources can help Cambodia reduce the dependency on imports and fossil fuels, avoid large capital-intensive fossil fuel-based power plants and avoid the costly diesel-powered decentralized generations can go a long way for Cambodia to curb not only the climate vulnerability but also boost its economy.

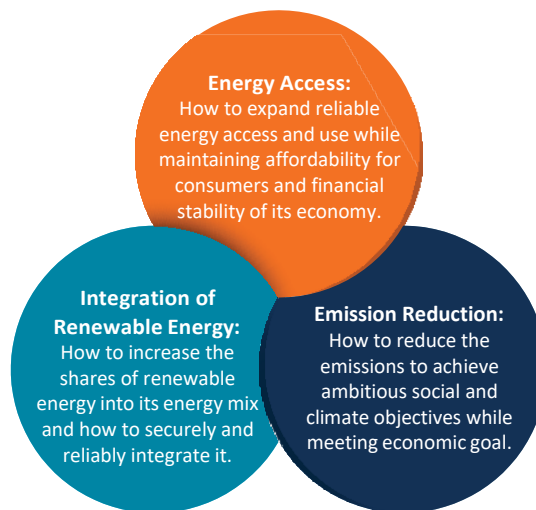


FIGURE 1: Challenges Faced By Cambodia

According to the International Development Research Centre and The United Nations, Cambodia is considered Southeast Asia's most vulnerable country to climate change, alongside the Philippines. With the combined political, economic, social, technological, legal, and environmental (PESTLE) actions towards a sustainable growth goal, Cambodia has a huge responsibility to meet the growing demands through new and improved renewable energy resources. This is stratified in Cambodia's Climate Change Strategic Plan, 2014-2023 to underline its commitment to combating climate change and accelerating the transition to a climate-resilient, low-carbon sustainable development model. Through this study, TERI has mapped these PESTLE factors that affect the grid-integration of renewable energy sources and recommended a holistic way forward for a sustainable future for Cambodia.

1. Political

- a. Strengthening regional ties in the ASEAN Region or Greater Mekong Region through cross border power exchange for RE balancing and load management

2. Economic

- a. Enabling green recovery for the Cambodian economy,
- b. Curbing the electricity prices through large scale integration of renewable energy using its abundant inland resources,
- c. The promotion of renewable energy through fiscal incentives like Tax policies, rebates, subsidies, and performance-based incentives, loan programs, guarantees, and credit enhancements,
- d. Concessional climate finance through soft loans, green bonds, guarantees, and blended finance,
- e. Promotion of global competitive bidding in renewable energy development and balancing mechanisms.

3. Social

- a. Creating an enabling environment to boost employment with renewables through creating jobs, enabling female employment and skilling, promoting the use of distributed renewable energy resources, and introducing mandatory project obligations to train the local workforce.
- b. Nurturing social entrepreneurship and women empowerment through clean energy applications
- c. Catalyzing adoption of renewable-based microgrid systems for rural electrification



4. Technological

- a. Focus on utility centric solar rooftop programs through RESCO model,
- b. Strengthening sustainably developed and responsibly operated hydropower projects,
- c. Adoption of grid-scale energy storage to mitigate intermittency in large scale grid integration of renewable energy,
- d. Large scale deployment of Distributed Energy Resources (DERs) and intelligent microgrids near load centers,
- e. Embracing blockchain technologies to foster peer to peer trading,
- f. Developing an integrated RE-forecasting and balancing mechanism,
- g. Establishment of Renewable Energy Management centers (REMCs) for renewable forecasting & scheduling,
- h. Increasing grid flexibility and improve the integration of renewable resources through Demand-Side Management (DSM).

5. Legal

- a. Amendments in the existing renewable energy grid integration regulations,
- b. Enforcement of Renewable Purchase Obligations (RPO) and must-run status
- c. Applying blockchain technologies in REC market mechanisms,
- d. Administering decentralized energy supply through One Nation-One Grid program to strengthen regional ties and improve balancing
- e. Upgradation of grid code and coordinated grid planning & strengthening

6. Environmental

- a. Administering Cambodia Climate Change Strategic Plan (CCCSP) 2014 – 2023 to meet the nation's Intended Nationally Determined Contribution (INDC) and Cambodia's Updated National Determined Contribution
- b. Diversifying financial support to curb air pollution impacts for clean energy transformation in mobility (electric vehicles, green hydrogen transportation, biofuels etc.), green power resources, clean cooking solutions, electrifying industrial applications etc.
- c. Implementing community-based biomass gasifier systems to address the need for clean and safe energy for household consumption while meeting the RE integration requirements.
- d. Carbon market development to enhance emission trading schemes



INTRODUCTION

The Asia-Pacific area emits half of the global carbon emissions, and it is expected to play a critical role in combating climate change. Many nations have already committed to adopting the Paris Climate Agreement's greenhouse gas reduction goals. Major economies such as Japan, the People's republic of China and the Republic of Korea have lately stated their aim to reach net-zero emissions by the middle of the century, and several other nations in the area are contemplating similar goals.

Reducing emissions necessitates a shift to clean energy, equally necessary for energy security and long-term growth. Fossil fuels supply 85% of the region's energy demands, and some nations are primarily reliant on imports, making them economically vulnerable. Meanwhile, one-tenth of the population in the region still lacks access to power, with many more relying on traditional biomass for cooking and heating, and many metropolitan areas suffer from severe air pollution.

Cambodia is located in South East Asia's lower Mekong region, with 181,035 square kilometres (km) and an 817-kilometre border with Thailand to the west, Lao People's Democratic Republic to the north, and Vietnam to the east.¹ Lowland plains surrounding the Mekong River and Tonle Sap Lake dominates the geographical terrain of the country.

Cambodia's GDP has increased at an annual average rate (AAR) of 7.2% each year since 2010.² The service sector was the largest and contributed the most (38%) to the economy in 2018. The AAGR of the services was 7.2% in 2010–18, however, lower than that of industry (11.1%), which indicates the industry's growing importance in GDP. Both industry and service sectors have resulted in the country's electricity demand growing much faster, at over 20% per year. Cambodia has constructed a slew of new power plants to keep up with its rapid expansion. In 2010, the country had 584 MW of the installed grid capacity, but by the end of 2020, it had grown to 3,897 MW.³ In this context, Cambodia must find new sources of electricity generation that are abundant, secure, affordable, and ecologically friendly since the country's fast economic and electricity expansion is expected to continue far into the next decade.

In 2020, renewable energy accounted for 49% of total electricity generated domestically in the country, which is 8,581 MU contributed by hydropower (45%) and the remaining 4% by solar and biomass resources.⁴ The technical hydropower potential of Cambodia is projected to be 10,000 MW.⁵ Around 90% of hydropower potential is associated with the Mekong River and its tributaries, and the remaining 10% is in the southern coastal highlands.⁶ Out of this enormous capacity, around 1,330 MW has been developed until 2020, and another 300 MW is in the feasibility study stage. The amount of energy generated by hydropower fluctuates considerably between the dry and rainy seasons, with less electricity produced during the hotter months. Furthermore, the country possesses minor and micro hydropower potential; however, the technical potential has yet to be estimated. On the other hand, Cambodia has abundant

¹ <https://www.neda.or.th/2018/en/news/detail?d=nGy4ADWewEb3QWewEb3Q>

² Cambodia Country Report, March 2021

³ Electricity Authority of Cambodia

⁴ Power Development in the Kingdom of Cambodia, December 2020

⁵ MME, 2016. Current Status of Renewable Energy in Cambodia. Presentation prepared for the International Renewable Energy Agency's Renewable Energy Statistics Training. Bangkok, Thailand 12-14 December.

⁶ Cambodia National Mekong Committee, 2003. National Sector Review 2003: Hydropower. Phnom Penh. Quoted in Open Development Cambodia. Hydropower Dams.

biomass energy supplies from several sources, including rubber plantations, fast-growing tropical trees, and agricultural waste. The Asian Development Bank (ADB) calculated a theoretical capacity of 15,000⁷ gigawatt-hours (MU) yearly from biomass resources based on the Ministry of Agriculture, Forestry, and Fisheries data.

Cambodia has one of the highest solar resources in the Greater Mekong Subregion (GSM), with solar irradiation ranging from 1,400 to 1,800 kWh per square metre per year on average across the country, resulting in a technical potential of over 8,000 MW. The peak solar insolation falls in the central part of Cambodia, including the load centres of Phnom Penh, which account for around 70% of national peak demand, is over 1,900 kWh per square metre per year. Solar power is also a viable choice for households in rural areas that do not have access to the grid, as the country has a target of achieving 70% of households having access to grid-quality electricity by 2030.⁸ However, commercial deployment of wind power in Cambodia is minimal as the theoretical potential in the country is in the order of 65 GW.

The electricity generation mix of Cambodia is primarily dominated by coal and hydropower plant. Around 91% of the total generation is constituted by coal (46%) and hydropower (45%). However, gestation period for building up coal or hydropower plants generally takes at least four to five years of construction time to start generating electricity. Given the rapid growth in peak demand and per capita consumption, building power generation facilities with longer gestation periods didn't seem appealing. Furthermore, Cambodia's reliance on neighbouring countries for coal imports, as well as limited water availability during dry seasons and methane emissions from hydropower facilities, force the country to diversify its energy sources. Therefore, Cambodia is taking proactive steps to capitalize on the free solar potential available in the country. In comparison, the country's first and only solar farm, in Bavet, took just one year from the start of construction to start generating power. This is because solar panels are all designed similarly and are simple to install. Solar panels may also be thought of as jigsaw pieces that can be assembled and extended over time to enhance the overall amount of power generated. These qualities allow solar power facilities to boost capacity quickly if electricity demand grows faster than planned.

Further, the Royal Government of Cambodia (RGC) is dedicated to tackling climate change and speeding up the transition to a climate-resilient, low-carbon, long-term development model. Since 1996, the RGC has been a party to the United Nations Framework Convention on Climate Change (UNFCCC), supporting worldwide efforts to combat climate change. Cambodia ratified the Paris Agreement and presented an ambitious Updated Nationally Determined Contribution (NDC) that detailed the country's climate policy developments and proposed mitigation measures. The focus for reducing greenhouse gas (GHG) emissions from the power sector will be possible through the large-scale deployment of renewable energy power generation. This large-scale penetration of intermittent power will impose constraints on the grid's availability and absorption capacity that must be overcome to meet the objectives. In this direction, TERI with support from CTCN conducted a technical assistance study on renewable energy integration of Cambodia. The broad objective of the study is to undertake technical assistance on a fast-track basis on conducting a gap analysis and recommend a practical approach and methodology with innovative technology options to achieve grid stability with renewable energy integration.

⁷ ADB. 2015. Renewable Energy Developments and Potential in the Greater Mekong Subregion. Manila.

⁸ Ministry of Mines and Energy, General Department of Energy, Kingdom of Cambodia



Through this report, the key challenges related to large-scale grid integration of renewable energy in Cambodia have been identified, and the way forward has been suggested for the progression of the power sector of the country. The report is organized into seven chapters:

Chapter 2 :	Detailed out the approach and methodology adopted in the study
Chapter 3 :	Conducted a diagnostic review of the Cambodian power sector. This chapter detailed the current generation and consumption mix of the country including the salient features of generation, transmission, and distribution arms.
Chapter 4 :	Presents the results of the system level load research analysis; it provides an insight into load patterns and peak demands of the country. This chapter also highlighted the present supply mix of the country and the opportunities for renewable energy in peak load management
Chapter 5 :	Highlights the key challenges faced in large-scale promotion of renewable energy in the country. The study undertook a PESTLE analysis which tries to determine exact trends of the renewable market from a macroeconomic point of view. This chapter also presents the global case studies in tackling the issues identified through gap analysis
Chapter 6	Suggests a way forward for the study on how the country can take forward the results of the study



APPROACH & METHODOLOGY

For conducting a comprehensive assessment to identify practical recommendations to aid the future expansion of renewable energy for the Cambodian power sector, some of the important pre-requisites are having a clear understanding of the demand variations along with its future projections, procedures for power supply system planning, infrastructure requirements for increasing demand among other key aspects.

In this regard, TERI undertook a comprehensive study which is divided into two (2) major work packages, “diagnostic review of Cambodian power sector”, and “gap analysis and development of a pragmatic approach to address the gaps identified”. The study involved undertaking utility profiling, system-level load pattern analysis and demand projections for the future, analysis of present supply mix, and identification of strategies for increasing renewable energy power procurement. The approach and methodology adopted for the same are presented in figure 2.

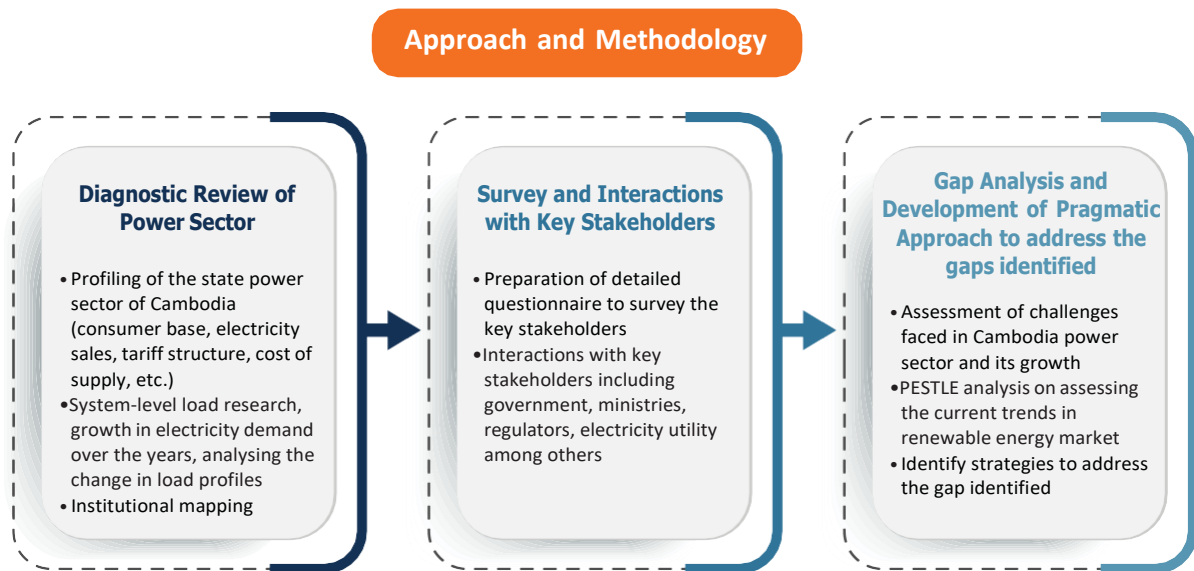


FIGURE 2: Approach And Methodology

2.1 Diagnostic Review of the Power Sector

A study on the country’s power sector profile including the demographic, economic, and electricity supply was carried out to understand various country-specific and utility-specific factors that influence the demand pattern of electricity. In this step, an in-depth study of the institutional framework of the Cambodian power sector was conducted and the roles and responsibilities of main actors in the value chain were mapped.

The demand-side analysis had been undertaken with an aim to evaluate the change in demand patterns taken place over the years and identify measures for effective load management for the future.

System-level load research was carried out with an attempt to understand the demand of the utility, both in terms of quantum as well as pattern. The demand pattern for the utility was studied using system-level load data captured and recorded by the Electricity Authority of Cambodia (EAC). The data collected

was analysed and graphically represented to identify demand variations for the utility. The system peak and off-peak periods were analysed to identify appropriate interventions for the utility for incorporating more renewable energy effectively into the grid.

Stakeholder interactions with utility officials and the other key stakeholders were conducted to understand the status of load management strategies implemented at present and also capture their perspective in identifying new strategies.

Change in the system-level demand data over the past years was analysed with the help of computation of month-wise, hourly slot-wise compound annual growth rate (CAGR) for the system-level demand from FY 2012–13 to FY 2019–20. The growth rate, thus computed, was used to forecast the future demand requirement. The future demand projections were made in an attempt to gauge the need for infrastructure augmentation and network expansion, if required to ensure the reliability of supply.

2.2 Gap Analysis and Development of Pragmatic Approach to Address the Gaps Identified

While demand-side interventions help in managing the power supply at the consumption end, supply-side interventions hold equal importance in maintaining the power supply position. The broad objective was to explore supply-side interventions in order to maintain reliable power supply with the increasing demand, as forecasted under the previous work package. With a push towards large-scale integration of renewable energy to the grid in an attempt to decarbonize the power sector, analysis was focused on identifying measures for “greening” the electricity grid.

In an attempt to understand the present power supply system planning procedures, a comprehensive analysis of the present supply mix of electricity by various generating sources was carried out. While gauging the potential for integration of renewable energy sources, a comprehensive PESTLE framework analysis was conducted to assess the macroeconomic market trends in promoting large-scale grid integration of renewable energy in the country. Using a gap analysis approach, list the potential challenges for achieving the grid stability with the renewable energy integration at the proposed level was also tabulated. Stakeholder interactions were also carried out to assess the challenges faced while attempting to increase the penetration of DERs within the country. This analysis incorporating global case studies helps to develop a pragmatic approach to address the challenges for achieving grid stability with renewable energy integration.





**DIAGNOSTIC
REVIEW OF THE
CAMBODIAN
POWER SECTOR**

3.1 Overview of Cambodia



3.1.1 Geography

The Kingdom of Cambodia is situated in the tropical locale of Southeast Asia in the Lower Mekong area. The country's panorama is overwhelmed by the swamp fields around the Mekong River and the Tonle Sap Lake. It borders Thailand to the north and west, Laos to the northeast, and Vietnam to the east and southeast. It has 443-kilometre (275-miles) coastline along the Gulf of Thailand. Of the country's total land area of 181,035 km², roughly 49% remaining parts are covered by woodland. There are about 2.5 million hectares of arable land and over 0.5 million hectares of field land. The environment in Cambodia is tropical and dependent upon both southeast and northwest storms.



Cambodia has a populace of around 15.1 million individuals, with a growth rate of about 1.8%. Cambodia encompasses twenty-five provinces, which are further subdivided into 159 districts and 26 municipalities.

3.1.2 Climate

Like that of the rest of Southeast Asia, Cambodia's climate is characterized by monsoons, referred to as tropical wet and dry due to their unique seasonal variations. Cambodia has a tropical monsoon climate with temperatures ranging from 21 to 35 degrees Celsius. There are two distinct seasons in Cambodia. The wet season lasts from May to October when the southwest monsoons blow inland, bringing moisture-laden winds from the Gulf of Thailand and the Indian Ocean. The dry season starts from November to April, when the northeast monsoon ushers in the dry season. From September through October, the country receives the most precipitation.

3.1.3 Economy

Cambodia, located between Thailand and Vietnam, is an appealing investment destination for enterprises attempting to grow in ASEAN. Current manufacturing companies are largely centered on food and beverages, chemicals, rubber, plastic, and paper. The garment industry accounts for most of Cambodia's manufacturing sector, accounting for 80% of the country's exports. Agriculture has always been the backbone of the Cambodian economy. Agriculture contributed 90% of GDP in 1985, employed around 80% of the labour force, and has been a prevalent contributor to the economy to date. Rice is the most important commodity, followed by maize, cassava, sweet potatoes, groundnuts, soybeans, sesame seeds, dry beans, and rubber. Tourism has been a source of foreign currency revenues and employment for Cambodian workforce in the Cambodian economy, similar to its neighbouring country Thailand. Although Cambodia exports mainly garments and products from agriculture and fisheries, it strives to diversify the economy.

Economic growth: Cambodia has made significant progress over the last two decades, reaching lower-middle-income status in 2015 and aiming for upper-middle-income levels by 2030. Cambodia's economy, driven by garment exports and tourism, has maintained an average real growth rate of 7.7%⁹ between 1998 and 2019, making it one of the world's fastest-growing economies. Energy, mainly electricity, plays a vital role in Cambodia's ascend in its development. According to the International Development Research Center and The United Nations, Cambodia is considered Southeast Asia's most vulnerable country to climate change, alongside the Philippines. With the combined economic and sustainable growth goal, Cambodia has a huge responsibility to meet the growing demands through renewable energy resources and energy efficiency measures. This is stratified in Cambodia Climate Change Strategic Plan to underline its commitment to combating climate change and accelerating the transition to a climate-resilient, low-carbon sustainable development model.

Impact of COVID-19 pandemic on the economic growth of Cambodia: In 2020, the global shock caused by the COVID-19 pandemic had a substantial effect on Cambodia's economy. Most of Cambodia's key engines of growth—tourism, manufacturing exports, and construction—slowed sharply due to the outbreak, accounting for more than 70% of the country's growth in 2019 and almost 40% of paid employment. In 2020, the economy grew at a negative rate of -3.1%,¹⁰ the steepest drop in Cambodia's recent history, as shown in the figure 3. This downturn in economic growth is evident in decline in electricity consumption by around -1.1% in 2020 compared to 2019 (Figure 3).

⁹ Overview: Development news, research, data | World Bank

¹⁰ Overview: Development news, research, data | World Bank



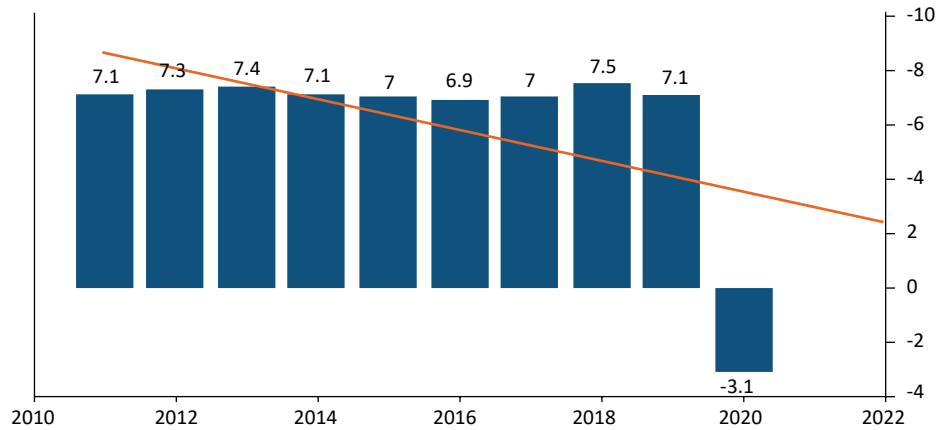


FIGURE 3: GDP Growth Rate of Cambodia

Cambodia's recovery from this impact is much looked into by sector analysts. However, the trend suggests that the GDP should bounce back slowly from 2022 onwards, as shown in the figure 3. According to the World bank, key reforms are needed for Cambodia to sustain pro-poor growth, foster competitiveness, sustainably manage natural resource wealth, and improve access to and quality of equitable access to public services such as electricity. This gives an alluring opportunity for the Kingdom of Cambodia for a market shift in its plans of development. Cambodia continues to have a severe infrastructure gap and would benefit from more excellent connectivity and investments in rural and urban infrastructure. This could increase the need for sustainable RE resources to be integrated to meet the demand and address the challenges in integrating renewable energy resources for its end-use electricity demand.

3.1.4 Population

The population increased steadily at an AAGR of 1.6% in 2010–2018. The urban population has grown by 3.4% per year, faster than the rural population. However, the rural population was still more prominent than the urban population, making up 77% of the total population in 2018. Population increased steadily

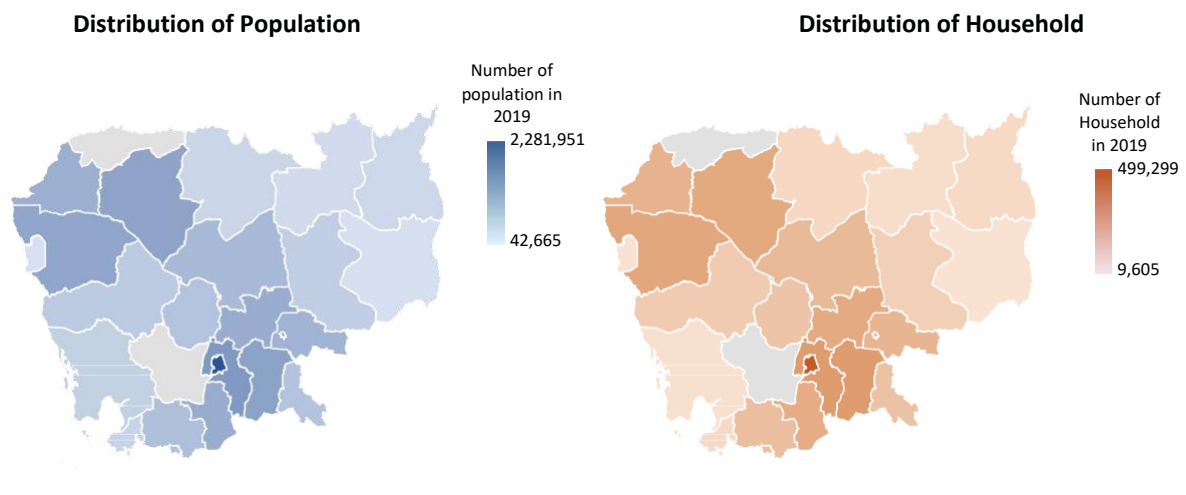


FIGURE 4: Distribution of the Population and Households by Provinces in Cambodia

at an AAGR of 1.6% in 2010–2018. The urban population grew by 3.4% per year, faster than the rural population. However, the rural population was still more prominent than the urban population, making up 77% of the total in 2018. The distribution of the population and households by provinces are given in figure 4

3.2 Diagnostic Overview of the Power Sector of Cambodia

During the 1970s, the electricity sector was seriously damaged by the civil war from 1970 to 1979. During this time, there was only one transmission line in Cambodia connecting the Kiriom I Hydropower Station to Phnom Penh capital town with a voltage rating of 115 kV and length of 120 km, which ceased to operate since 1973 when most electricity-related facilities including generation, transmission and distribution facilities were nearly destroyed.

Since 1985, the Cambodian government is making efforts to reestablish the electricity sector. However till today, there is no national electricity network and electricity is supplied via small isolated electricity system.

The Electricity Law, adopted by the National Assembly on November 6, 2000, and signed by the King on February 2, 2001 defines the main actors in Cambodia's power sector and governs their roles and relationships.

3.2.1 Institutional Mapping

The Electricity Law establishes the sector regulator, the EAC, distinguishing between its responsibilities and those of the Ministry of Mines and Energy (MME). EDC is a state-owned power utility. The Law establishes that EAC regulates EDC and all other power service providers, including mini-grids, Independent Power Producers (IPPs), and private transmission companies. Figure 5, provides an overview of the institutional structure of the power sector of Cambodia.

As per the provisions of the Electricity Law, each electricity service provider is required to have a license issued by EAC. At the end of 2020, valid licensees totalled 429: 1 consolidated generation, distribution, and national transmission license (EDC); 26 generation licenses to IPPs; 8 special purpose transmission licenses; 8 consolidated licenses consisting of a Special Purpose Transmission and a distribution license; 335 distribution licenses; 5 retail licenses; 12 consolidated licenses consisting of generation and distribution licenses; and 34 subcontract licenses. The number of licenses grew from 143 in 2006.

- **The Ministry of Mines and Energy (MME):** The MME oversees the entire electricity industry. Energy Policies, Electric Power Strategies, Power Development Plan Technical Safety and Environmental, Standards, and other duties in the power industry are the responsibility of the Ministry.
- **Electricity Authority of Cambodia (EAC):** The Royal Government granted the Electricity Authority of Cambodia the right to an autonomous body to control electric power services and govern the relationship between the delivery, receiving and usage of electricity, The Electricity Authority of Cambodia considers the government policies, strategies, and planning in the power sector, the government policies, strategies, and planning in the power sector, aiming to reduce the long and



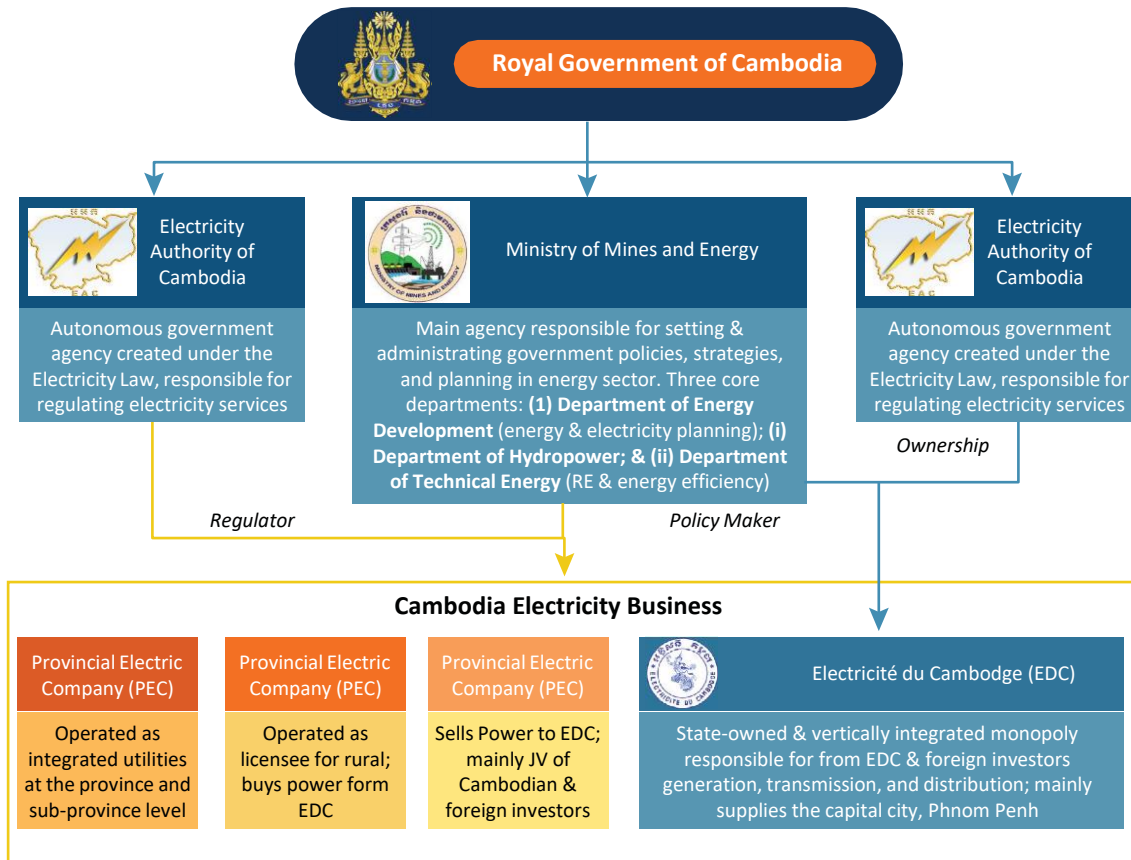


FIGURE 5: Institutional Structure of the Power Sector of Cambodia

short-run marginal cost of supplying electricity throughout the Kingdom of Cambodia. It serves as the regulatory body for the Electric Power Services, including issuing regulations and licenses, reviewing expenses and approving tariffs, resolving disputes, and so on.

- **Ministry of Economy and Finance (MEF):** The Ministry of Economy and Finance (MEF) accounts for the administration of financial and economic policy and affairs in the Kingdom of Colombia. EAC submits the budget to the Government, through the MEF, for review and approval.
- **Rural Electricity Enterprises (REEs):** The supply of electricity to the rural areas of Cambodia is provided by REEs which operate as licensees, buying power from EDC and selling power into local distribution networks. REEs may have their own generation assets. Promoting private participation in electrification, including rural electricity enterprises (REEs), is mandated by Cambodia's 2001 Electricity Law. In the past, it was estimated that 600–1,000 REEs provided electricity to off-grid customers, traditionally through diesel.
- **Provincial Electricity Companies (PECs):** Provincial electricity companies (PECs) have operated as integrated utilities at the province and sub-province level; these organizations have mostly been phased out in favour of REEs and IPPs.
- **Independent Power Producers (IPPs):** Independent power producers (IPPs) have a generation license and sell electricity to suppliers or industries through a Power Purchase Agreement (PPA).

- **Electricité du Cambodge (EDC):** In the Kingdom of Cambodia, EDC has been granted the Consolidate License comprising of Generation License, National Transmission License and Distribution License. In its License, EDC has been authorized to operate specified generation facilities, purchase electricity from sources available at present and in the future, plan, develop and operate the transmission system, and distribute electricity in its authorized distribution areas.

3.2.2 Role of EDC

Generation: In Cambodia, generation is dominated by the private sector, and EDC purchases power from independent power producers (IPPs), mostly joint ventures between Cambodian and foreign investors. The EDC is also in charge of power imports. In terms of distribution, EDC primarily serves the larger urban areas, while other small, privately held electricity entities service Cambodia's rural areas.

Electricity Imports: In recent years, Cambodia has imported around 31% of its energy from fossil fuel-based generation in neighbouring countries. The share of imports in the consumption mix of Cambodia is shown in the figure 6. This calls for an urgent need to shift towards cleaner national resources of electricity within Cambodia. Owing to the commitments made by the Kingdom of Cambodia towards its Nationally Determined Contributions (NDC) to mitigate climate change, a shift towards cleaner renewable energy solutions to meet the growing needs of the country is highly predated. The high gestation period to set up thermal and hydro powerplants also focuses on the tapped potential for renewable energy sources, especially solar and biomass. This will not only ensure energy security for Cambodia but also helps reduce the high electricity tariffs and greenhouse gas emissions in the longer run.

Transmission: EDC develops and operates the transmission system in Cambodia. Other private licensees are granted Special Purpose Transmission Licences, which authorizes to provide transmission and sub-transmission services by operating facilities specified in their licenses

Distribution: EDC distributes electricity in its authorized distribution areas. Other private licensees are granted distribution licenses, which allow purchase of electricity from other licensees specified in their License and provide distribution service in the authorized area specified in their licenses. So all licensees other than EDC can purchase electricity only as specified in their License and not from any other source. By the end of 2020, only four licensees were operating the isolated system.¹¹

For smooth, efficient, and economic development and operation of the Electricité Supply System of National Grid in Cambodia, EDC purchases electricity from all sources connected to the Electricité Supply System of National Grid; aggregate the cost of all sources of electricity, calculate the average cost of electricity and then determines the tariff for supply to licensees and consumers based on this average cost. Based on this, the electricity injected into the National Grid by all sources, including the Solar PV system and injected at any level either through the system owned by EDC or through the system owned by other licensees, must be purchased by EDC only.¹²

¹¹ EAC Annual report 2020

¹² Regulation on General Conditions for connecting Solar PV Generation sources – EAC - 2015



3.3 Electricity Demand and Supply Mix

In FY 2019–20, Out of the 12400.75 MU of electricity procured in Cambodia, 8581 MU were procured from its local generating units and approximately 3820 MU were imported from the neighbouring countries of Laos, Thailand, and Vietnam. The break-up of the electricity mix is given in figure 6.

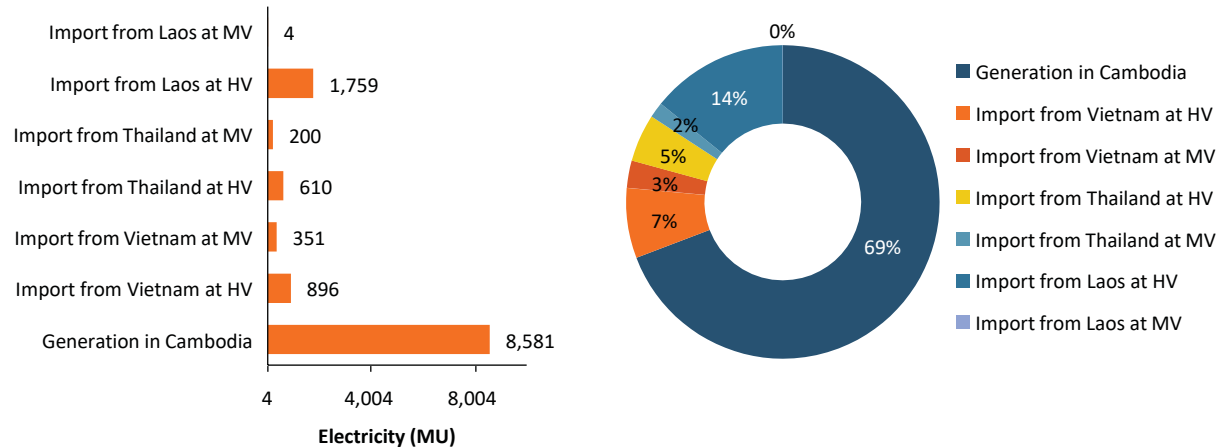


FIGURE 6: Electricity Generation Mix of Cambodia

Figure 7 shows that 8561 MU is the generation within Cambodia with an installed capacity of 2187 MW. The significant share of the nation's electricity demand is met from electricity generated by Electricité du Cambodge, Independent Power Producers, and other licensees operating generation facilities, as shown in the figure 7.

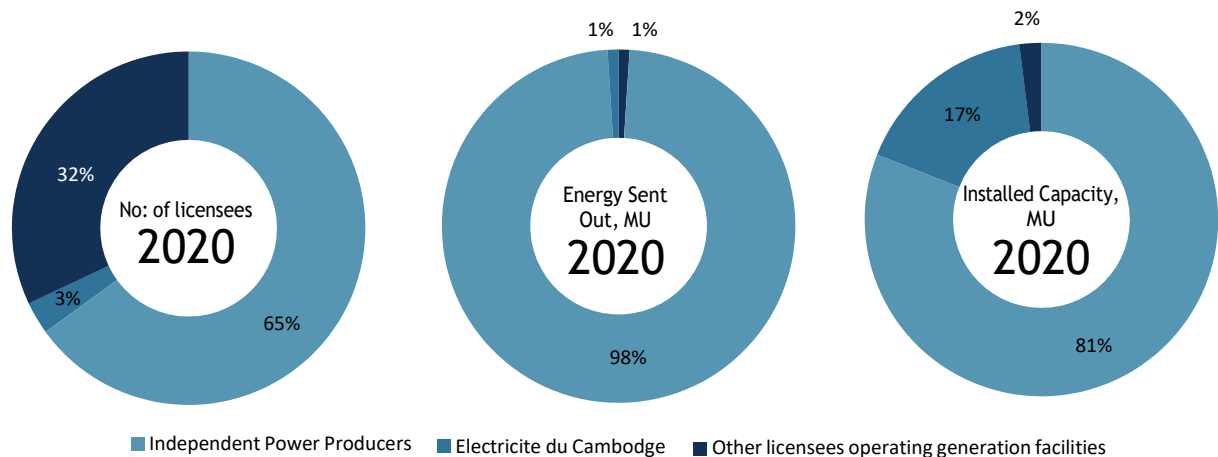


FIGURE 7: Electricity Supply Mix

3.3.1 Supply Mix

The electricity production facilities in Cambodia use five different sources for electricity, vis-à-vis hydropower plants, diesel power plants, coal-fired thermal power plants, wood and other biomass power plants, and solar power plants. The share of various sources of electricity in the installed capacity of the country against a total of 2991 MW is shown in figure 8.

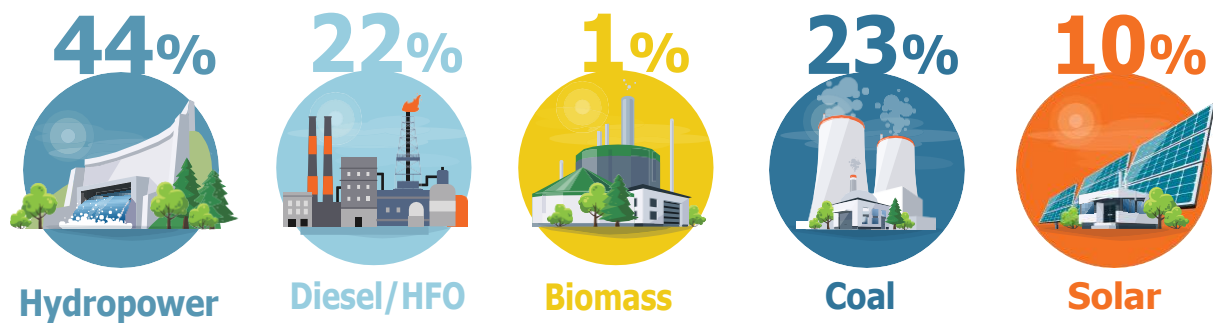


FIGURE 8: Installed Capacity as per Generation

The share of coal and hydropower in Cambodia's energy supply increased significantly from 2010 to 2020 with the commissioning of new coal and hydropower plants; during this period, the share of coal increased from 9.7% to 23%, while the share of hydropower increased from 0.1% to 44%.

3.3.2 Electrification

According to EAC, by the end of 2020, almost 97.49% of the consumers were connected to the National Grid system. As per IEA's World Energy Outlook-2020, more than 99% of the population in the urban cities of Cambodia has access to electricity as opposed to 67% in rural towns in 2019. Figure 9 shows the progress of electrification of villages and households in Cambodia.

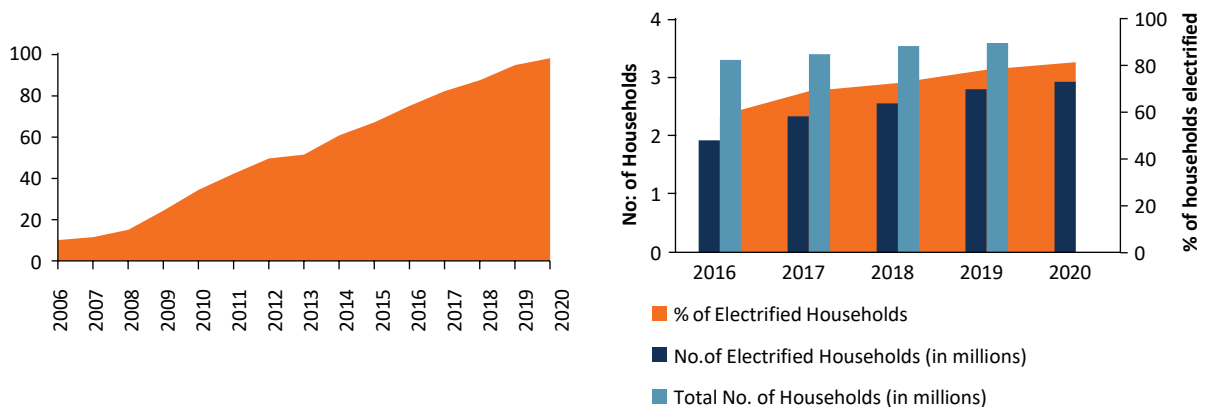


FIGURE 9: Progress of Electrification



3.4 Tariff

Electricity tariffs in Cambodia are higher than those in neighboring countries, reflecting the high cost of petroleum-based generation and the fragmented power supply system in the country and inefficiencies in power generation and transmission infrastructure. In Phnom Penh, householders pay about \$0.18/kWh, and industrial consumers pay as much as \$0.21/kWh. Tariffs are even higher outside of Phnom Penh, at about \$0.7/kWh, and supply is even less dependable. Retail electricity tariffs established by the EAC for 2016 through 2020 are summarized in Table 1¹³. Retail tariffs are expected to decline, reflecting the drop in the overall cost of supply as the share of imports, and diesel-based electricity decreases and supplies from low-cost coal and hydro plants increases. EDC's weighted average cost of supply was estimated at \$0.106/kWh in 2014 and \$0.095/kWh in 2015. The tariff that REEs can charge residential consumers has been reduced to \$0.20/kWh. While the EAC is an independent regulatory authority, a no-subsidy policy has been consistently applied in Cambodia's energy sector, except for lifeline tariffs for poorer consumers, so retail tariffs are not expected to go below EDC's average cost of supply. The decreasing cost of implementation of solar projects and high retail tariffs, combined with abundant solar resources, offer great potential in Cambodia for utility-scale solar projects without subsidies such as feed-in tariffs, by achieving solar power production at grid parity.

TABLE 1: Retail electricity tariffs (\$/kWh)

Types of Consumers	2016	2017	2018	2019	2020
Industrial and commercial customers					
Purchase from grid substation	0.13	0.13	0.13	0.13	0.13
Purchase from national grid	0.17	0.17	0.17	0.16	0.16
Purchase from provisional grid	0.17	0.17	0.16	0.16	0.16
Residential customers					
Supplied by EDC	0.22	0.19	0.19	0.19	0.18
Supplied by licensees (REEs)	0.20	0.20	0.19	0.19	0.19
Subsidized tariff for poor household and agriculture					
Urban consumers with use below 50 kWh/month	0.15	0.15	0.15	0.15	0.15
Rural consumers with use below 10 kWh/month	0.12	0.12	0.12	0.11	0.11
Pumping in agriculture sector; use from 21:00 to 7:00	0.12	0.12	0.12	0.11	0.11





POWER TARIFFS IN MAJOR SOUTHEAST ASIAN ECONOMIES, 2019

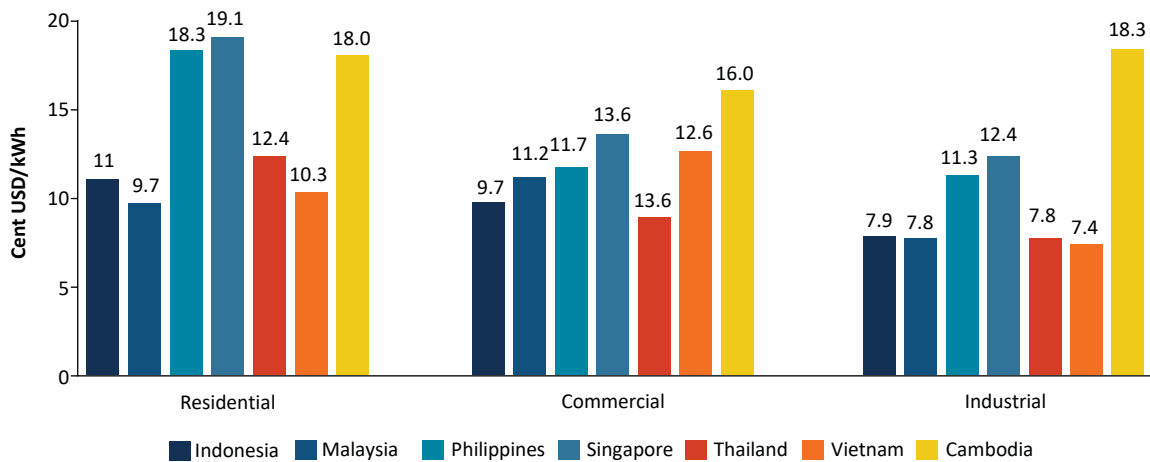


FIGURE 12: Power Tariffs in Major Southeast Asian Economies (2019)

3.5 Losses

Each year, the infrastructure for supplying energy to customers and the number of villages supplied with power grows due to the issuance of new licenses, the development of supply regions, and the growth of grid supply. EDC tries to reduce the losses at every stage of development. As of 2020, the overall percentage of loss amounts to 10.5% compared to 11.58% in the previous year.¹³

However, the distribution loss of the provinces average upto 6.82 percentage.

3.6 Cambodia's Energy Resources¹⁴

The country remains highly vulnerable to the impacts of climate change due to its high dependency on climate-sensitive sectors such as agriculture, water resources, forestry, fisheries, tourism, etc. Electricity production relies mainly on fossil fuel combustion, which accounts for 95.2% of the total mix. In comparison, hydropower and other renewable energy represent only 3.3% and 1.5%, respectively. The promotion of low-carbon planning and technologies to support sustainable development is one of the eight strategic objectives of Cambodia Climate Change Strategic Plan 2014 – 2023 (CCCSP).

3.6.1 Fossil Fuel

Cambodia imports all of its fossil fuels, including coal and oil. Preliminary estimates for national coal resources are minimal (about 7 million tonnes), and commercial-scale mining has yet to begin. In addition, Cambodia has relatively little oil exploratory drilling and no refineries. The nation possesses unexplored and generally unquantified petroleum extraction potential; nonetheless, various geological

¹⁴ Cambodia Energy Sector Assessment, Strategy and Road Map-ADB

characteristics, including parallels to neighbouring oil and gas producing areas in Vietnam and Thailand, hint to commercially feasible oil and gas potential. Seismic data reveal that onshore regions have three times the potential petroleum resources as offshore locations, according to the General Department of Petroleum of the Ministry of Mines and Energy (MME).

3.6.2 Hydro Energy

The hydroelectric potential of Cambodia is significant, particularly due to the quick current of the middle Mekong River, which runs through the provinces of Stoeng Treng and Kratie. Other smaller sites exist on rivers in the highlands of the country's northeastern and north-central highlands. Although the Tonle Sap is Cambodia's most important hydraulic feature, the rivers that flow into it have little or no economic potential.

In general, developing Cambodia's water potential looks to be more vital for agricultural expansion than for electricity production. Lower Se San 2 Project, Cambodia's largest hydroelectric dam, commenced functioning in November 2017 and was planned to be fully operational by October 2018. Stung Treng Dam is a projected hydroelectric dam with an average annual production of 4,870 GWh, over 2.5 times that of Lower Se San 2.

The technical hydropower potential of Cambodia is projected to be 10,000 MW. Around half of the hydroelectric resources are on the Mekong River, 40% on tributaries of the Mekong River, and 10% in the southern coastal highlands. Only 980 MW of the 10,000 MW capacity have been built, 400 MW are under construction, and another 90 MW are in the feasibility study stages.

3.6.3 Renewable Energy

Mini/micro/pico hydropower, solar, biomass, and other renewable energy sources renewable energy sources are available in Cambodia. Compared to its neighbours, Cambodia's development of renewable energy sources is developing at a snail's pace due to a lack of expertise, funds, and data. As a result, these sources provide a minimal contribution to the entire energy supply mix, which is primarily reliant on imported fuel oil for power production. To promote RE development, Cambodia is constructing an RE plan, which lay out the policy goal, objectives, and suggestions for developing the required infrastructure to deliver renewable power services in rural regions.

"Cambodia is short of energy, which is one of the reasons for its low level of industrial development. Consideration should be given to more eco-friendly energy sources such as hydropower. During this stage of increasing energy supply, the integration of renewable energy sources must be considered in future energy production" -CCCSP¹

Biomass: Cambodia has abundant biomass energy resources from a variety of sources, including rubber plantation forests, fast-growing tropical trees like Gliricidia and Acacia, and agricultural residues like rice husk, rice straw, corn cobs, waste from palm oil extraction, cassava stalk, sugarcane bagasse, and cashew nut shells. According to ADB, the overall theoretical potential of agricultural leftovers is around 15,000 gigatonne-hours (GWh) each year.



Solar energy: Cambodia has some of the highest solar resources in the Greater Mekong Subregion (GMS), with solar irradiation averaging 1,400–1,800 kWh per square metre per year across the nation resulting in an estimated technical potential of over 8,000 MW.

Wind energy: Localized wind evaluations show that portions of the nation contain medium-intensity wind resources suitable for utility-scale turbines. Wind speeds vary from 6 to 9 metres per second per year in the southern sections of Tonle Sap Lake, the southwestern mountainous highlands, and along the coast; nevertheless, this only accounts for 3–5% of Cambodia’s geographical area. Based on these observations, the ADB calculated Cambodia’s theoretical wind potential to be 65 gigatonnes, with a potential annual output capacity of 154 terawatt-hours (TWh). Considering the grid’s ability to absorb this load, Cambodia’s technical wind potential was projected to range between 18 and 72 MW.



GROWING ELECTRICITY DEMAND IN CAMBODIA

Cambodia is witnessing strong economic growth, rising electrification rates, and rising electricity consumption as a result. The government faces a difficult task in keeping up with high peak electricity demand growth while also expanding access to previously unserved areas and addressing concerns of energy security, affordability, and environmental sustainability

Considered as an initial step for identifying measures for effective integration of renewable in the grid, load research assists in understanding the demand of the utility, both in terms of quantum and pattern and profile. Analysis of the system-level load data and growth rate of various consumer categories was carried out to understand the changing demand patterns at the system level and to also understand the impact of various consumer categories at the system level. Figure 13 highlights the demand pattern of the utility at the system level during the last 10 years.

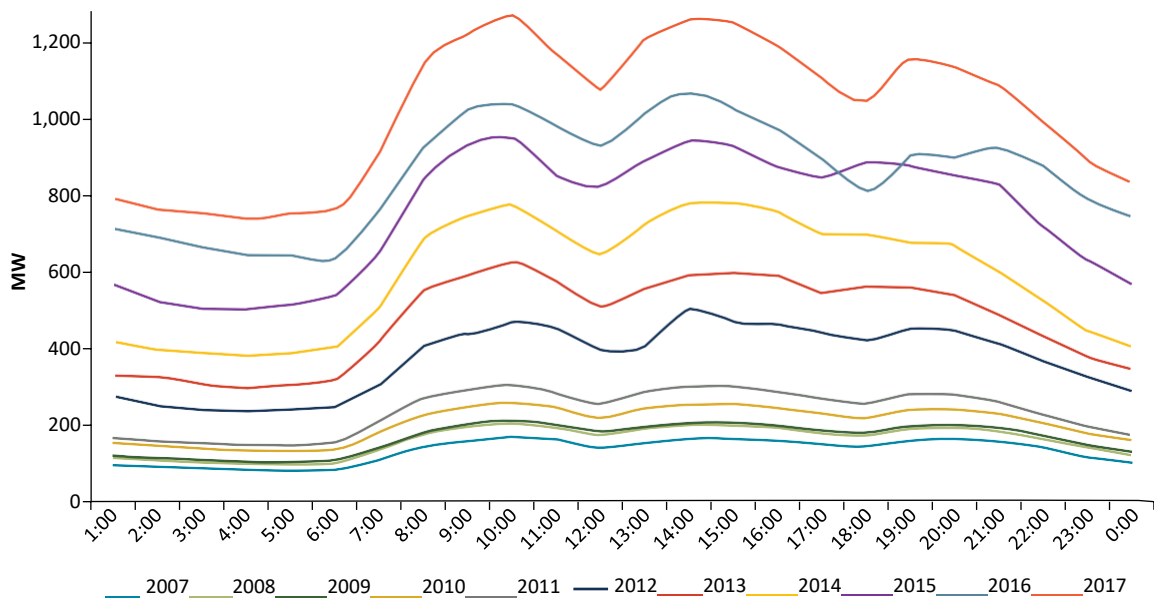


FIGURE 13: Electricity Demand Pattern of EDC

It has been observed that the load pattern, peaking time as well as ramping rate for the utility tends to remain the same over the years. This can be attributed to various parameters, one of the major ones being the same consistency in consumer behaviour patterns over the years. However, the annual electricity demand from 2007 to 2020 is growing at the rate of 18%, which is mainly attributed to the increasing electricity access among the mass population and the industrial boom that happened in the country during the last decade especially among the textile, food processing, and tourism industry.

Figure 13 shows two distinct peaks in the Cambodian system-level load curve during daytime; i.e., from 09:00-10:00hrs and 13:00-14:00hrs. Morning peak (9:00-10:00hrs) is attributed mainly due to the pooled effect of commercial activities in the country's capital region and the start of operations for the majority of the industrial consumers. However, this pattern tends to form a "V" shaped curve between 11:30 hrs and 12:30 hrs which is primarily due to the break timings in the commercial and industrial establishments. The demand used to ramp up after 13:00 hrs due to the high starting current requirement in the industrial establishments to resume operations after lunch hours. The demand tends to continue to be uniform till

evening hours from when it moderately declines till 18:00 hrs. A moderate peak is observed after 18:30 hrs, which is due to the incremental lighting requirement from the households. Beyond 22:00 hrs the demand falls continuously and attains an average demand ranges from 800–850 MW. The ramping and peaking of power demand is observed to be high during daytime as the average demand tends to be uniform across the day and night; this can be due to the country's dependency on tourism and three-shift operations of industrial consumers.

4.1 Peak Demand

From 2012–2017 the annual peak electricity demand growth in the country is 20%. Table 2 detailed the peak demand at national levels and all provinces during the last 5 years.

TABLE 2: Province Wise Annual Peak Demand of EDC

Location	2012	2013	2014	2015	2016	2017
National Grid	508	625	784	951	1,068	1269
PHN	410	493	563	674	757	777
SRP	47	57	59	68	83	89
SHV	19	25	30	40	46	68
KGG	10	17	14	22	32	36
PKK	7	7	6	4	4	7
MMT	4	5	4	7	7	6
TKO	7	9	18	20	23	21
BIB	21	23	26	4	65	71
KPT	5	6	13	18	16	15
KGT	3	3	3	5	3	3
pRV	3	3	8	14	15	21
BTG	9	11	19	23	24	26
ST	3	4	5	3	8	12
RTK	4	4	5	6	7	13
SVR	5	7	8	12	30	19
BVT	15	16	17	17	16	27
MDKR	1	1	1	1	2	4
KSM	0.4	05	1	1	1	1
KRT	1	2	3	3	8	9
SNL	1	1	2	2	3	2
KPS				38	42	46

Table 2 denotes that the peak demand of the national grid got doubled over the last 5 years, i.e., from 508 MW in 2012 to 1269 MW in 2017. This clearly indicated the economic development and increased access to electricity in the country during the past 5 years. However, around 80% of the national peak demand is concentrated among four provinces namely, Phnom Penh, Siem Reap, Sihanouk Ville, and Battambang.



4.2 Losses:

From 2012–2017 the average distribution loss in the country reduced from 7% in 2012 to 3 per cent in 2016 and slightly increased to 4 per cent in 2017. Figure 14 shows the average distribution loss in Cambodia as opposed to that in Phnom Penh, the most densely populated and largest electricity consuming province in Cambodia.

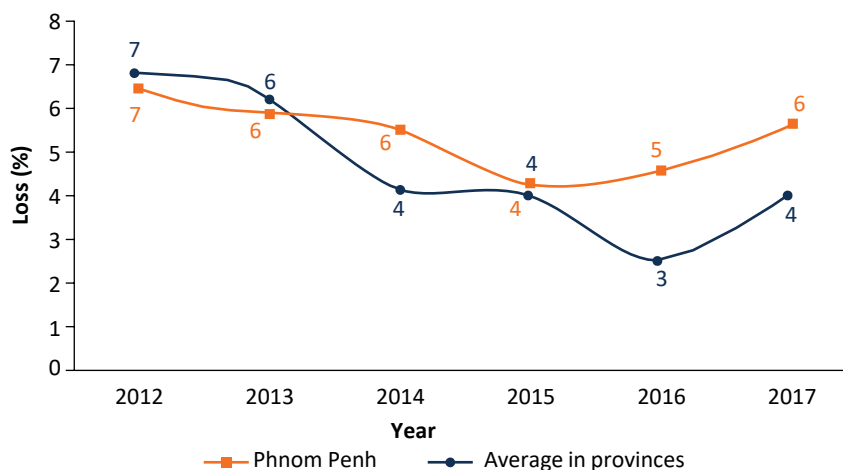


FIGURE 14: Average Distribution Loss in Cambodia as Opposed to that in Phnom Penh from 2012-2017

Phnom Penh: It is Cambodia’s capital and most densely populated province in the country. Since the French protectorate of Cambodia, it has served as the country’s commercial, industrial, and cultural hub. It holds Cambodia’s most populous region, with more than 15% of the country’s total population. Furthermore, this province absorbs more than 60% of the country’s overall electricity demand.

Siem Reap: Cambodia’s fourth most populous province is also the country’s cultural hub. The renowned Angkor temples are located here, as with many other tourist attractions such as floating villages and Tonlé Sap. Tourism is a significant part of Siem Reap’s economy; it is believed that over half of the town’s jobs are connected to the tourism sector.

Sihanouk Ville: Coastal province of Cambodia, located on the Gulf of Thailand at the tip of an elevated peninsula in the country’s south-west. The local economy is mainly defined by its deep water port and the neighbouring oil terminal, which was established as an international maritime gateway. The Sihanoukville Special Economic Zone (SSEZ) is an international economic and trade cooperation zone that was created to promote favourable market conditions such as policy advantages, a stable political environment, favourable trade status, completed infrastructure, low labour costs, and high quality services

Battambang: Battambang is the country’s leading rice-producing province. The province’s abundant rice fields have resulted in a primarily agricultural economy, earning it the nickname “Rice Bowl of Cambodia.” Agro-based and food-processing sectors are dominant.

4.3 Future Demand Projections

Cambodia is a well sought-after traveller destination in South East Asia, mostly popular for its bright sunny beaches. Presently, the Gross Domestic Product (GDP) for the country is predominantly contributed by the service sector including the hospitality industry (38%) followed by other industrial subsectors (12%). The hospitality industry is an electricity-driven sector. Further, the total electricity requirement and per capita consumption of the country has been increasing steadily on year-on-year basis.

As per ADB estimates, electricity demand grew at an average annual rate of 18% from 2011 to 2015. In the future, on an 8.8% CAGR in power demand through 2030, with Cambodia's energy consumption expected to climb to 18,000 MU by 2030, a more than threefold increase over demand in 2015.

Similar findings were observed while undertaking the computation of future demand projections based on the system-level data collected from EAC. The future demand was projected for the next 10 years, i.e., from 2021 to 2030, under three different scenarios while taking into impact of COVID.

Scenario I: Projection with the base year 2019, i.e., before the COVID-19 pandemic

The demand for 2019 as the base year and the GDP growth rate at 7%

Scenario II: Projection with base year FY 2020, i.e., COVID-19 impacted year

The demand for 2020 as the base year and GDP growth rate as 6%, after considering a 1.1% drop in electricity demand during COVID-19.

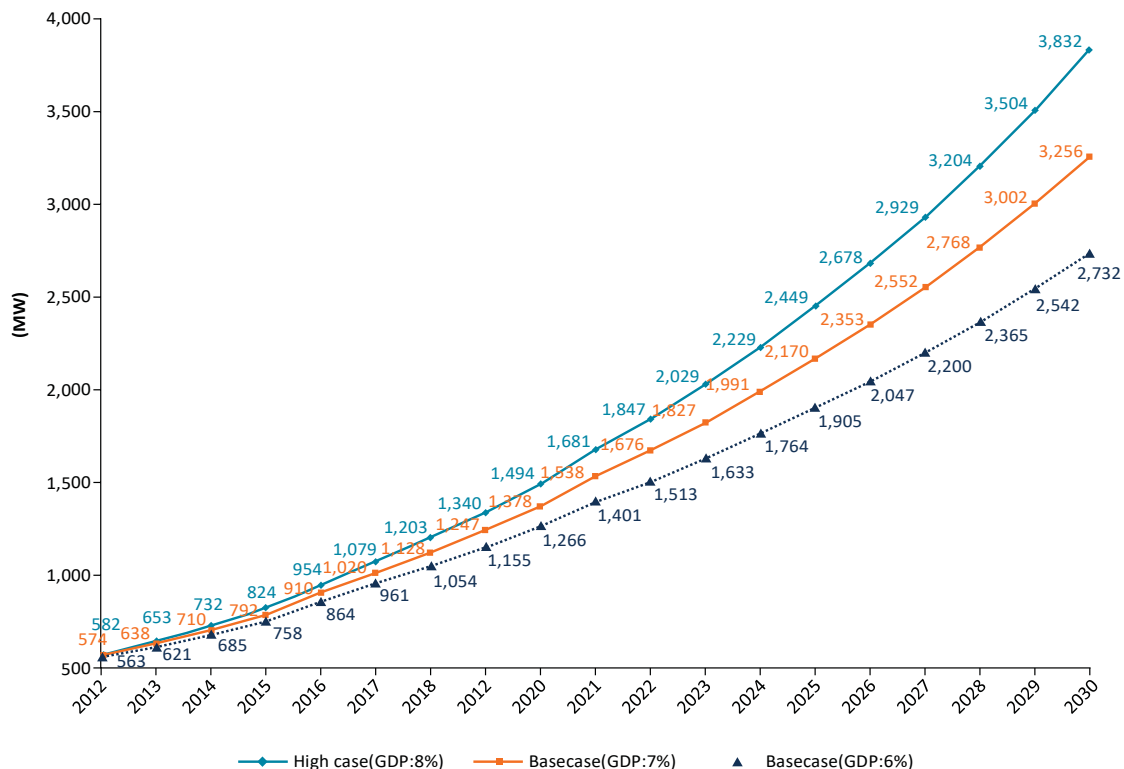


FIGURE 15: Growth Peak Demand for the Next 10 Years Under Three Scenarios



Scenario III: Projection with base year FY 2019, fast recovery of economy post COVID-19

The demand for 2019 is the base year and with a high GDP growth rate, i.e., 8 percent.

Figure 15 depicts the growth peak demand for the next 10 years under the three scenarios. It is observed that under scenario-I, the peak demand is projected to grow from 1312 in 2019 to 3256 in 2030. On the other hand, under scenario-II, the peak demand is expected to increase from 1408 MW in 2020 to 2732 in 2030. Under a fast recovery scenario, the demand is expected to grow from 1312 in 2019 to 3832 in 2020.

4.3.1 Supply-side Analysis

It is evident from the above analysis that the electricity demand is growing to get doubled in the next 10 years. Therefore, adequate integrated resource planning needs to be carried out to meet this growing demand in the country. According to EDC projections (refer to figure 16), hydropower will dominate energy production in the short term, but coal power plants fuelled by imported coal will also be a key source by 2022. This additional generating capacity has allowed Cambodia to lessen its reliance on oil for electricity generation, and therefore its vulnerability to foreign oil price increases. This is also a significant counterbalance to the fast-rising demand for oil in the transportation sector. However, rising coal use has created several issues that must be addressed, including increased carbon emissions, localized air pollution, control of coal importation facilities in the southwest, and exposure to imported coal at international rates.

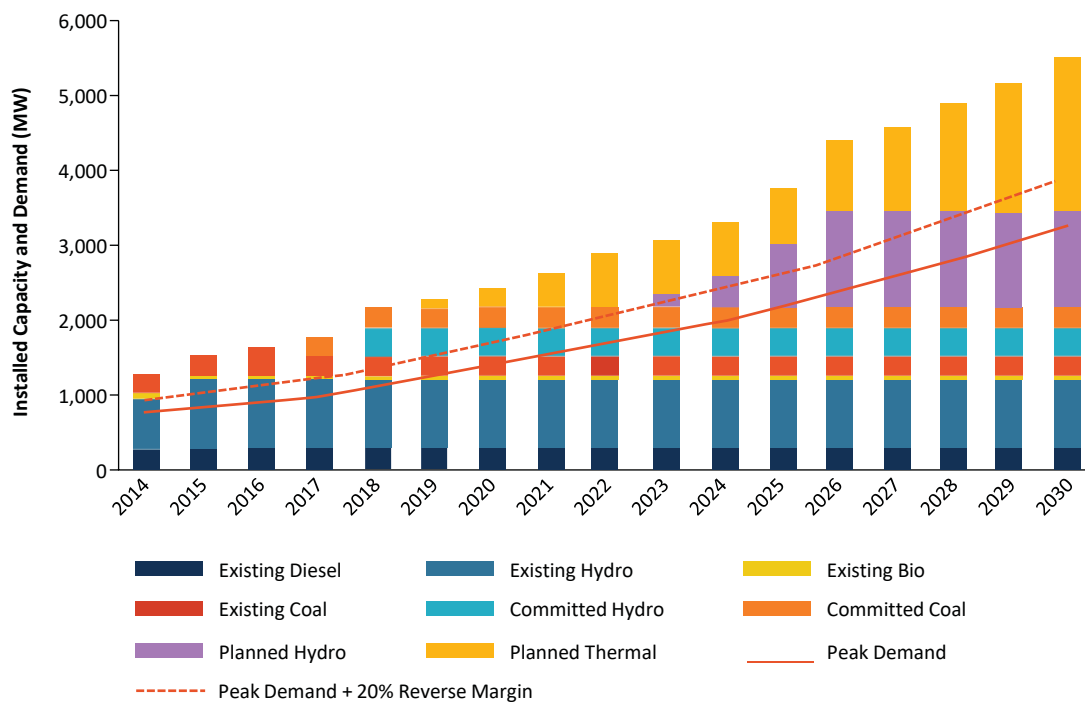


FIGURE 16: EDC Projections on Energy Demand and Supply Mix up to 2030

Further, building new generating plants (hydro and coal) far from Phnom Penh's primary load centre, is posing many operational problems for EDC's National Control Centre in terms of ensuring the power system is run in a way that minimizes power system stability concerns. This indicates that some of the newly installed generating resources have not been fully utilized, requiring the need for further transmission equipment expenditures. It is important to note that during the COP26 in Glasgow, Cambodia committed to stop constructing new coal power plants beyond already approved projects in the pipeline. Therefore, it would be beneficial to promote renewable-based power plants especially solar, which could be created near local load centres with a minimum gestation period.

4.4 Why does Cambodia need to trap its Sunshine?

Geographical position and solar potential: Cambodia is a tropical nation, just a few degrees above the equator, with temperatures ranging from 21 to 35 degrees Celsius. Throughout the year, the sun shines for an average of 8 hours each day in Cambodia. Cambodia's recorded solar irradiation, which is a measurement of solar energy received over a square metre of land, is relatively stable, averaging 5 kWh/m² daily and maximum at 5.6 kWh/m² in central Cambodia. These figures are far higher than those of some of the early movers in solar energy, for example, over twice as high as Germany's.

Free and secure fuel source: When compared to typical conventional sources such as coal, which necessitates importing resources from neighbouring nations, generating energy from a solar plant is quite straightforward. By turning sunlight into electricity, well-placed solar panels can simply and efficiently harness the sun's energy. The increased solar output would lessen Cambodia's dependency on importing resources and electricity from its neighbours because solar energy is free and guaranteed every day.

Falling solar prices globally: Over the last 10 years, the global solar energy sector has developed as competition for solar panel production has increased dramatically. Solar panels cost \$3.15 per watt in 2008, but by 2020, they cost only \$0.10.¹⁵ According to experts, the cost of constructing new big solar power plants for energy generation would drop by another 71% by 2050.

Support country's vision on rural electrification: In Cambodia, solar technology is readily available, and it has shown to be a great alternative for rural areas that are too far away from the conventional grid facilities. The solar home system has gained popularity among households in rural communities due to a significant price reduction. Solar home systems are now used as one of the major sources of power by more than half of Cambodia's off-grid homes. The Royal Government of Cambodia has set a goal of electrifying 70% of households with grid-quality electricity by 2030. Solar energy will become a vital component in bringing dependable electricity access to distant areas in Cambodia as the price of solar household systems continues to plummet year after year.

Effective tool for peak load management: Solar energy can only create electricity when the sun is shining. This corresponds to Cambodia's increasing need for power during the day. Solar power generation coincides with the two distinct peaks in the Cambodian national grid. Therefore, large-scale adoption of solar both at transmission and distribution level could clip the peaks for better load management.

¹⁵ <https://www.energy.gov/eere/solar/sunshot-2030>



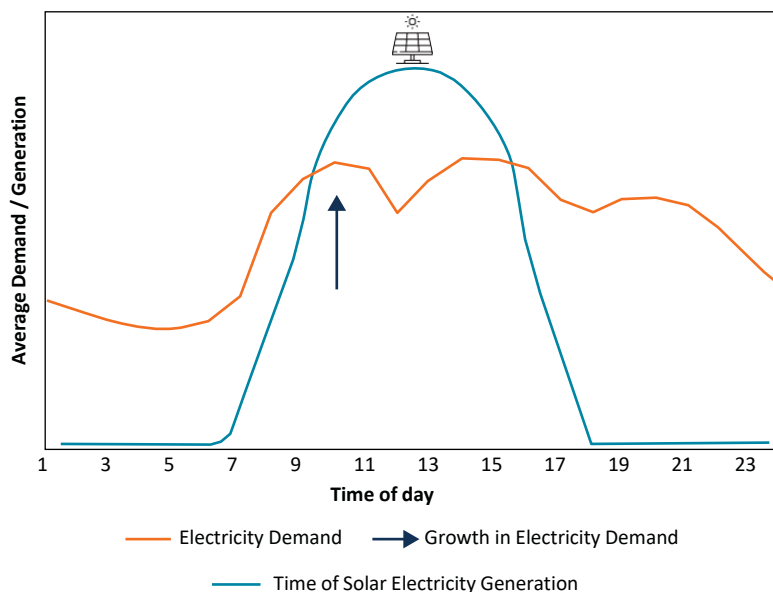


FIGURE 17: Solar Energy Generation Vs Average Demand of Cambodia

Fight climate change: Cambodia is one of the world's most vulnerable countries to climate change, which has resulted in a rise in extreme weather events including floods and droughts. According to a recent assessment by the Cambodia Climate Change Alliance, climate change impacts might lower Cambodia's overall GDP by 10% by 2050. It cautions that one of the most significant economic implications of rising temperatures will be a decline in worker productivity in labour-intensive industries. Solar energy produces no direct air pollutants and is widely acknowledged as a critical component in the fight against climate change.

Embedded with social and health benefits: Currently, around 92%¹⁷ of the population of Asia and Pacific, are exposed to levels of air pollution that are hazardous to their health. Air pollution, which is generated by the combustion of fossil fuels and biomass resources, is hazardous and can cause early mortality, asthma, and long-term harm to the respiratory and cardiovascular systems. Solar energy is a reliable source of electricity that may be installed close to people's homes, helping to keep the local air quality clean and Cambodians healthy.

Based on in-depth stakeholder discussions with officials of Ministry of Mines and Energy as well as Electricity Authority of Cambodia, about 150 MW of solar may be added to the grid by 2025, and up to 350 MW by 2030, with no severe grid impacts and no technical modifications to the current transmission and sub-transmission system. Solar power can assist to mitigate daytime peak demand and improve hydropower storage performance during the dry season, complementing hydropower. In medium and high solar PV penetration scenarios, uptake of solar will result in saving from avoided thermal generating and imports, as well as postponed construction or full avoidance of 300 MW of coal-fired production by 2030. Therefore, effective transmission and distribution planning must be undertaken to reduce the burden on the present network. In addition to this, transmission linkage support from neighboring countries also providing balancing support. Intending to address these challenges, EDC has taken numerous measures, including planning for installation and commission of new transmission lines, transformers, and sub-stations, bifurcation of overloaded feeders, among other measures, and has been gradually making progress in the direction of ensuring reliable power supply to all.

¹⁶ <https://www.ccacoalition.org/en/content/air-pollution-measures-asia-and-pacific>

PESTLE



Political



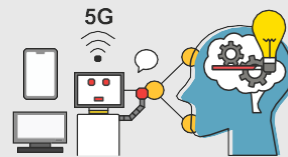
Social



Legal



Economic



Technological



Environmental

IDENTIFYING THE GAPS
AND OPPORTUNITIES
FOR RENEWABLE
ENERGY GRID
INTEGRATION THROUGH
PESTLE FRAMEWORK
AND CASE STUDIES

The availability of resources, socioeconomic structure, political difficulties, and environmental concerns all play a role in energy structure redesign and deployment of renewable energy generation in the electricity system of any nation, let alone Cambodia. However, high capital costs, lack of technical knowledge, in addition to the destruction caused by natural disasters, and current trends of lower fossil fuel prices, are challenging Cambodia from reaching its desired targets of RE penetration. Hence, the strategic planning process of renewable energy implementation in Cambodia needs a holistic analysis to meet the increasing energy demand from renewable energy sources. TERI in this report analyses the challenges and opportunities of renewable energy integration through PESTLE analysis (Political, Economic, Social, Technological, Legal and Environmental). It provides a bird's-eye view to determine exact trends of the market from a microeconomic point of view.¹⁶



FIGURE (I): Schematic diagram of factors considered for PESTLE analysis

5.1 Political

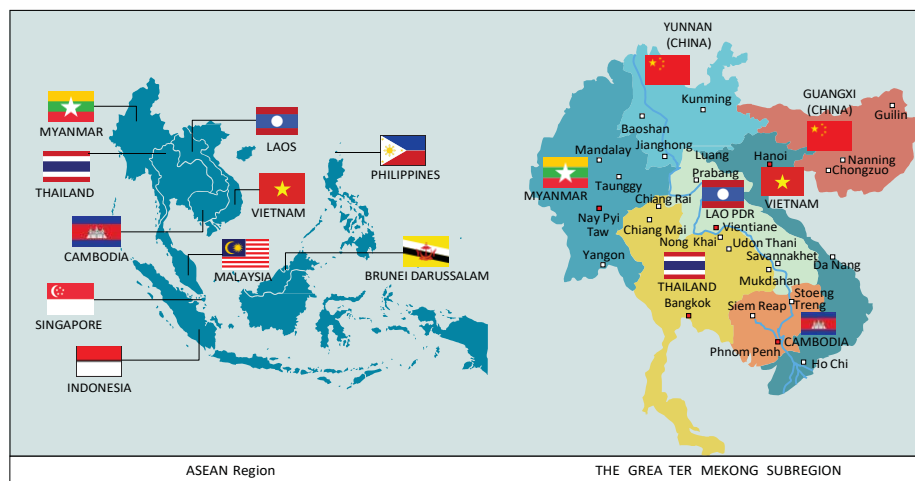
Political concerns cover a wide range of topics, including geographic locations, regulatory power, government policies, bureaucracy, international relations, corruption, and many more.

The Kingdom of Cambodia is located at a very diplomatic location at the Lower Mekong Region sandwiched between the Gulf of Thailand and the countries Thailand, Laos and Vietnam that coexist not only through cultural and economic interchange but also through energy exchange. This opens opportunities to strengthen the cross-border power ties between neighbouring nations through green corridors to transfer renewable energy-based electricity. This helps the nations of the Lower Mekong Region in Energy Security and helps in grid balancing, meeting the renewable energy commitments and reducing the dependency on high-cost carbon fuels.

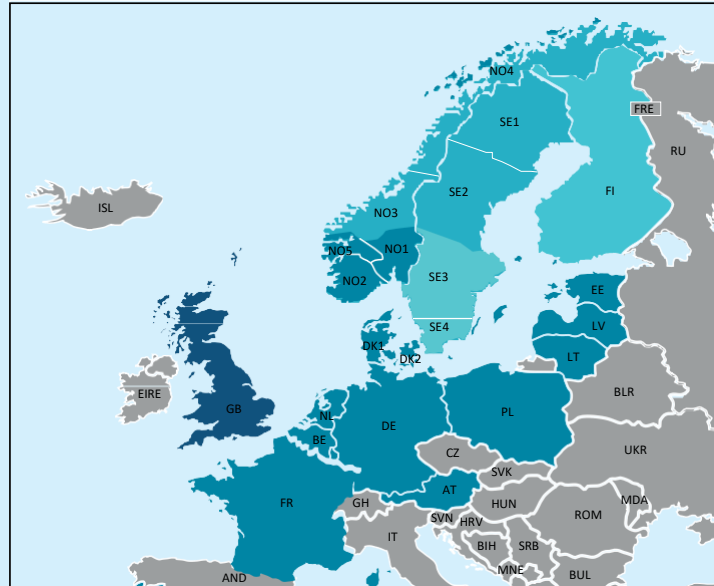
Electricity prices in Cambodia are among the most expensive in the region due to a shortage of integrated high-voltage transmission system and the high cost of imported diesel fuel. Power in provincial cities is more expensive and less reliable than the supply in Phnom Penh. Regional corporations can ensure cheaper, reliable power to bordering provinces of Cambodia.

5.1.1 Strengthening Regional ties in the ASEAN Region or Greater Mekong Region through Cross-border Power Exchange for RE-balancing and Load Management

In contrast to the monopolistic and centrally planned eras, today's electricity market price development is based on the decentralized decision-making by mutually independent firms. The strategic necessity of energy sector collaboration between nations in building a sustainable energy future is now widely acknowledged across the world. This is demonstrated by the successful functioning of sub-regional and regional power networks in Central America, Europe, East Asia, and Africa. One of the most successful inter-regional cooperation is the Nordic Pool of European Power Exchanges. Cambodia can strengthen its interconnections with Laos, Vietnam, and Thailand. Similar regional power networks can be brought out in the ASEAN Region or the Greater Mekong Region, where Cambodia is a part. Through such cooperations and cross-border power exchange Cambodia can benefit in increasing the share of clean energy, RE balancing and load management, improve reliability and sustainability.



Inspiration Corner



The Nord Pool

Nord Pool is a European power exchange owned by Euronext and the continental Nordic and Baltic countries' Transmission System Operators (TSOs). Nord Pool provides electricity trading services throughout Europe. Nord Pool handles power trading markets in the following countries: Norway, Denmark, Sweden, Finland, Estonia, Latvia, Lithuania, Germany, Poland, the Netherlands, Belgium, Austria, Luxembourg, France, and the United Kingdom. Nord Pool is a Nominated Electricity Market Operator (NEMO) in 15 European nations, as well as a serviced power market operator in Croatia and Bulgaria.

Nord Pool is a European power exchange owned by Euronext and the continental Nordic and Baltic countries' Transmission System Operators (TSOs). Nord Pool provides electricity trading services throughout Europe. Nord Pool handles power trading markets in the following countries: Norway, Denmark, Sweden, Finland, Estonia, Latvia, Lithuania, Germany, Poland, the Netherlands, Belgium, Austria, Luxembourg, France, and the United Kingdom. Nord Pool is a Nominated Electricity Market Operator (NEMO) in 15 European nations, as well as a serviced power market operator in Croatia and Bulgaria.

Cooperation and commerce between national electrical networks in the Nordic nations have a long history. With the formation of Nordel in 1963, cooperation was institutionalized. As a result, there was more collaboration on technical concerns and commerce, leading to creating a

unified Nordic power market. In terms of the commercial settlement process, various responsible balance parties seek to balance demand and supply. In real operation, the system operator has responsibility for the physical balance. The Louisiana Declaration, published by the Nordic Ministers of Energy in 1995, said that a pan-Nordic energy market would be economically and environmentally advantageous to all nations and should be established as soon as feasible. The development of the unified Nordic market took place in stages. The Nord Pool, a single exchange between Norway and Sweden, was founded in 1996. Finland and Denmark joined in 1998 and 2000, respectively. As a result, the spot market (day ahead) covered the whole Nordic region. Today, all customers have the option of choosing their electricity distribution utility, and generators enjoy market access.

The complementarities in Nordic nations' resources were the driving reasons behind developing a Nordic electrical market. Hydropower is used extensively in Norway and Sweden, but thermal power is heavily used in Finland and Denmark. As a result, the Nordic power system's economic efficiency, supply security, and environmental performance have all improved. Furthermore, market unification optimizes the use of Swedish and Norwegian hydropower, resulting in lower electricity prices (average prices) and lowest carbon emissions across the Nordic region. At the same time, increased supply security in dry years is achieved by integrating thermal capacity in Denmark and Finland. In this coalition, the development of a reliable transmission network is critical. This aids Transmission System Operators (TSO) in the Nordic region to maintain a stable demand-supply balance, especially during high renewable energy penetration levels, i.e., wind power from offshores of Denmark. The Ancillary Services Market, a market for acquiring primary, secondary, and tertiary reserves, accomplishes this balancing task. To some extent, this market differs from nation to country. Each market participant's settlement is dependent on the outcome of all of the foregoing market items and procedures.

5.2 Economic

Employment, gross domestic product (GDP), inflation, economic stability, local, and international investments, as well as pay rates, labour force, and income division, are all significant economic variables that impact the growth of renewable energy

The Cambodian electrical system has to face several teething troubles since energy consumption is anticipated to rise considerably over several decades. Still, indigenous energy supplies in the form of fossil fuels are becoming increasingly scarce. To keep up with increasing demand, it is critical to expanding power output in the form of renewable energy. The widespread integration of renewables is affected by the economic freedom and an investment attractive economy.



5.2.1 Green Recovery of Cambodian Economy



Cambodia has one of the most open economies in what is a fairly open economic region. The index of Economic Freedom, compiled annually by the Heritage Foundation in the United States, ranked Cambodia 118th among 170 countries in 2021¹⁷ with an economic freedom score of 57.3. While in the same ranking system Cambodia ranked 35th in 2003.¹⁸ Cambodia's poor performance in the rankings contrasts directly with neighbouring Vietnam, which improved its standing to 90. Cambodia is ranked 24th among 40 countries in the Asia-Pacific region. Its overall score is below the regional and world averages. Cambodia's economic freedom trend, which has been declining since 2017, has not reversed, and the economy remains largely unfree.

In addition to enhancing the regulatory environment to increase commercial freedom, long-term growth will need substantial, wide, and well institutionalized reforms to boost scores for judicial performance and government integrity, as well as better property rights. The economy remains heavily dependent on tourism revenues and garment exports. More than half of the labour force is engaged in subsistence farming. As mentioned in Chapter 3, the impact of COVID-19 pandemic on the economic growth of Cambodia, the global shock caused by the COVID-19 pandemic had a substantial effect on Cambodia's economy. The European Union, Cambodia's largest export market, partially suspended Cambodia's preferential trade treatment in 2020 because of the government's violations of human rights.

This has also led to the economic downfall of Cambodia. In order to uplift Cambodian economy to an investment-friendly zone, it is high time that the Government of Cambodia take plausible initiatives to ramp up the declining economic situation to its former glory. In 2020, the economy grew at a negative rate of -3.1% , the steepest drop in Cambodia's recent history.

Among the factors are a good number of considerable interests to potential investors: the fiscal burden, regulatory barriers, labour market restrictions, and trade policy.

Rebuilding better after COVID-19 will necessitate swift and coordinated actions from a wide range of stakeholders, including national and local government officials, financial institutions, electrical distribution utilities, grid operators, and energy consumers. Leaders must address significant socioeconomic challenges that have emerged or been aggravated as a result of the current economic and public health crisis: economic downturn, record-high unemployment, high power bills, and health hazards. Cambodia can take inspirations from its neighbouring nations for fast recovery of this crisis and large deployment of renewable energy sources.

Based on a report by the World Resources Institute, Decarbonization, Decentralization and Digitalization are the mottoes for rapid turnaround of economies.¹⁹

¹⁷ <https://www.heritage.org/index/country/cambodia>

¹⁸ The Unctad-icc Series of Investment Guides – AN INVESTMENT GUIDE TO CAMBODIA, 2003 https://unctad.org/system/files/official-document/iteiia20036_en.pdf

¹⁹ <https://www.wri.org/insights/clean-energy-can-help-southeast-asia-recover-after-covid-19>

Inspiration Corner

How Vietnam is planning to recover the economic crisis through decarbonization by promoting RE adoption.²⁰

Recently, the Resolution of the XIII National Congress of the Communists Party of Vietnam stipulated in February, 2021 that Vietnam should be committed to adapting effectively to climate change, preventing, combating and mitigating natural disasters and epidemics, and managing, exploiting and using resources rationally, economically, effectively, and sustainably. It further sets the protection of the living environment and people's health as top targets and sets the goal of building a green and circular economy, which respects the environment. This is expected to be achieved by :

- Underpinning policies aimed at realizing Vietnam's energy transition by a commitment to the "3 D's": decarbonization, decentralization and digitalization.
- Internalizing environmental and public health costs in fossil fuel generation, phase out (implicit) fossil fuel subsidies and halt the development of fossil fuel plants and imports.
- Deregulate the electricity markets to allow independent power producers and retailers to compete in all segments of the market including generation, transmission, and retailing.
- Promote public awareness about the efficacy and potency of renewable energy technologies (RETs)

5.2.2 Curbing the Electricity Prices

Despite the increasing use of low-cost electricity generation options, energy prices in Cambodia remain high compared to other countries in the region. The Royal Government recognizes that the high cost of electricity and inadequate supply significantly limits economic growth and hinders the country from attracting investments and stimulating economic activities.



²⁰ The Role of Renewable Energy in post-COVID-19 Recovery in Vietnam-Nguy Thi Khanh et. al.



Electricity imports, largely from heavy fuel oil, represent around 15% of consumption and the government is aiming to become self-sufficient in the medium term to help address high tariffs, which are deterring greater foreign investment. Cambodia's electricity prices are some of the highest in the region and range from USD 0.09 - 0.25 per kilowatt hour in urban areas connected to the central grid to USD 0.40 – 0.80 per kilowatt hour in rural areas²¹. In March 2021, household price of electricity in Cambodia was 0.150 US dollars per kWh, as against a global average price of electricity of 0.134 US dollars per kWh.²²

Large-scale integration of renewable energy using its abundant inland resources can help Cambodia reduce the dependency on imports and fossil fuels, avoid large capital intensive fossil fuel-based power plants and avoid the costly diesel-powered decentralized generations and thereby reduce the electricity prices. Every dollar invested in the energy transition gives three to eight times the return, according to the World Economic Forum, citing numbers from IRENA.

Inspiration Corner



In Indonesia, plans to increase electricity tariffs for 12 non-subsided groups starting in 2020 after two years of flat rates area is a wake-up call on the real costs of fossil-based electricity. Solar and wind can now undercut the price of power from the fossil-heavy electricity grid, a reflection of decades-long reductions in renewable energy prices. In Philippines, a study released last year showed that the full retain price of solar power was already cheaper than grid electricity rates, a trend since 2018. Another study showed that in Southeast Asia, clean energy can reach levelized costs as low as \$64 per megawatt-hour (kWh) for solar photovoltaics and \$42/MWh for wind, which are cheaper than new coal and other fossil-based generation plants.

5.2.3 Financial Incentives to Promote Clean Energy

The promotion of renewable energy through fiscal incentives is a prodigious way to increase the integration of RE resources. Common financial incentives include:

- (i) Tax policies give tax breaks or credits, as well as reduce or eliminate some taxes, to encourage the use of renewable energy and energy efficiency.
- (ii) Rebates, subsidies, and performance-based incentives give a direct monetary incentive to boost energy efficiency and renewable energy while requiring no repayment.



²¹ Cambodia (hydropower.org) -hydropower.org/status report

²² Cambodia electricity prices, March 2021 | GlobalPetrolPrices.com

Inspiration Corner

1. To attract project developers and investors and build renewable energy markets, fiscal incentives have been widely employed worldwide. Indonesia, for example, provides incentives such as income tax exemption and reduction for 5–6 years, a tax deduction for 6 years, and VAT and import duty charge exemptions. The Philippines offers a seven-year income tax break, a zero-per cent VAT rate, and duty-free renewable energy equipment and raw materials for ten years, as well as accelerated depreciation. Singapore also offers investors tax and non-tax advantages.
2. The Singapore Productivity and Innovation Credit provides a tax break and/or financial incentives to stimulate green technology research and development. The Vietnamese government provides incentives in the form of a preferential tax of 10% (the standard tax rate is 20%), tax exemption for the first four years, tax decrease in future years, and exemptions on import duty payments. Malaysia and Thailand are likewise well-versed in such fiscal tools.
3. Singapore began charging a tax on carbon dioxide emissions in 2019 as part of its Climate Action Plan to enhance mitigation efforts. During the transition period of 2019–2023, the starting tax rate has been set at S\$5 per tonne of greenhouse gas. Following an impact study, the price will be raised to S\$10–S\$15 per tonne in 2023.²³

(iii) Loan programmes, guarantees, and credit enhancements are frequently designed to provide lower interest loans and/or minimize the risk associated with loans for renewable energy and energy efficiency technologies and projects.

5.2.4 Concessional Climate Finance through Soft Loans, Green Bonds, Guarantees, and Blended Finance

Debt financing is one of the most traditional financial tools adopted by banks to raise funds. Historically, development banks have provided more than 70% of renewable energy funding in the form of loans.²⁴ However, even under the most optimistic income scenarios, the demand for climate investment considerably outstrips what public resources can supply.



²³ National Climate Change Secretariat. 2021. Carbon Tax. Singapore

²⁴ IRENA (2018)



5.2.5 Promotion of Global Competitive Bidding in Renewable Energy Development and Balancing Mechanisms



A well-managed competitive bidding procedure can lower project costs and PPA rates considerably. A rigorous and competitive bidding process, in addition to good planning and teamwork, could bring down costs at each level. Competitive auctions are often regarded as the gold standard for achieving transparency and price competitiveness globally.

(i) Green bonds are an innovative sustainable energy financing strategy worldwide, with issuances from financial and non-financial corporations across several core markets. Different instruments are utilized by different countries to drive green bonds. The government of Indonesia is the driving force behind green bond

issuance, accounting for 99% of all green bonds issued in the country. However, in Malaysia and Singapore, the private sector is pushing the issue of green bonds.

Inspiration Corner

In India, through global competitive tender, the solar tariff is brought down to USD 0.021 per kWh. Similarly, wind tariff is also brought down to USD 0.027 per kWh through the competitive tendering model.

In this similar directive, to overcome the intermittent nature of renewable energy, the Ministry of New and Renewable Energy, Government of India with support from Solar Energy Corporation of India (SECI) floated a tender that will deliver “round-the-clock” electricity from the renewables. Under this tender, SECI received bids from the project developer in the range of USD 0.04 – 0.06 per kWh.

Inspiration Corner

For example, the Asian Development Bank Malaysia's Green Technology Funding Scheme contributed USD17.6 million to install 47.5 MW (GTFS) is a loan guarantee programme that of floating solar PV power generating panels in provides a 2% yearly rebate on interest or profit Vietnam, while ING Bank provided USD 37.4 million green loans to create a 50 MW portfolio as a 60% government guarantee on financing of rooftop solar projects in Singapore. rates imposed by financial institutions, as well as a 60% government guarantee on financing supplied by financial institutions.

For risk mitigation and credit enhancement in clean energy, blended finance uses public funds to stimulate private investment. The Tropical Landscapes Finance Facility (TLFF) and the Credit Guarantee Investment Facility in Indonesia have used this method. These give technical assistance to the private sector, make finance more accessible, and help to build bankable projects. TLFF focuses on increasing investment in renewable energy capacity and providing power access to disadvantaged, off-grid populations in the clean energy sector.

5.3 Social

Local energy demand, lifestyle and social development, cultural structure, business culture, demographics, employment, women empowerment, and few other issues are considered when PESTLE analysis is carried for integration of renewable energy.

Cambodia's energy route will determine the foundation for the country's future growth, including economic success, business and job possibilities, and health consequences. Simultaneously, present investment decisions in Cambodia's energy industry will have a significant influence on combating global warming and ensuring the livelihoods of the people of Cambodia. By expanding the percentage of renewables in the electricity sector, Cambodia can considerably increase employment. Renewable energy technologies tend to be more labour intensive than conventional energy technologies. By an analysis made by TERI, RE technologies have a 25-fold higher employment effect per installed capacity than fossil fuel-based power generation in developing nations like Cambodia. Biomass and solar energy will be the major drivers of deployment. When the incomes earned in the primary and secondary industries are spent, induced jobs are created. For example, wages spent by workers on food at grocery shops and restaurants, home rents and other expenses stimulate further employment in these businesses.

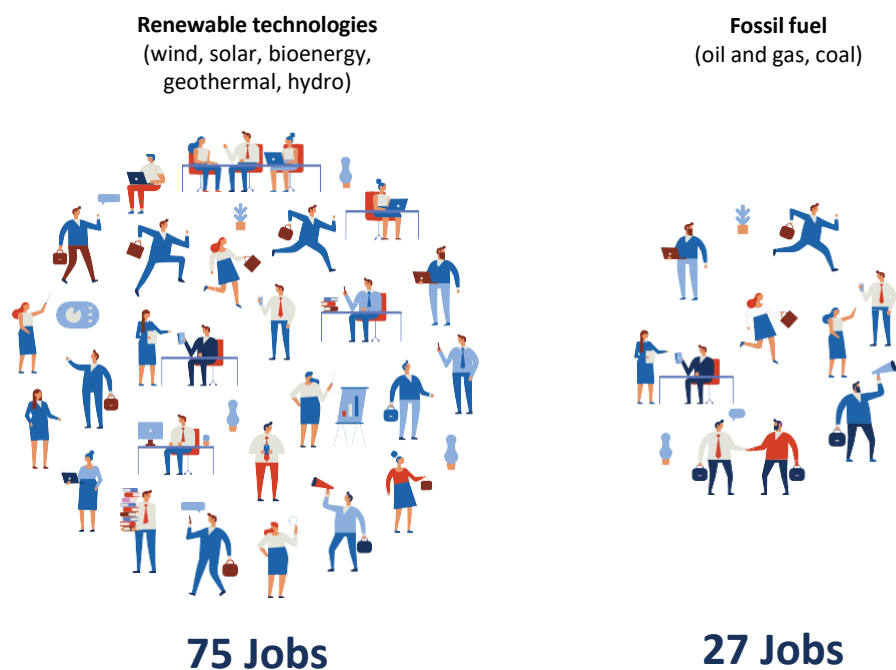


5.3.1 Creating an enabling Environment to Boost Employment with Renewables



The growing use of renewable energy technology generates job possibilities all the way up and down the supply chain, with the sector employing 11 million people globally as of 2018. According to an analysis made by McKinsey²⁵ published in May 2020, government expenditure on renewable energy and energy efficiency produces as many employment as spending on fossil fuels.

Furthermore, the renewable energy business employs a varied and inclusive work force, with demands spanning from unskilled labour to executive roles. Furthermore, energy efficiency occupations directly provide local employment prospects as well as opportunities inside small and medium-sized businesses, which represent 89–99% of all businesses and 52–97% of total employment in Southeast Asia.



Employment through the sector could be broadly classified into three categories: direct, indirect, and induced jobs. Direct jobs include employment in the project deployment in the project deployment phase. Indirect jobs include jobs in the secondary industries that supply equipment to the primary industries.

²⁵ <https://www.mckinsey.com/business-functions/sustainability/our-insights/how-a-post-pandemic-stimulus-can-both-create-jobs-and-help-the-climate>

When the incomes earned in the primary and secondary industries are spent, induced jobs are created. For example, wages spent by power plant workers on food at grocery shops and restaurants, home rents, and other expenses stimulate further employment in these businesses. Skilling and re-skilling of the new workforce in the Cambodia's electricity sector will be most crucial. Because the power sector's increasing workforce need a diverse range of abilities, it is critical to understand the requirement of skilled, semi-skilled and low-skilled employees in renewable energy power plant deployment and operations.

Current Initiatives

By financing \$127.8 million loan support and constructing much-needed transmission infrastructure for sustainable electricity supply and \$6.7 million grant, ADB's upcoming Grid Reinforcement Project will boost Cambodia's economic productivity, competitiveness and diversification, create jobs and support the country's recovery from COVID-19 pandemic. The project is said to create 1,300 direct jobs in the construction with spillover effects that will boost household incomes. It will also support the Electricite du Cambodge's efforts to promote inclusion and gender equality at the workplace and encourage women's participation in the energy sector.

Nearly 5 million Cambodians do not have access to grid power and must rely on vehicle batteries, wood, and other traditional energy sources. For cooking, about 62% of homes utilize firewood, 5% use charcoal, 31% use liquefied petroleum gas, and 2% use electricity.²⁶ The country's historically high power cost makes access expensive for the poor, while also limiting economic competitiveness and deterring investment. Recognizing that expanded access to modern and affordable forms of energy is critical for Cambodia's social and economic advancement, the Government of Cambodia's National Strategic Development Plan (NSDA), 2014-2018 and Industrial Development Policy (IDP), 2015–2025 prioritize the need to develop the energy sector in an affordable and sustainable manner, while also taking adverse environmental and social impacts into account.

Cambodia can nurture various steps for the holistic development of Cambodia whilst integrating renewable energy sources into energy mix.

1. Make female employment and skilling a requirement for public renewable energy initiatives.
2. Improve the availability of data about job opportunities in the renewable energy sector.
3. Promote the use of distributed renewable energy resources. Distributed renewable energy technologies such as biomass, rooftop solar and small hydro can provide employment in rural areas at the same time ensuring proper management of the distributed energy resources that power local micro-grids.
4. Introduce mandatory project obligations to train local workforce to maintain renewable energy installations and establish favourable conditions for women.

The integration of employment opportunities for renewable energy projects creates a sense of ownership in the villages. Furthermore, combining renewable energy projects with the employment programme would assure the long-term maintenance of renewable energy installations of renewable energy installations and might result in cost savings and synergies, such as with biomass projects.

²⁶ ADB-2018-Cambodia Energy Sector Assessment, Strategy and Road Map



Inspiration Corner



According to the Solar Foundation, solar job growth grew in 29 states in 2018, with more than 20% job growth in Alabama, Alaska, Florida, Illinois, Kansas, Montana, North Dakota, and Wyoming. While solar jobs declined 3% nationwide as a result of Trump administration panel import taxes, the solar has gained almost 150,000 new jobs since 2010 and anticipates employment to rise 7% in 2019.



5.3.2 Nurturing Social Entrepreneurship and Women Empowerment through Clean Energy Applications

Inspiration Corner



In Indonesia, the Wonder Women programme aims to empower women to extend last-mile energy access using off-grid renewable energy technology. Since its inception in 2013, the programme has trained over 500 “wonder women” who have sold over 55,000 clean energy technologies to over 250,000 people in Indonesia’s poorest and more remote areas, where the vast majority of the population lacks access to electricity, clean water, and modern cooking methods. Women social entrepreneurs receive training to improve their ability to start and run enterprises. Technology usage and maintenance, sales and marketing, bookkeeping, and financial management are all covered during the capacity-building programme. In the long term, this initiative saw benefits such as lower fuel costs, greater energy affordability, higher income, poverty reduction, skill development, gender equality, and lower carbon emissions.

5.3.3 Catalyzing Adoption of Renewable-based Microgrid Systems for Rural Electrification

Decentralization is concerned with smaller, scattered energy producing units that offer electricity to clients wherever they are, primarily via renewable energy sources such as solar panels, or small run-off river hydro projects, biomass-based generating stations, etc. These are known as the Distributed Renewable Energy Systems. This can help countries survive upheavals and calamities, as well as provide energy to people in Cambodia who do not have access to power. Furthermore, with decentralized solutions, swaths of rural Cambodia that have failed to keep up with the rest of the modern world might have access to energy for the first time.



Inspiration Corner



Since 2018, a 4 MW solar battery microgrid in Occidental Mindoro, Philippines, has provided 24/7 electricity to a rural village without the need for government subsidies, and at a cheaper cost to customers than current oil-based sources. Another solar battery microgrid project in Sabang, Palawan, Philippines, is expected to save the government at least \$4 million in subsidies over a completely diesel-powered facility.

The United States Agency for International Building (USAID) supported Solutions Using Renewable Energy (SURE) Inc. through a grant to assist the development of a renewable energy microgrid power system that covers the unelectrified coastal region of Roxas, Green Island, Philippines. The project also includes an electrical water pump to address a shortage of access to fresh water and an ice machine to improve the local fish market, both of which are connected to the microgrid.

The microgrid was designed to provide a 24x7 reliable electricity supply to 50 households on the island. The 25.5-kilowatt (kW) power plant includes a 20-kilowatt (kWE) biomass gasifier that runs on coconut shells and wood chips, 3 kW of wind power, 2.5 kW of solar photovoltaic (PV) panels, and a lead-acid battery bank. The project also includes the ice machine with a daily capacity of 900 kilograms of flaked ice, which is estimated to be the daily quantity of ice required by the local population to keep fish, which is one of its primary sources of revenue. This initiative resulted in local job creation, skill development, improved food security, and access to clean water utilizing renewable energy.



5.4 Technological

Technological factors are vital when integrating renewable energy to the existing grid to design a new grid for the countries. Studies related to grid integration of renewable energy focus on various aspects in technology which should be taken into consideration, such as technological interventions, smart and emerging technologies, innovative business models for management, monitoring and control, network design, forecasting models, market structure, trading mechanisms, tariff system, research facilities, and few others.

The application of new technologies especially smart grids and microgrids are still very new but few countries already adopted them with the technologies. Integrating more renewables into the grid needs further training on feed-in tariff system, smart network design, distributed generation, smart metering, monitoring and control of the grid which indicate a new pathway of capacity building, research and investments in renewable energy sector. On the other hand, maintenance and monitoring of these technologies of the existing network is also an issue for the continuous development in energy sector.

The application of new technologies especially smart grids and microgrids are still very new but few countries already adopted them with the technologies. Integrating more renewables into the grid needs further training on feed-in tariff system, smart network design, distributed generation, smart metering, monitoring and control of the grid which indicate a new pathway of capacity building, research and investments in renewable energy sector. On the other hand, maintenance and monitoring of these technologies of the existing network is also an issue for the continuous development in energy sector.

5.4.1 Utility-Centric Solar Rooftop Programmes



Being the tail end of the electricity supply chain, distribution utilities constitute a crucial link with the consumers and can, therefore, help accelerate the growth of the solar rooftop sector. A utility-driven RESCO model is suitable where the utility will undertake facilitation and payment collection. It is beneficial to those consumers who cannot afford to pay the upfront cost. They can buy solar energy every month and get the subsequent benefits. Aggregated procurement by the utility can ensure a better quality of installation, and regular operations and maintenance ensure better system performance and quality of supply. This model of implementation will promote more investments that will enable rapid integration of RE into the electricity grid.

Some of the issues, such as anti-islanding features and assessment of adequate PV hosting capacity in their distribution network and access to solar inverters as and when necessary, are all critical considerations. Other concerns about the quality of power injected to the grid, including harmonics caused by power electronic devices used in solar PV systems, are primarily linked to the quality of electricity injected into the grid also need to be studied. Utility-specific technical studies on grid integration of RE need to be carried out to tackle these issues.

5.4.2 Sustainable Hydro Power

As a renewable energy, hydropower plays an essential role in decarbonizing the energy system, achieving net-zero carbon targets and helping to mitigate the impacts of climate change. Sustainably developed and responsibly operated hydropower projects can make a significant contribution to national and international efforts to achieve Sustainable Development Goals: in particular SDGs 6 (sustainable water management), 7 (affordable, reliable, sustainable, and modern energy for all), 8 (sustainable economic growth and jobs), 9 (resilient infrastructure) and 13 (urgent action to address climate change).



“Sustainable hydropower is a clean, green, modern and affordable solution to climate change. Going forward, the only acceptable hydropower is sustainable hydropower.”²⁷

Unlike other countries that depend on fossil fuel-based energy sources, Cambodia is blessed with ample hydro resources and a considerable share (44%) in the energy mix, as shown in figure 8 in Chapter 3 of this report. However, recent power shortages due to droughts and lower water levels in the dams have forced Cambodia to shift to alternative sources such as coal, LNG, solar PV, and imports from neighbouring countries to meet the electricity demand. Rather than shifting to depleting and polluting fossil fuel-based generations, more focus should be given to renewable energy-based generations for a reliable and secure economy in future. National security and stability can be improved by reducing the dependency on coal and imports for the nation’s electricity needs. Investment in new sustainable hydropower capacity, as well as modernizing and upgrading existing capacity, is part of pragmatic, holistic energy policymaking and is essential for the energy transition.

5.4.3 Adoption of Grid-scale Energy Storage to Mitigate Intermittency in Large-scale Grid Integration of Renewable Energy

While increasing the share of intermittent renewable energy resources, the risk of grid stability and reliability of these sources rises with varying electricity demand. Energy storage technologies (ESTs) help solve the problem by storing surplus energy and making it available on demand. Energy storage is an essential tool for mitigating such increased volatility or power quality issues by providing voltage support, smoothing output variations, regulating power flow in the network, and matching supply and demand. ESTs also provide ancillary



²⁷ The San José Declaration on Sustainable Hydropower



grid services such as frequency management, energy time-shifting, power quality enhancement, load levelling, peak shaving, facilitating RES grid integration, network development, and overall cost reduction and operational reserves.

Among the various ESTs are pumped hydro storage (PHS), compressed air energy storage (CAES), flywheel energy storage (FES), supercapacitor energy storage (SCES), superconducting magnetic energy storage (SMES), and electrochemical energy storage, which include lead-acid (Pb-A), nickel-cadmium (Ni-Cd), sodium-sulphur (Na-S), sodium nickel chloride (NaNiCl₂), Lithium-ion (Li-ion) and flow battery energy storage (FBES). The applications of different ESTs based on the power ratings of the system is provided in figure 18.

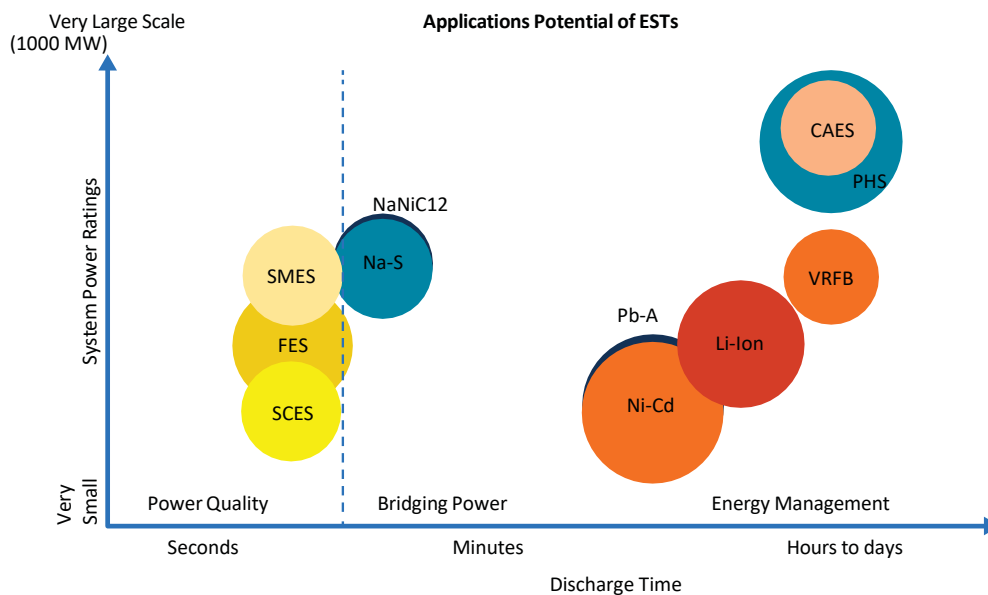


FIGURE 18: Application Potential of Energy Storage Technologies (ESTs)

Presently, the installed capacity of energy storage is continuing to increase globally at an exponential rate. 92.6% of all currently installed ESTs are contributed by pumped hydro systems followed by electrochemical ESTs (5.2%),²⁸ as shown in figure 19.

Cambodia is blessed with hydro resources that can be doubled up as pumped hydro systems to manage the growing renewable energy resources. Apart from this, Cambodia should take up battery energy storage systems (BESS) for better grid management and balancing. BESS testing projects should be taken up on priority similar to that initiated in other developing countries like India.

The Asian Development Bank (ADB) has approved a \$6.7 million grant to pilot Cambodia's first utility-scale battery energy storage system. The amount includes \$4.7 million from the Strategic Climate Fund

²⁸ A Review of Energy Storage Technologies' Application Potentials in Renewable Energy Sources Grid Integration-Dec-2020
Henok Ayele Behabtu

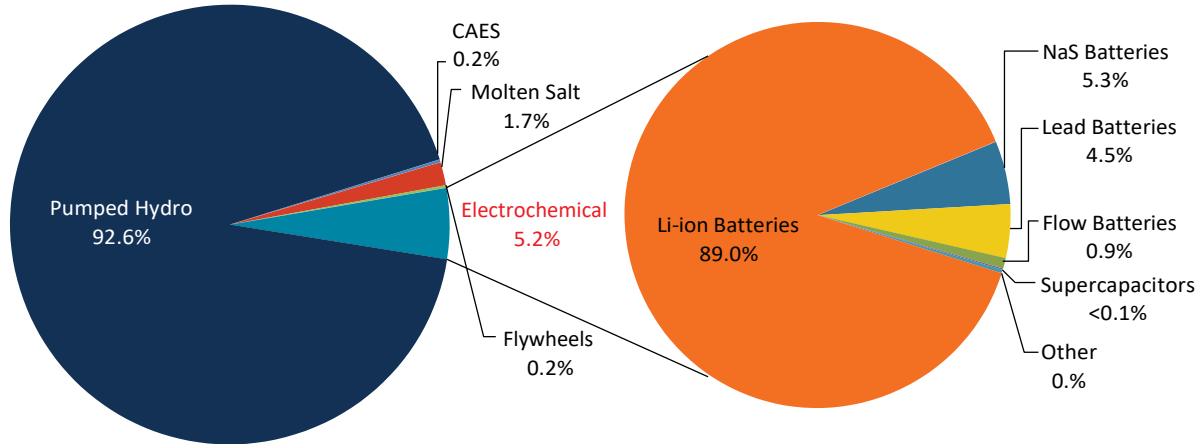


FIGURE 19: Global Installed Capacity Mix of Energy Storage

under the Scaling Up Renewable Energy Programme in Low-Income countries and \$2 million from the Clean Energy Fund under the Clean Energy Financing Partnership Facility.²⁶ It will be located near the ADB-supported 100-megawatt (MW) National Solar Park. The government intends to raise the capacity of solar photovoltaic output to 415 MW by 2022. The BESS system can store 16 MWh of power and provide services such as renewable energy integration, transmission congestion alleviation, and supply and demand balancing, among other things. The pilot BESS project is said to include on-the-job training as well.

Energy storage systems as a source of power balancing

Apart from conventional power plants as spinning reserves, energy storage systems such as pump hydro storage, compressed air energy storage, batteries, fly wheel, hydrogen storage, battery electric vehicles, lead acid batteries, lithium-ion batteries, sodium sulphur batteries, and so on are being considered globally as measures to deal with variability in RE generation, frequency and voltage control, spinning reserves, and emergency power supply. Various types of batteries are appropriate for different grid circumstances based on their power density, energy density, discharge duration, and time scale at which they can respond, etc. The IEC whitepaper outlines several energy storage devices, as well as their potential and appropriate responsibilities for grid integration, in Table 3.



TABLE 3: Grid side role of various energy storage systems²⁹

Role	Time scale(s)	Description	Benefits to RE integration	Examples of EES technologies
Time shifting / Arbitrage / Load levelling	Hours to days	EES allows storage of off- peak energy and release during high-demand period	A solution to diurnal generation cycles that do not match load cycles	NaS batteries, CAES, PHS, RFB
Seasonal shifting	Months	EES stores energy for months at a time, releasing it at times of the year when RE output is typically lower	Allows use of renewably-generated energy year-round, reducing reliance on traditional generation in seasons with, for example, low sunlight	Hydrogen, SNG
Load following / Ramping	Minutes to hours	EES follows hourly changes in demand throughout the day	May mitigate partial unpredictability in RE output during critical load times	Batteries, flywheels, PHS, CAES, RFB
Power quality and stability	< 1 second	Provision of reactive power to the grid to handle voltage spikes, sags and harmonics	Mitigates voltage instability and harmonics caused or exacerbated by uncontrollable variability of RE generation	LA batteries, NaS batteries, flywheels, RFB
Operating reserves				
Frequency regulation	Seconds to minutes	A fast-response increase or decrease in energy output to stabilize frequency	Mitigates uncontrollable moment-to-moment variability in RE generation output	Li-ion batteries, NaS batteries, flywheels, PHS (with advanced variable speed control)
Spinning Reserves	~10 Minutes	A fast-response increase or decrease in energy output to cover a contingency, e.g. generator failure	Mitigates partial unpredictability of RE generation output, providing (or removing) energy when the RE resource does not perform as expected	PHS, flywheels, batteries

²⁹ Source: IEC whitepaper on "Grid integration of large-capacity Renewable Energy sources and use of large-capacity Electrical Energy Storage" October 2012, <http://www.iec.ch/whitepaper/pdf/iecWP-gridintegrationlargecapacity-LR-en.pdf>

TABLE 3: Grid side role of various energy storage systems²⁹

Role	Time scale(s)	Description	Benefits to RE integration	Examples of EES technologies
Supplemental reserves	Minutes to hours	A slower response resource that comes online to replace a spinning reserve	Provides firm power in the event of an especially severe and long-lasting drop in RE output. Use for RE integration is expected to be infrequent and low-value	PHS
Efficient use of transmission network	Minutes to hours	EES can help grid operators defer transmission system upgrades through time-shifting and more efficient operating reserves	Reduced transmission costs, mitigates locational dependency challenges of RE generation	Li-ion
Isolated grid support	Seconds to hours	EES can assist in the integration of RE on small power grids, such as those in use on islands	Time-shifting and power-quality applications to mitigate variability and unpredictability of RE generation	LA batteries
Emergency power supply / Black start	Minutes to hours	EES may be used to re-start the power system in the event of a catastrophic failure	No specific benefit accrues to RE integration, but storage resources may nonetheless provide black start capability to the grid	LA batteries



Inspiration Corner



AES India, a subsidiary of AES Corporation and Mitsubishi Corporation, has commissioned a utility-scale battery storage-system—a 10 MW solution for 1 hour that is serving the electric grid operated by Tata Power Delhi Distribution Limited (Tata Power-DDL). The Advanced Control System provides flexibility into the control of the Battery Energy Storage System (BESS) to serve multiple applications by integration with an energy management system (EMS). The project includes a lithium-ion battery, and to demonstrate this advanced technology, the specific battery technology which has been deployed is Lithium Nickel Manganese Cobalt oxide or commonly termed as NMC battery technology. LG Chemical is the manufacturer of battery packs/modules. The project is situated at Rohini, New Delhi, a 66-/11-kV substation operated by Tata Power-DDL. The 10-MW size of the project is divided into four BESS transformers (each with a rating of 2.5 MVA). Each of these transformers is connected to the two cores of BESS, thus making 8 cores in total. Each core is divided into 31 racks for battery nodes. The capacity of one battery module is 6.5 kWh with a voltage rating of 51.7 V. There are 14 modules connected in one node, in series, thus making each node with a rating of 85 kWh. For maintaining the temperature of batteries, there are individual battery fans for each module and it starts operating when the temperature reaches above 40°C. Each battery module also has individual BMS which communicates the battery status with each other and also with central BMS. As per the balance of the plant, the C-rate for the battery is fixed at 1 C. The BMS of the battery module helps in maintaining the state of charge (SOC) in the range of 45–55%, against the prescribed levels of SOC from the manufacturer which states that SOC of the battery can vary between 10% and 99%. The auxiliary energy consumption for the whole system ranges in 1–2% of the battery capacity. The inverters are connected at 415 V (L-L) to switchgear with individual switch-breaker and this voltage level is being stepped up to 11 kV by an isolation transformer (which is used to physically isolate the BESS from the grid to ensure safety to the system), injecting the power at the secondary end of substation transformer. The charging of the system takes place from the grid supply by reversing the direction of power flow through the BESS transformer (that is, HT to the LT side). The system is utilized for frequency regulation, energy arbitrage, deviation settlement mechanism (DSM), peak shaving, and reactive power control.

5.4.4 Large-scale Deployment of Distributed Energy Resources (DERS) and Intelligent Microgrids near Load Centres

Decentralization is concerned with smaller, scattered energy-producing units that offer electricity to clients wherever they are, primarily via renewable energy sources such as solar panels, or small run-off river hydro projects, biomass-based generating stations, etc. These are known as Distributed Renewable

Energy Systems. This can help countries survive upheavals and calamities, as well as provide energy to people in Cambodia who do not have access to power.

According to the Rural Electrification Master Plan (REMP), the government intends to develop rural electrification using RE as well as other methods. Several nations have implemented incentives to promote generation from distributed RES to stimulate the use of low-carbon technology. DERs impose several benefits such as:

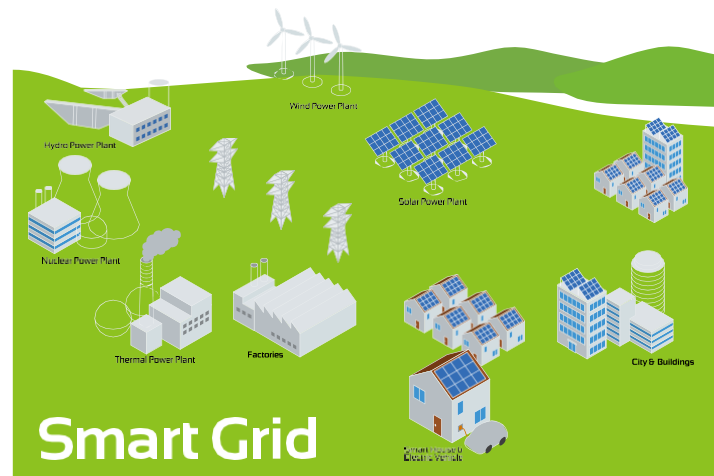
- (i) Energy-efficient, lower CO₂ emissions, and environmentally friendly
- (ii) Reduced network (infrastructure) and central generation capacities
- (iii) Generation closer to loads, resulting in lower power losses in the network
- (iv) Diversity in energy supply and location, resulting in more secure and reliable supply

Currently, distributed RES amounts to only a tiny proportion of the entire network generating capacity; hence its impact on the network performance is insignificant. However, with the increased number of new and renewable energy resources being connected to the grid, these will start to impact and create potential problems to existing power networks (that were not designated to accommodate RES)

In the early 2002, as the primary grid expanded more rapidly into rural areas, more than 250 previously isolated mini-grids became small power distributors (SPDs). These mini-grids were diesel-fired power plants primarily. These SPDs can be converted to mini or micro renewable energy (mainly solar, small hydro or biomass) powered load centres and coexist with the national grid. A **"hybrid-renewable-energy system" (HRES)** involving in different renewable resources can be used to supply sustainable power in these areas.

Benefits of Coexistence of National Grid along with distributed renewable energy-based mini or microgrids:

- (i) Helps the utilities to access electricity that is cheaper than its own avoided cost,
- (ii) Improves the resilience of the nation's electric distribution infrastructure
- (iii) Reduces the risk of total black-out
- (iv) Enhances the capacity factor and improve the quality of electricity
- (v) Generates additional revenue for the community and/or project developers; potential to develop a public-private partnership
- (vi) With additional community revenue: potential to promote community development and rural livelihoods, e.g., income-generating activities, support local education, healthcare cultural activity, and watershed protection



- (vii) Easier integration of sophisticated monitoring, data collection and control technologies for better management of small distribution networks
- (viii) Better fault resolutions
- (ix) Take the aid and support of EDC to implement local microgrids while managing localized demands through capacity building of natives.

Loads are linked at the distribution network, with minimal automation, such as transformer tap changers and circuit breaker auto-reclosing. This configuration results in power flow from producing plants to medium and small-sized loads via transmission and distribution networks, i.e., unidirectional power flow. Significant RES connections at the distribution level will alter future power networks' structure and power flow, leading to reverse power flows and bi-directional power flows.

Frequent and thorough technical studies on grid integration of renewables will help to tackle these issues related to DERs, such as:

- (i) Change in voltage level and violation of statutory limits
- (ii) Difficulties in power flow control and potential reverse power flow
- (iii) Increase in short circuit contribution and fault levels
- (iv) Issues with protection management
- (v) Potential voltage imbalance, which is specific to single-phase small-scale distributed generation.

The distributed generation owner must guarantee that the system is safe for installers, operators, and users.

Inspiration Corner



Smart microgrids are rapidly being promoted as important concepts for future energy delivery, as a supplement to the traditional centralized energy system. To demonstrate new urban management systems, the City of Yokohama developed the Yokohama Smart City Project (YSCP), which uses smart grid technologies for energy management of households, buildings, and local communities, introducing large-scale integration of renewable energy, and promotes next-generation transportation systems. The goal of the project is to create a social structure that can grow sustainably in an existing metropolis. To achieve this, the city implemented a Community Energy Management System (CEMS), which connects each EMS, such as those in houses and buildings, with stationary energy storage to ensure effective energy management. The city also prioritizes the utilization of renewable energy sources, as well as efforts to influence people's attitudes toward energy consumption. In addition, customers will be given incentives to reduce their power usage, therefore helping to reduce CO₂ emissions at a reduced social cost.

Advanced microgrids or smart microgrids enumerates various benefits such as:

- (i) Adding resilience to the grid infrastructure, compensating locally for the fluctuating supply of renewable energy, and providing ancillary services such as Volt-Ampere reactive (VAR) support and voltage regulations to portions of the bulk power system.
- (ii) End-user demands are met by assuring UPS for essential loads, managing power quality and dependability at the local level, and encouraging customer engagement through demand-side management and community involvement in energy supply.
- (iii) Operates in and seamless transition between "islanded" and "grid parallel" modes
- (iv) Provide interconnection and interoperability for smart grids
- (v) Provides cyber security for performance and data
- (vi) Supports power quality enhancements for connected loads
- (vii) Provides two-way communications (frequency, verification, data latency)
- (viii) Provides data management and system predictions
- (ix) Provides Volt/VAR/frequency controls and support for interconnectivity and island
- (x) Enables dynamic local feeder reconfiguration
- (xi) Improves reliability for critical loads

Inspiration Corner



Hybrid Renewable energy systems powering smart micro-grids-

With efficiency, dependability, and economics, a hybrid system may meet and overcome the constraints of renewable energy supplies. Different countries in ASEAN, especially Malaysia, Thailand, Indonesia, Philippines, and Vietnam have recently initiated devotion for green and sustainable energy deployment and has adopted various hybrid RE systems to meet their flexible RE demand.

In India, a biomass-solar PV hybrid system operation was implemented including an Energy Management System (EMS), which ensures that the demand of different goods by the community (AC and DC power, heating domestic water, cooling and water for irrigation and domestic use) is satisfied with the minimum operational cost, thanks to proper optimization of the programmable units scheduling. For each time step, the most cost-effective schedule is obtained using Mixed Integer Linear Programming (MILP) embedded in a rolling horizon approach considering start-up penalties, battery wear cost, ramp limits of each component and other operational constraints.



- (xii) Provides outage management (i.e., number, duration, and extent)
- (xiii) Balances distributed and central control
- (xiv) Enables price-driven demand response
- (xv) Reduces peak loads for the interconnected grid
- (xvi) Integrates with intermittent and variable output renewable energy resources
- (xvii) Defers generation, transmission, and distribution investments

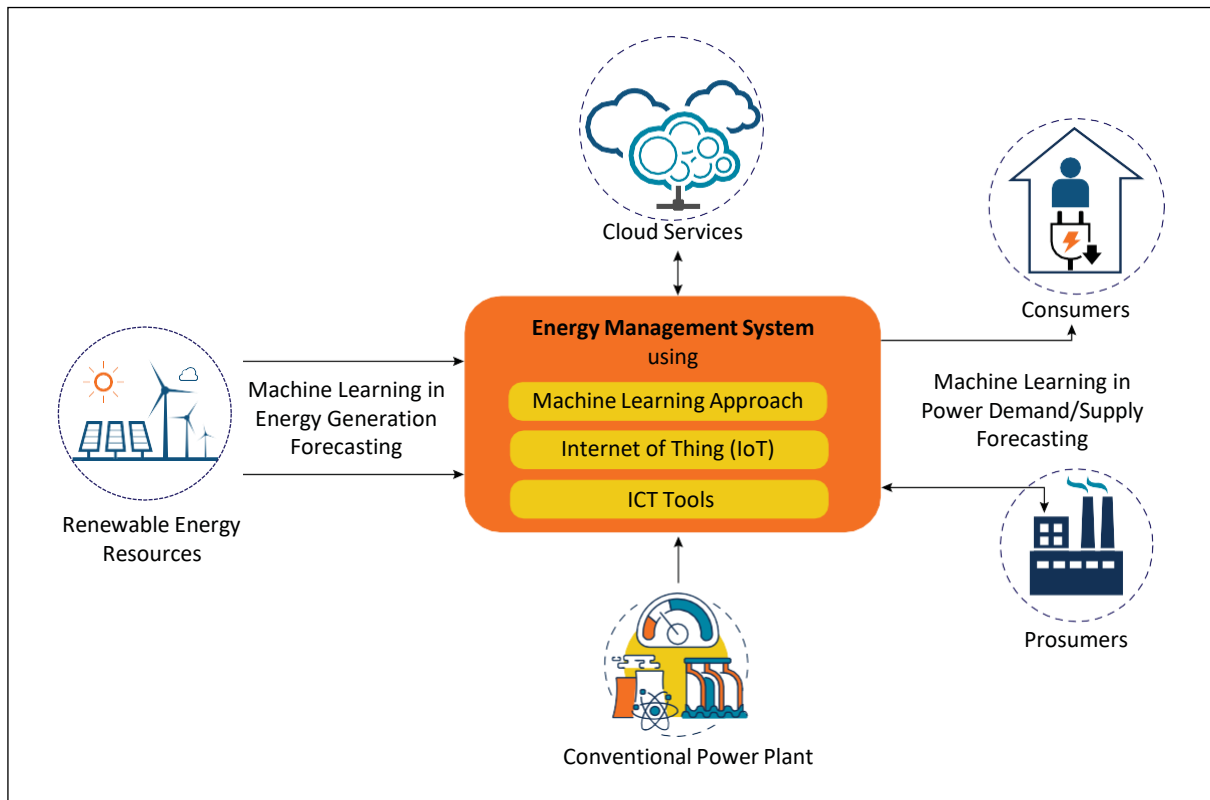


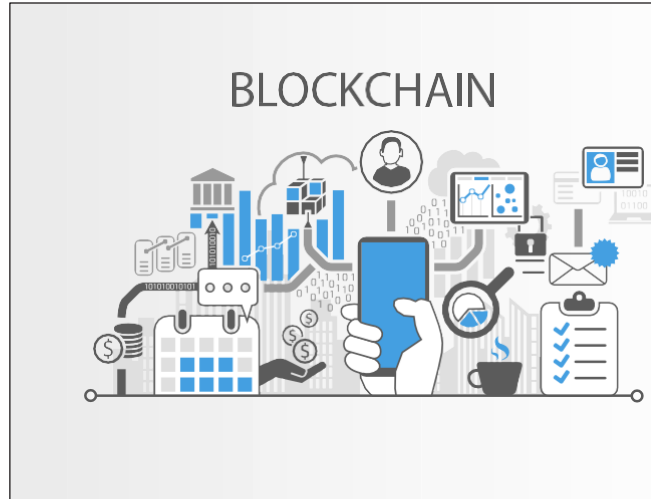
FIGURE 20: Usages of Advanced Technologies in Hybrid-renewable Energy Systems (HRES)

5.4.5

Embracing Blockchain Technologies to Foster peer-to-peer Trading

The peer-to-peer (P2P) electricity trading model creates an online marketplace where prosumers and consumers can trade electricity without an intermediary at their agreed price. P2P empowers prosumers and consumers, resulting in higher renewable energy installations and system flexibility. P2P systems also

help with balancing, congestion control, and the provision of ancillary services. P2P trading enables users to assist their local communities by consuming renewable energy while earning more from distributed generation, with or without storage systems. At the same time, customers who do not have renewable generation capacity can profit directly from local renewable generation via P2P power trading. Along with increased local use of variable renewable energy, P2P power trading can aid in the reduction of investments in generating capacity and transmission infrastructure required to meet peak demand.



Inspiration Corner



Metabolic's Spectral, a smart energy services firm, is in a mission to hasten the worldwide transition to 100% renewable, clean energy. Spectral, in collaboration with Alliander, the Netherlands' most advanced distribution system operator and architect of the Jouliette platform, the new token aims to empower individual and communities to easily manage and share their locally produced renewable energy. This allows the community to freely exchange renewable energy generated by its photovoltaic (PV) panels (independent of the national power grid) and therefore circumvent current market obstacles. The community can simply manage its micro-economy with the Jouliette platform, and unlike purely speculative currencies, the Jouliette tokens are supported by real energy and, the Jouliette tokens are supported by real energy output. Beyond energy exchange, the community plans to use the Jouliette for other purposes, such as trading products at local shops & cafes, facilitating a local time-banking system, and integrating other intra-community services, such as a car-sharing programme.

Power Ledger in Australia is merging two cutting-edge technologies – Blockchain and renewable energy – to change global energy markets and, ultimately, to power the globe with renewables. The company's blockchain-based platform facilitates peer-to-peer (P2P) solar energy trading, allowing consumers to sell excess electricity to other residential and business customers. P2P energy trading (individuals and wholesale for utilities), EV charging, transmission grid monitoring, P2P asset finance, and asset ownership token trading are all possible with this platform.



5.4.6 Developing an Integrated Re-forecasting and Balancing Mechanism

Renewable energy, unlike conventional power generation, cannot be “tamed.” Solar and wind energy output may fluctuate dramatically, often falling to near nothing in a matter of minutes (e.g., passing cloud). This makes their integration into transmission grids a significant challenge as it can threaten the stability and security of the overall grid. Therefore, the following measures need to be considered for the smooth and efficient operation of renewable energy integrated systems.



- (i) A good forecast and appropriate balancing action
- (ii) Optimum structure for renewable energy management structure
- (iii) Ancillary market
- (iv) A dynamic power market with short-term products
- (v) Appropriate grid code and control mechanism
- (vi) Adequate reserves
- (vii) Accounting and deviation settlement mechanism
- (viii) Flexible power system and demand-responsive consumption and
- (ix) Creating capacity for managing infirm power.

Scientific renewable energy generation forecasting methodologies and cutting-edge control centre capabilities are the need of the hour for large-scale integration of renewable energy to maintain security and reliability of the grid. The establishment of Renewable Energy Management Centers (REMCs) and the requirement for real-time viewing of RE generating data at the control centre.

Solar energy forecasting can be a low-cost solution for increasing grid flexibility and dependability in Cambodia. The Philippines now employs solar and wind energy forecasting on its network, putting the country in a favourable position to integrate renewable energy into other ASEAN nations due to their capacity to anticipate power output (Huang et al., 2019, p.719).

Renewable energy predictions using Artificial Neural Networks (ANN)

The unpredictable nature of renewable energy supplies, along with the neural network approach’s sophisticated capacity to absorb complicated time series inputs, has encouraged the application of ANN techniques in renewable energy forecasting. Various refinement architecture of neural works, such as “multi-layer perception (MLP), “recurrent neural network” (RNN) and “convolutional-neural network (CNN), as well as “long-short-term memory” (LSTM) models, have been proposed in renewable energy forecasting applications.³⁰ These models can forecast short-term time series in renewable energy sources and use previous information that impacts its value in the future. Several studies of ANN models for renewable energy forecasting or prediction have been done including solar irradiance and solar energy

³⁰ Prospective Methodologies in Hybrid Renewable Energy Systems for Energy Prediction Using Artificial Neural Networks- Md Mijanur Rahman et.al. Sustainability 2021

prediction, wind power prediction as well as hydropower prediction. Another design of the solar energy systems using MLP and autoregressive neural methods has been done by Loutfi. The model could predict solar radiation on an hourly basis with very simple data such as temperature and humidity. The backbone of any prediction models are historic data. Keeping in view the ambitious targets of Cambodia, steps should be taken to maintain historical weather and predictive variables data, e.g., weather data, humidity, temperature, wind speed, irradiation, kinetic energy, flow rate, time variable, location variable and seasonal variable, etc., and also establish an effective system for RE forecasting and modelling.

5.4.7 Establishment of Renewable Energy Management Centers (REMCS) for Renewable Forecasting & Scheduling

Like many RE-rich countries, Cambodia can establish REMCs to forecast, schedule and manage the varying renewable energies in its RE-rich provinces or load centres like Phnom Penh. A typical example is the recent adoption of REMCs in India who designed the Green Corridors and REMCs with a greater vision than Europe and the United States when it comes to renewable energy management.



Inspiration Corner

Due to the intermittent and unpredictable nature of RE generation, the Government of India's aim of 175 GW RE capacity by 2022 creates problems to grid management. The renewable energy management centres are outfitted with Artificial Intelligence-based RE forecasting and scheduling technologies, giving grid operators improved visualization and situational awareness.

The Renewable Energy Management Centers (REMCs) are co-located with the State Load Dispatch Centers (SLDCs) in its RE-rich states Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Madhya Pradesh, Gujarat and Rajasthan, as well as the Regional Load Dispatch Centers (RLDCs) in Bengaluru, Mumbai and Delhi, and the National Load Dispatch Center (NLDC). As of 2020, the eleven REMCs monitor 55 GW of renewable energy (solar and wind).

The Government of India had authorized the REMCs as a Central Scheme. It had designated POWERGRID, a Maharatna CPSE under the Ministry of Power, as the Implementing Agency. These REMCs are administered at the regional and national levels by Power System Operation Corporation of India Ltd. (POSOCO) and at the state level by State Load Dispatch Centres (SLDCs).



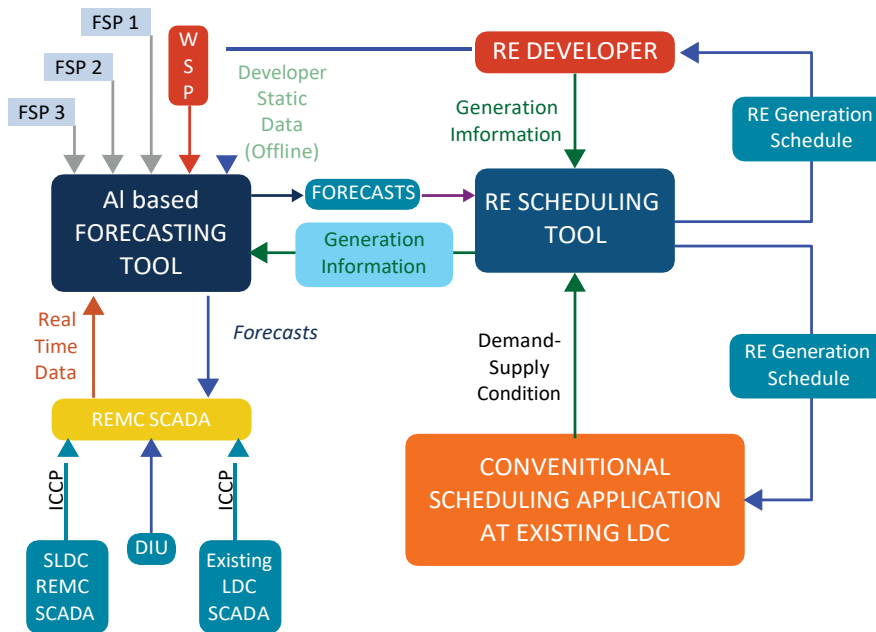


FIGURE 21: Thematic Diagram of REMC Mechanism in India

5.4.8 Increase Grid Flexibility and Improve the Integration of Renewable Resources through Demand-Side Management (DSM)



DSM may be strategically employed to optimize the periods when power is consumed to reflect generation availability.

Demand-side management can involve moving flexible demand to periods of high renewable output, such as preheating electric hot water heaters or charging electric automobiles during times of high solar energy production, and reducing demand during peak hours, therefore lowering the ramp's slope.

5.5 Legal

Policies related to renewable energy implementation, business organization, and the law and order situation are the main legal issues that significantly impact the integration of renewable energy sources.

Investor and consumer confidence are affected by a country's law and order condition. Security and safety are essential for investment and attract international investors. Despite the fact that most governments attempt to maintain a stable law and order environment, investors continue to be concerned about security.

Cambodia's regulatory framework for accelerating renewable energy adoption is inadequate since the government has yet to set formal renewable energy objectives outside of hydropower.

5.5.1 Modifications in the Existing Renewable Energy Grid Integration Regulations

1. According to the regulations, for installation of Solar PV System to use electricity for its own consumption and synchronized with the Electricity Supply System of National Grid, in the first step, only Big Consumers (medium voltage consumers) and bulk Consumers (high voltage consumers) are allowed to install Solar PV system and connect it to their system and synchronize with the Electricity Supply System of National Grid, to provide the additional electricity source for their consumption.³¹ These regulations may be broadened to all consumers who wish to install solar PV systems and synchronize to the grid. Promotion of hybrid solar rooftop systems will also be beneficial as it provides the consumers more flexibility in using SPV systems.
2. In Cambodia, the maximum capacity of the solar Power Project, as mentioned on the AC side at the output of inverter-based on rated inverter capacity, shall not be more than 50% of the Contract Demand in kW as stated in the Power Supply Agreement with the consumer. This may be increased to 100% or more based on the penetration capacity of the distribution transformers of the integrating regions in various provinces. For example, most states in India limit system capacity to 100% of the sanctioned load, and in some cases, more than 100% is allowed.



5.5.2 Enforcement of Renewable Purchase Obligations and Must-Run Status

Harnessing renewable energy relies on nascent and expensive technologies, which raises the cost of generating and supplying power. This is especially true for solar power technologies since the initial expenditure is significant. In order to boost this industry, incentives are needed to pique the attention of investors and make renewable energy a financially feasible option. RPOs are national government mandates that require electricity distribution companies to source a proportion of their total electricity volume from renewable energy sources rather than traditional sources like thermal, hydroelectric or nuclear power plants.



³¹ Regulations on General conditions for connecting Solar PV Generation sources to the Electricity Supply System of National Grid or to the Electrical System of a Consumer connected to the Electricity Supply System of National Grid-EAC-2015



Similarly, at the generation end, the share of renewable energy sold (including solar and biomass) is only 4% when their share in the total installed capacity is over 11%. The over-dependency on fossil fuels is evident in the increase in the share of coal-based power generation from 37% in 2018 to 46% in 2020. By providing a must-run status for renewable energy sources and imposing RPOs will ensure better utilization of renewable energy-based sources to meet the electricity demand.

EAC should establish RPO regulations in the country, ensuring transparency in the compliance process involving Distribution Licensees, Captive Power Producers, and Open Access Consumers. EAC should monitor the RPO compliance of provinces or distribution entities through the creation of a centralized monitoring system.

The following information may be noted for effective implementation and monitoring:

1. Energy Source: A source of energy, whether solar, non-solar, or otherwise.
2. Obligation (per cent): Implies the defined obligation in percentage corresponding to an energy source
3. Obligation (MU): The defined obligation in million units (MUs) corresponding to an energy source
4. RE: RE total corresponding to an energy source
5. REC: Renewable Energy Certificate total corresponding to an energy source
6. Total (RE + REC): The sum of the RE and REC associated to an energy source.
7. Achievement (percentage): The proportion of success
8. Surplus/Deficit (MU): The calculated energy surplus/deficit in million units (MUs)

Inspiration Corner

Renewable Purchase Obligations (RPOs) were established as part of India's National Action Policy on Climate Change to produce 15% of the country's power from renewable energy sources by 2008. The Renewable Acquire Obligations (RPO) are targets set for power utilities to purchase a specific percentage of their total power demand from Renewable Energy Sources under the Electricity Act of 2003 and the National Tariff Policy of 2006. The State Electricity Regulatory Commissions (SERCs) set these RPO objectives for each state annually. This has resulted in the development of the Renewable Energy Certificate (REC) market mechanism in India.

Inspiration Corner

The National Electricity Coordinator (CEN) of Chile has created a blockchain platform that will be used to track the use of renewable energy in copper production. The Renova initiative isn't only about copper; it also seeks to give renewable energy traceability and a database of the country's renewable energy resources. Companies are looking to renewable energy as a way to offset the environmental consequences of copper mining since there is a rising need in the mining sector for more transparent and ecologically responsible operations.

In Chile, the renewable energy sector is rapidly expanding. Despite this, it is nevertheless usual to sell duplicate contracts or account for the same renewable energy certificate twice. The Renova platform reduces the risk of fraud in the renewable energy sector and provides miners with extra assurance that they are receiving the clean energy they are paying for, which is more expensive than regular power. Renova will also help Chile achieve its goal of becoming carbon neutral by 2050.

5.5.4 One nation-one grid

As mentioned in Chapter 3, there is no national electricity network, and electricity is supplied via small isolated electricity systems. It was estimated that 600–1,000 REEs provided electricity to off-grid customers, traditionally through diesel. Cambodia's 2015 Power Development Plan (PDP) calls for extending the transmission network by about 2,600 kilometres (km) to connect all provinces to the national grid by 2020, as well as supporting the electrification drive

and lowering energy costs.³² Backed by the national plan to connect all 24 provinces to the national grid by 2020, a decentralized energy supply may become crucial to solving the problem. Biogas, solar and wind power generation could add further diversity to domestic power production, helping to reduce prices while increasing the reliability of the energy supply. With the expansion of the grid, more REEs are being connected to the national grid supply and are no longer reliant on expensive diesel supply. Keeping in mind the benefits of advanced micro-grid systems for better RE integration, trading, forecasting, management, etc., a hybrid system capable of islanding and micro-management deems most effective. Cambodia still being at the nascent stage of power reforms; it is easier to adopt the best operating system through detailed simulation studies and pilot demonstration projects.



³² ADB-2018-Cambodia Energy Sector Assessment, Strategy, and Road Map

Upcoming initiatives

The Asian Development Bank (ADB) has authorized a \$127.8 million loan to fund the building of transmission lines and substations to help deliver a secure and dependable power supply to Phnom Penh and three other Cambodian provinces. The Grid Reinforcement Project, along with ADB's ongoing assistance to Cambodia in power system planning, shows that adequate, reliable, and environmentally sustainable power supply can be provided at a reasonable cost to support equitable development.

5.5.5 Upgradation of Grid Code and Coordinated Grid Planning & Strengthening

As mentioned elsewhere in the study, with the increasing RE penetration in Cambodia, the transmission of green power across the country becomes challenging without robust transmission and distribution planning. As a result, it is advised that a coordinated approach to grid planning is necessary, and examining the RE potential distribution across the country is essential for future network development. While the gestation period for RE projects (solar and wind) ranges between 6 and 12 months depending on plant capacity, the associated transmission network for evacuation of RE power (including transmission network development, establishment of RE pooling station/sub-station, and system strengthening for absorption of additional RE power) takes approximately 3–4 years. It may be preferable if EDC performs grid strengthening and expansion work that requires capabilities to deal with concerns such as Right of Way (RoW), among other things.



Inspiration Corner



Laws, policies, regulations and grid codes, which enabled Germany to adapt to the increasing penetration of RE.

To support dynamic expansion of renewable energies, Germany has different renewable energy support policies;³³

1. Regulatory policies

- » Feed-in tariff (incl. premium payment)
- » Biofuels obligation/mandate
- » Heat obligation/mandate

2. Fiscal incentives

- » Capital subsidy, grant, or rebate
- » Investment or production tax credits
- » Reductions in sales, energy, CO₂, VAT, or other taxes

3. Public financing

Public investment, loans, or grants

Expansion of power grids

Rapid expansion and modernization of electricity grid in Germany has been started to ensure that it is better equipped for transporting electricity from renewable energies. Against this background, the German government has approved plans to amend the Energy Management Act so that, for the first time, it facilitates coordinated nationwide planning of grid expansion. Through strong public involvement, the proposed rules will ensure a large measure of transparency, making it possible to generate great acceptance for grid expansion. In addition, the proposed "Act concerning measures to speed up the expansion of power grids" is to make it possible to ensure faster construction of very-high-voltage transmission lines. The electricity grids are also due to be modernized, for instance, through "Smart Grids".

Experience of grid operators worldwide shows that besides several other factors integrating a significant amount of wind largely depends on the accuracy of the wind power forecast. Varieties of challenging operating conditions for successful management of wind energy integration in the grid by transmission system operator are:

³³ REN21, Renewable Energy Policy Network for the 21st Century, Renewables 2011, Global status report

1. Overload on control area internal power lines but also lines that interconnect with the neighbouring control areas
2. Overloads of transformers linking the transmission level with the distribution level
3. Problems with local voltage stability
4. Problems with frequency stability/system balance

All technical problems arising due to grid integration of wind energy have been addressed in Germany by respective transmission system operators. Some of the key issues are:

1. Excess power produce from wind: When the actual wind power in feed exceeded the demand such as during low load conditions, the excess wind capacity has to be transported to neighbouring TSOs (Transmission System Operators) where the electrical demand is much higher.
2. Wind power forecasting: 50 Hertz, a transmission system operator in Germany uses three different forecast tools. It receives wind power forecast data from four different forecast service providers. The forecast horizon is 96 hours and beyond that it's updated twice a day. The information is combined using a weighted sum. Dispatchers use the information to develop an operational forecast.
3. Power congestion: During periods of congestion in the grid at 50 Hertz, Germany redispatches power plants to manage overloads. European Commission Renewable Electricity Directive requires that wind generators are guaranteed priority dispatch, except for those conditions that affect the stability of electricity grid. To ensure a reliable and secure electricity supply, the directive states that wind production can be curtailed if the grid is endangered. As part of the process, the curtailment orders are determined using information about generators that have the most impact on the congestion at that time. However, this curtailment only occurs during heavy flow of power. As a last measure, 50 Hertz manually curtails winds by informing the respective distribution system operators about the required amount of power to be curtailed and for how long.

New German grid codes for connecting PV systems to the medium voltage power grid:

The penetration of renewable energies in the power grids has been increasing in the last couple of years due to successful regulations like the Renewable Energy Law in Germany and comparable regulations in Spain and elsewhere. This expansion of renewable energies, especially PV systems, can only happen due to an unlimited access to the power grid. A high penetration of renewable



energies harbours the risk of grid instability in case the generating plants are not able to support the grid. On this background, the German Association of Energy and Water Industries introduced in 2008 the new grid codes for connecting power plants to the medium voltage power grid.

Dynamic grid support:

By dynamic grid support, voltage stability during voltage drops in the overlying high-voltage grid is meant and often referred to as Fault-Ride-Through (FRT). Due to an increasing penetration of decentralized generating plants in the medium-voltage grid, it is necessary to include these plants in dynamic grid support. This means generating plants have to be able:

1. To stay connected during a fault,
2. To support the voltage by providing reactive power during the fault, and
3. To consume the same or less reactive power after the fault clearance.

Short circuit:

The short circuit current of the network in the area of the grid connection point is increased by the short circuit current of the generating plant and can thus exceed the limits of the power grid. Thus, it is essential to take the short circuit into account when connecting a generating plant to the grid. The short circuit of a synchronous generator is typically eightfold of the rated current, whereas generators with converter like PV have typically the same short circuit current as rated current. Thus, there is no necessity for PV to limit the short circuit current by, for example, an external current limiter.

Active power control:

The generating plant must be able to reduce its power output. The following cases allow the network operator to temporarily limit the feed-in power or disconnect the plant:

1. Risk of unsafe system operation
2. Risk of bottlenecks and congestion in the network
3. Risk of unwanted islanding
4. Risk of static or dynamic grid instability
5. Risk of instable system due to frequency increase
6. Carry out repairs or construction

In the context of production management, feed-in management, and network security management:

The plant must be capable of power output reduction steps of 10% (or smaller) of the agreed rated output power. A setpoint given by the network operator must be reachable from any operation point in any operation mode. Commonly used setpoints at present time are 100%, 60%, 30%, and 0%. The network operator does not interfere in the control of generating plant, but only gives a signal for the setpoint.

Static grid support by reactive power control:

Static grid support voltage means stability in the medium voltage grid under normal operation. Slow changes in voltage have to be kept in acceptable limits. In case of operation requirements and on demand of the system operator generating plants have to supply static grid support. The generating plant has to be able to provide reactive power in every operating point according to the following displacement factor at the grid connection point:

$$\cos\varphi=(0.95)_{\text{underexcited}} \text{ to } (0.95)_{\text{overexcited}}$$

Today, PV systems are designed to produce active power only. Reactive power is avoided due to losses in the inverter, lines and transformers. To meet the requirements of the grid codes, the inverter of a PV system has to be designed bigger. A 500 kVA inverter will then be designed for a rated active power of 475 kW. Overall, an increase of system costs has to be expected. Reactive power has to be only provided during feed-in operation, so there is no need to provide reactive power during the night.

The reactive power setpoint can be either fixed or adjustable by a signal from the network operator. The setpoint value is either:

1. A fixed displacement factor $\cos\varphi$ or
2. A variable displacement factor depending on the active power $\cos\varphi P$ or
3. A fixed reactive power value in MVar or
4. A variable reactive power depending on the voltage Q

The generating plant must be able to traverse the agreed area of reactive power within a few minutes and as often as required. If the network operator provides a characteristic, each value resulting from this has to be automatically set within 10 seconds.



5.6 Environmental

Climate change, carbon footprints or different types of pollution, health concerns, natural resources, or the availability of renewable energy sources are all considered environmental considerations.

5.6.1 Cambodia Climate Change Strategic Plan 2014–2023



In response to climate change challenges and its commitment to the United Nations Framework Convention on Climate Change (UNFCCC) in 1996, the Royal Government of Cambodia issued the Cambodia Climate Change Strategic Plan 2014–2023 (CCCSP) in 2013.

Cambodia's Updated Nationally Determined Contribution (NDC)

Cambodia had ratified the Paris Climate Agreement and filed its Nationally Determined Contribution (NDC) to the UNFCCC, in which the government committed to a greenhouse gas (GHG) mitigation contribution for 2020–2030, subject to the availability of international funding. The goal for the energy sector was to reduce GHG emissions by 27%, or 3,100 gigagrams of carbon dioxide (Gg Co₂) equivalent (about 1.8 million tonnes of carbon dioxide [Mt-CO₂] equivalent) by 2030, compared to baseline emissions of 11,600 Gg Co₂ equivalent, primarily through the promotion of energy efficiency and renewable energy in the energy, manufacturing, and transportation sectors.

Further, Cambodia emphatically endorsed the objectives outlined in the Sustainable Development Goals (SDGs) 2016–2030. Following the SDGs' adoption by the UN General Assembly in late 2015, the RGC worked to adapt the objectives to the country context and created a completely localized framework—the Cambodian SDGs (CSDGs). In addition to the worldwide 17 goals, an 18th target mandating the removal of landmines and unexploded munitions was included. The final framework includes 18 CSDGs, 88 nationally relevant goals, and 148 globally and locally defined indicators.

The updated NDC has been significantly improved in various areas. For starters, coverage has expanded to include climate change mitigation objectives in the agricultural and waste sectors and more comprehensive activities in important sub-sectors like energy efficiency. It features a more robust set of adaptation efforts, which remain Cambodia's top priority. Second, in accordance with our REDD+ policy; governments' efforts to decrease emissions from deforestation and forest degradation, as well as to promote conservation, sustainable forest management, and the augmentation of forest carbon stocks; Cambodia have set ambitious aim in the Forestry and Land Use sector (FOLU) of halving the rate of deforestation by 2030. The mitigation projects are distributed among seven sectors: energy, waste, industry, transport, agriculture, building, and the FOLU.

By 2030, the FOLU is predicted to account for the majority of the 59.1 percent decrease in emissions. Other sectors such as energy (21.3%), agriculture (9.6%), industry (IPPU) (9.1%), and waste (0.9%) are expected to make

Affordable and Clean Energy



substantial contributions.

The focus for reducing emissions from the electricity industry will be on renewable energy power generation. Roadmap study on Integration of RE (Renewable Energy) resources is one of the mitigation projects/ activities under NDC of Cambodia. The roadmap aims 25 % of the renewable energy in the energy mix (solar, wind, hydro, and biomass) by 2030.

In other areas, Cambodia have enhanced their target for reducing Green House Gases (GHG) emissions since their original NDC in 2015. The new NDC also prioritizes gender and disadvantaged populations to ensure that the adaptation and mitigation efforts contribute to a more inclusive society. Finally, much effort has been expended in developing a strong framework for measuring, reporting, and verification (MRV) to provide reliable data on progress achieved and obstacles faced. This will assist Cambodia in refining its policies so that they not only meet Cambodia's NDC obligations but also its climate change objectives under the Sustainable Development Goals (SDGs).

Challenges in achieving NDC:³⁴

Cambodia's national energy policies and plans appear to be in line with the aims of Goal 7 and associated CSDGs. However, substantial financial resources are still required to invest in critical facilities such as power plants, the national grid, substations, and power management technologies. These investments will provide rural communities with access to clean energy that is accurately measured, efficient, and adequate. Despite Cambodia's rapid growth in power development, several obstacles remain, including power sources, network connectivity, financial assistance, plentiful renewable energy sources, and energy loss. Access to clean cooking fuel continues to be a significant concern. The aim is still far behind the plan, and a substantial number of people continue to rely on wood for cooking, contributing to indoor air pollution and negatively impacting vulnerable individuals.

5.6.2 Air Pollution Impacts

Increased usage of fossil fuels pollutes the environment and endangers human health. Outdoor air pollution caused 4.2 million premature deaths worldwide in 2016, according to the World Health Organization, with Southeast Asia and the Western Pacific having the largest number of deaths. According to a Harvard study, exposure to air pollution is related with an increased incidence of COVID-19 infection and death. Measures to minimize air pollution are part of an efficient pandemic recovery plan. A shift to low-carbon energy is a positive step towards cleaner air.

According to World Health Organization recommendations, Cambodia's air quality is deemed somewhat dangerous. According to the latest available statistics, the country's annual mean PM_{2.5} concentration is 26 g/m³, which exceeds the recommended level of 10 g/m³.

Vehicle emissions, road dust, the garment industry, tourism, agriculture, mining, power generation, and



traffic congestion all contribute to poor air quality in Cambodia. According to available statistics, Phnom Penh has persistently high levels of air pollution. Increasing the share of thermal power plants in the country can cause dangerous effects on the air quality as well as the health of the Cambodian population.

Switching to low emission end-use applications like green mobility (electric vehicles, green hydrogen transportation, biofuels etc.), green power resources, clean cooking solutions, electrifying industrial applications, etc., can mitigate all types of pollution from the Kingdom of Cambodia. Integration of renewable sources of energy to meet green initiatives for end-use applications is essential.

³⁴ 23603Cambodia_VNR_PublishingHLPF.pdf (un.org)

Cambodia joined the Climate and Clean Air Coalition (CCAC) in 2014 to encourage national and international efforts to minimize short-lived climate pollutants (SLCPs). Cambodia declared an interest in decreasing its hydrofluorocarbon emissions, as well as other SLCP emissions from agriculture, municipal solid waste, transportation, industry, and home energy, upon joining. Cambodia, represented by the Ministry of Environment, participates in the Coalition’s HFC, Waste, and Supporting National Action & Planning (SNAP) Initiatives.

Inspiration Corner

Financial Support for Changing the Energy System Structure to Improve Air Quality in the Metropolitan Area of Kraków.³⁵

Energy generated via the use of solar panels has a specific position in Poland’s so-called energy mix. 2021) (Gnatowska and Mory-Kucharczyk). The Republic of Poland’s government prioritizes growing the volume of solar energy generation through popularizing and co-financing private home investments in photovoltaic panels. The government’s MY ELECTRICITY PROGRAM’s principal purpose is to enhance energy generation from solar micro-installations. This initiative is aimed at homes, and co-financing is limited to no more than 50% of installation expenses and a maximum of 5,000 PLN. Installations with 2–10 kW installed power may be considered.

The installation of solar panels on single-family homes, which is co-financed by the government’s My Electricity Program, is the investment cost in improving the air quality in this region and thereby raising the well-being of its residents.

5.6.3 Role of Biomass



In Cambodia, biomass is the most often used energy source in the residential sector. It is mostly used for cooking and heating, which may have an impact on health owing to indoor air pollution. The biomass is mostly derived from wood cutting and forest encroachment, which may have an influence on the ecosystem owing to significant forest loss. Using data from the Cambodia Socio-Economic Survey 2015, a study explored the effects of electricity consumption on household welfare, such as incomes and school performance of children in the homes, as well as its environmental repercussions.

³⁵ Blazy Rafał et.al, (2021) Renewable Energy Sources vs. an Air Quality Improvement in Urbanized Areas - the Metropolitan Area of Kraków Case- *Frontiers in Energy Research*, Vol:9, pg:657,



The study discovered that household access to electricity, as well as the ability to spend on electricity consumption, contributes to positive household welfare effects and the environment by reducing biomass consumption, and the more household spends on biomass, the more susceptible they are to lung disease. The study also confirmed the critical importance of human capital building in improving the well-being and the environment. These findings have policy implications for improving cheap access to power so that all households can utilize electricity for essential needs and productivity, and also to reduce the negative effects on environment.

- a. Household access to electricity contributes to the favourable impacts on household well-being.
- b. The more a household spends on biomass, the more likely they are to suffer from lung disease.
- c. The study proved the critical significance of human capital creation in improving welfare and the environment.

5.6.4 Carbon Markets Development to Enhance Emission Trading Schemes

Carbon pricing is an important policy tool for promoting renewable energy transitions. Carbon pricing may promote investments in low-carbon technology advances, boost international cooperation, and establish synergies between energy and climate policy by internalizing the social cost of greenhouse gas emissions. Emissions trading systems are one option for carbon pricing plans. Trading systems give certainty about the permissible emissions trajectory while enabling carbon prices to fluctuate when emissions are capped.



Emissions trading systems incentivize emissions reductions where they are most cost-effective. Emissions trading systems have piqued the attention of sub-national, national, and supranational jurisdictions as a policy tool for achieving climate change mitigation goals.³⁶

When defining the function of a trading system, policymakers should consider what the plan is intended to achieve and what it is expected to perform. An emissions trading system, for example, maybe designed to generate carbon reductions as its primary duty, or it could serve as a backup for other measures. In actuality, the system may operate differently than planned—as a way of raising cash for future emission reduction initiatives or in industries other than those covered by the system. While defining the function of an emissions trading system, policymakers might consider other predicted system impacts, such as modifying company behaviour or transferring investment.

³⁶ Implementing Effective Emissions Trading Systems: Lessons from international experiences-IEA



Inspiration Corner



Indonesia and Thailand have adopted their carbon market measures such as emissions trading schemes (ETS) and crediting mechanisms. Thailand used a Voluntary Emission Trading Scheme to evaluate its monitoring, reporting, and verification (MRV) system and created operating guidelines. Emissions trading is also being considered by Indonesia. The “Nusantara Carbon Scheme (NCS)” is Indonesia’s own voluntary carbon market launched in March 2021. NCS was created to raise awareness among local stakeholders about how a locally built market-based instrument may be used to incentivize mitigation activities.



WAY FORWARD

A renewable energy transition is essential for Cambodia to achieve its goal of low- carbon pathways in the power sector since one of its key objectives is environmental protection, resulting in an economic structure that is climate-change adapted and a low-carbon society. The Cambodian power sector has a unique opportunity to steer transition towards low-carbon pathways as enormous generation capacity expansion and transmission, and distribution systems are planned under the upcoming Power Development Plan.

Resources availability, socio-economic & political challenges, and environmental concerns play an integral role in restructuring the energy sector and renewable energy deployment in any country's power system; Cambodia is no exception. High capital expenditures, a lack of technical know-how in implementing emerging technologies, and the devastation caused by natural catastrophes and current fossil fuel pricing patterns prevent Cambodia from meeting its projected RE penetration objectives. As a result, to fulfill the growing energy demand from renewable energy sources, Cambodia's strategic planning procedures for renewable energy implementation require a comprehensive study. In this direction, TERI conducted PESTLE analysis (Political, Economic, Social, Technological, Legal, and Environmental) to explore actionable recommendations for the country.



1. Political

- » Strengthening regional ties in the ASEAN Region or Greater Mekong Region through cross border power exchange for RE balancing and load management

2. Economic

- » Green recovery of the Cambodian economy
- » Curbing the electricity prices
- » Financial incentives to promote clean energy
- » Concessional climate finance through soft loans, green bonds, guarantees, and blended finance

- » Promotion of global competitive bidding in renewable energy development and balancing mechanisms

3. Social

- » Creating an enabling environment to boost employment with renewables
- » Nurturing social entrepreneurship and women empowerment through clean energy applications
- » Catalyzing adoption of renewable-based microgrid systems for rural electrification

4. Technological

- » Utility-centric solar rooftop programmes
- » Sustainable hydro power
- » Adoption of grid-scale energy storage to mitigate intermittency in large-scale grid integration of renewable energy
- » Large-scale deployment of Distributed Energy Resources (DERs) and Intelligent Microgrids near load centres
- » Embracing blockchain technologies to foster peer-to-peer trading
- » Developing an integrated RE-forecasting and balancing mechanism
- » Establishment of Renewable Energy Management Centers (REMCs) for renewable forecasting & scheduling
- » Increase grid flexibility and improve the integration of renewable resources through Demand-Side Management (DSM)

5. Legal

- » Modifications in the existing renewable energy grid integration regulations
- » Enforcement of Renewable Purchase Obligations (RPO) and must-run status
- » Applying blockchain technologies in REC market mechanisms
- » One nation-One grid
- » Upgradation of grid code and coordinated grid planning & strengthening

6. Environmental

- » Cambodia Climate Change Strategic Plan 2014–2023
- » Air pollution impacts
- » Role of Biomass
- » Carbon markets development to enhance emission trading schemes

Political: Active participation of all stakeholders in studying the cross-border transfer potentials corresponding to different feasible scenarios would help better capture the changing sector profile in the



other countries, assess the costs and benefits transparently, and build a consensus on that. Therefore, strengthening regional ties in ASEAN and Greater Mekong Region would enable the Cambodian power sector to meet the balancing requirements for renewables. Despite the fact that each country is sovereign in its own right, some level of regulatory cooperation would be required to enable the smooth growth of the regional grid from the design, operation, and commercial settlement perspectives. It would also be essential to ensure transparency, consistency, and predictability in regulatory approaches. Mutual trust between partner nations is, without a doubt, a necessary condition for regional cooperation to flourish. Given the geopolitical sensitivity, it is sensible to use a “building block” strategy, beginning with bilateral trade and gradually expanding to include different nations in the Greater Mekong Region. It’s never easy to plan and operate an extensive, linked system. The region’s countries may be equipped differently in this regard, both hardware, and software. For this, a structured and need-based capacity-building programme would be beneficial.

Economic: The Cambodian government recognizes that high electricity tariffs and unreliable electricity supply hamper economic growth and make it difficult for the country to attract investments and stimulate economic activity. By utilizing falling prices in renewables, the government could rationalize the tariffs and increase economic activities in the country. Further, for attracting clean energy investments government could bring tax reforms, debt financing, and promoting competitive bids among global players.

Social: Affordable and reliable power supply determines a country’s future in socio-economic indices. Increasing the penetration of renewables, especially among rural areas, can considerably stimulate employment opportunities in a post-pandemic scenario. These initiatives would help achieve the goal of 100% rural electrification and help create a sense of ownership among rural communities. Introducing new employment opportunities through RE-based rural microgrids would nurture social entrepreneurship and women empowerment.

Technology: Transmission infrastructure is critical to the smooth operation of the regional grid. Thus, a long-term basin-wide approach should be used to build a well-knit intra and inter-regional transmission system. This is critical to reduce right-of-way limitations and the risk of power-transfer congestion. In this context, implementing appropriate intelligent smart grid technologies like advanced RE forecasting models, adopting blockchain technologies to enable peer-2-peer trading and energy storage systems to fulfill balancing requirements is also crucial.

Legal: The investor’s trust largely depends on the legal and policy framework of the country. In this direction, Cambodia’s regulatory framework for accelerating renewable energy adoption is inadequate since the government has yet to set formal renewable energy objectives outside of hydropower. Enforcement of renewable purchase obligations among designated entities and introducing amendments in existing regulatory frameworks tailored to local conditions could help to accelerate the deployment of clean energy in the country.

Environment: With the country’s present fossil fuel resources incompatible with climate and sustainable development goals, and the COVID-19 epidemic producing fuel price instability and economic uncertainty, now is the time to prioritize renewable energy sources in its energy planning and growth strategy. Therefore, catalyzing investments in the renewable sector through unlocking socio-political synergies helps achieve the country’s Nationally Determined Contribution (NDC) targets and has multi-folded environmental benefits.



We are an independent, multi-dimensional organization, with capabilities in research, policy, consultancy and implementation. We are innovators and agents of change in the energy, environment, climate change and sustainability space, having pioneered conversations and action in these areas for over four decades. We believe that resource efficiency and waste management are the keys to smart, sustainable and inclusive development. Our work across sectors is focused on (a) promoting efficient use of resources; (b) increasing access and uptake of sustainable inputs and practices; and (c) reducing the impact on environment and climate. Headquartered in New Delhi, we have regional centers and campuses in Gurugram, Bengaluru, Guwahati, Mumbai, Panaji, and Nainital. Our 1,000-plus team of scientists, sociologists, economists and engineers delivers insightful, high quality action-oriented research and transformative solutions supported by state- of-the-art infrastructure.

