KINGDOM OF CAMBODIA

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Energy Tech Roadmap

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National Council of Science, Technology & Innovation

Ministry of Industry, Science, Technology & Innovation

EnergyTech Roadmap

General Department of Science, Technology & Innovation

Foreword

This EnergyTech Roadmap is a comprehensive policy document navigating the efforts towards the dynamic landscape of energy technology in our pursuit for a socioeconomic development and a sustainable future. The challenges we face nowadays are overwhelming, attributed by rapid population growth, urbanisation, and industrialisation all of which put the stress on our limited resources and contribute to the climate crisis. The need for self-reliance in energy security and the transition to sustainable energy sources has become our priority, as illustrated in Cambodia's Sustainable Development Goals, requiring bold and transformative action. However, we live in an era of unprecedented scientific and technological advancement, where innovative solutions have the potential to tackle and reshape our energy landscape.

The EnergyTech Roadmap serves as a stepping stone, guiding us through the web of opportunities brought on by the energy transition. It lays out a strategic framework, informed by research, expert consultation, industry insights, and collaboration across diverse fields, to shed light on energy security and a sustainable energy future. Within this roadmap, a wealth of knowledge, expert analysis, and actionable recommendations covering a wide spectrum of key energy technologies Cambodia needs to embrace, from renewable energy sources such as solar, wind, and hydropower, to advanced energy storage systems, smart grids, and electrification of transportation. Furthermore, we explore emerging fields such as nuclear and hydrogen energy, where ongoing research and development hold promise for addressing our most pressing energy challenges.

This roadmap is not a static but a living document, designed to adapt to the fast change of energy landscape. It reflects the collective efforts of scientists, engineers, policymakers, entrepreneurs, and visionaries who are working tirelessly to shape a sustainable future. However, the EnergyTech Roadmap is more than just a compilation of technical information. It is a call to action for all relevant stakeholders to work together to bring an energy transition for Cambodia to become a self-sufficient energy security nation.

As the Minister of Industry, Science, Technology & Innovation, and the Chair of National Council of Science, Technology &Innovation, I would like to congratulate the General Department of

Science, Technology & Innovation on the extraordinary accomplishment on producing this EnergyTech Roadmap. I highly comment all STI actors playing in energy sector to materialize this important document for sustainable development for our noble endeavour.

Phnom Penh, 21 July 2023

Senior Minister
Minister of Industry, Science, Technology & Innovation
and Chair of the National Council of Science, Technology & Innovation

***Kitti Setha Pandita* CHAM Prasidh**

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A special thanks to the members of the sub-committee for providing guidance, feedback, and strategic insights to shape the priorities, milestones, and strategies outlined in this roadmap, as follows:

- Ministry of Mine and Energy
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- Ministry of Industry, Science, Technology & Innovation
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Executive Summary

Energy has not only been the primary source for human survival but also the prerequisite for economic development and modern civilisation. Throughout human history, the evolution of humankind from prehistory to the digital age in the present time is strongly correlated with the discovery of new energy sources, starting from the discovery of fire to electricity, nuclear power, hydrogen, and other sources such as renewable and clean energy, enabling the economic prosperity and dramatic poverty reduction of many countries around the globe. Energy is not only specifically important for economic development but is also becoming the strategic and political driver for today's geopolitical and competitive world. A crisis in energy often leads to serious problems that hinder not only the economic prosperity of a country but also the security and survival of that nation. Consequently, all nations, including Cambodia, are seeking to ensure energy security and self-sufficiency to pursue their national interests and security in this competitive era. The discovery and transition to new energy sources in recent decades have been strongly associated with the progress of science, technology, and innovation. Hence, this Energy Technology (EnergyTech) Roadmap for Cambodia is a strategic policy document guiding and providing insights to stakeholders of the Royal Government of Cambodia (RGC) to wisely take courses of action regarding key technologies to be adopted in order to ensure the realisation of the Rectangular Strategy Phase 4, the Industrial Development Policy 2015-2025, and many others, and to, ultimately, realise the RGC's vision 2030 and 2050, as without energy security, the failure to achieve this goal is almost certain. This energy technology roadmap aims to achieve the vision ***"To become an energy self-sufficient nation through the deployment of technology and innovation, and leveraging renewable energy sources for sustainable development by 2030".*** With this regard, this roadmap has been developed on the basis of co-creation, multi-stakeholders, and a consensus-building framework involving key ministries, researchers, experts from the private sector, and related development partners. The roadmap has identified the opportunities and threats that Cambodia has been facing derived from the contextual analysis based on the Social, Technological, Environmental, Economic, and Political (STEEP) landscape of Cambodia. This roadmap then identified key drivers that Cambodia needs to consider to achieve the vision set forth in this roadmap, as well as energy security, including increasing local energy generation, enlarging the share of renewable energy, and leveraging energy efficiency. To realise the above-mentioned targets, eight strategic products and services related to fossil energy, renewable energy, new energy sources, storage capacity, power stability, power transportation/distribution, efficiency, and conservation

energy consumption have then been prioritised. Key technologies in each product and service will then be determined based on their strategic importance, high economic impacts, and high potential for success in Cambodia's context in the short, medium, and long term. The study indicated that Cambodia shall focus on energy from oil, hydropower, and solar PV in the short to long run for energy production. In power security and stability, safety and quality control technology and key technologies such as energy management systems, flexible AC transmission, and real-time detection shall be in focus. Battery storage capacity, high power density, and pump storage are technologies to be considered in power storage. Grid substations and smart grid systems will ensure efficient transportation and distribution of energy. Technologies such as smart homes/devices, power-efficient motors, integrated electric motors, energy-saving labels, and so on are proposed key technologies to ensure energy efficiency and conservation for the RGC to achieve its vision. Additionally, this EnergyTech Roadmap also depicts the necessity of two major findings, which are the current world megatrend for energy, including electrical vehicles, and possible new sources of energy, including nuclear power and hydrogen power, which Cambodia shall explore through scientific research and development. This roadmap also provides insights into how these technologies will be obtainable. Last but not least, key recommendations to the relevant stakeholders and policy implications to RGC, with hindsight, to take the right courses of action in order to achieve the vision of this Energy Technology Roadmap and energy security as the main agenda for economic development, in turn achieving the government's vision and the country's prosperity.

To this end, in order to achieve the optimal result, a monitoring and evaluation framework shall be in place and continuously conducted, and this roadmap shall be reviewed and finetuned every three to five years to ensure that it is relevant and effective in guiding the direction for energy technology development in Cambodia to achieve the goals.

Abbreviation

ADB	:	The Asian Development Bank
AI	:	Artificial Intelligence
ASEAN	:	Association of Southeast Asian Nations
EAC	:	The Electricity Authority of Cambodia
EEC	:	Energy Efficiency and Conservation
EEIs	:	Energy Efficiency Indicators
ERIA	:	Economic Research Institute for ASEAN and East Asia
ESCO	:	Energy Service Company
EV	:	Electrical Vehicles
DNI	:	Direct Normal Irradiation
GDE	:	General Department of Energy
GDP	:	Gross Domestic Product
GHG	:	Greenhouse Gas
GHI	:	Global Horizontal Irradiation
GWh	:	Gigawatt Hours
IDP	:	Industrial Development Policy
IEA	:	International Energy Agency
IOT	:	Internet of Thing
ktoe	:	Kilotons of Oil Equivalent
kWh	:	Kilowatt Hours
LED	:	Light-Emitting Diodes
LPG	:	Liquefied Petroleum Gas
MME	:	Ministry of Mines and Energy
MW	:	Mega Watt
MWp	:	Megawatt-peak
NSDP	:	National Strategic Development Plan
OCA	:	Overlapping Claims Area
R&D	:	Research and Development
REAP	:	The Renewable Electricity Action Plan
REF	:	Rural Electrification Fund
RGC	:	Royal Government of Cambodia
SDG	:	Sustainable Development Goal
STEEP	:	Social, Technology, Environment, Economic, and Political
STI	:	Science, Technology & Innovation
TFEC	:	Total Final Energy Consumption
TPES	:	Total Primary Energy Supply
TWC	:	The World Count
TWh	:	Terawatt Hours

Table of Contents

1 Introduction

1.1 Background

Energy is a public resource which is vitally important underpinning human and economic development. Throughout human history, the evolution of human species, especially the progress in economy and civilisation, has been strongly associated with the discovery of energy sources and types, and the advancement of energy technology. The availability of energy has transformed the course of humanity over the last few centuries (Mika, et al., 2021). For instance, the invention of energy production from steam has led to a tremendous change in human civilisation history, leading to the industrial revolution, the critical point for modern life in human history. The transition from steam energy to electricity and the continuous advancement in energy technology to the present time, have accelerated the economic modernisation and prosperity of many countries around the globe. Energy is not only important for economic development but also has strategic and political importance. Consequently, all nations are seeking energy security and self-sufficiency to ensure their national interests and security.

In fact, the United Nations Agenda 2030 highlights accessing energy in its Sustainable Development Goal (SDG) 7, which aims for "affordable, reliable, sustainable, and modern energy for all by the year 2030" (UN, 2015). Based on the International Energy Agency (IEA), 770 million people in the world could not access electricity in 2019 (IEA, 2019). The accelerating progression to address this challenge has happened mostly through the expansion of electricity grids and the use of fossil fuels (IEA, 2015). Electricity generation is still heavily reliant on fossil fuels, nuclear, or large-scale hydropower, making sustainability aspects of energy sector development problematic (Mika, et al., 2021). In the world, there are various sources of energy, including fossil fuels, nuclear power, hydropower, and now other renewable technologies. The energy system has transformed dramatically since the Industrial Revolution. Demand for energy is growing across many countries in the world, as people get richer and populations increase (Hannah Ritchie, 2022). Based on The World Count (TWC), which is a global energy consumption observatory, global energy consumption will reach 740 million terajoules (an additional 30% growth) by 2040. To generate the electricity as well as the energy, the location is one of the primary factors to consider when thinking of energy generation. Some countries and regions are better suited to certain types of renewable energy, depending on their

natural resources. According to Bloomberg Terminal, 2019, the total primary energy supply in Cambodia was about 4,671 kilotons of oil equivalent (ktoe) in 2015. Therefore, to reach SDG goal 7, Cambodia should have a clear strategy, such as this energy technology roadmap, which could improve energy sufficiency and sustainability with cutting-edge technologies by 2030. This roadmap's goal is to (1) increase renewable energy capacity, (2) increase energy generation, and (3) promote the use of green energy across all sectors to reduce CO_2 emissions.

1.2 Country Context

1.2.1 Demographics, Energy Products

Cambodia has a land area of 181,035 square kilometres in the southern part of the East Asia Peninsula with a population of 15, 552, 211 (Male: 48%, and female: 51.5%) in 2019. The population growth rate is 1.4%[1]. Cambodia's economy increases rapidly, with an average growth rate of 7.7% from 1998 to 2019, making it one of the fastest-growing economies in the world[2]. It remains among the lowest in Asia, with poverty falling substantially from 47.8% in 2007 to 14.0% in 2014, and poverty rates declining by 1.6% a year from 2009-2019/2020 according to the World Bank 2022. However, the World Bank Open Data (2021)[3] reported that Cambodia's economy decreases at an average rate of 3% because of the COVID-19 pandemic and global economic downturn, and GDP per capita is $1,625 in 2021. Cambodia moves to lower-middle income status in 2015, and plans to become a higher-middle and high-income country by 2030 and 2050, respectively.

Cambodian sources of energy have primarily depended on diesel power plants, biomass (agriculture and firewood), thermal power plants (coal), hydropower plants, and other renewable energy. The Electricity Authority of Cambodia (EAC) annual report 2015-2017 recorded that Cambodian source of energy relied primarily on "Diesel" (91%) and "Coal" (3.20%) in 2010. From 2010-2017, diesel consumption dropped sharply to 10.69% because Cambodia has turned to hydropower (60.67%), coal (53.80%) and biomass (0.89%) as the main sources of energy (Mika, et al., 2021). Even though these trends make the status of energy in Cambodia better, the Asian Development Bank (ADB)[4] reports that around 5 million citizens

[1] (NIS, 2019)
[2] (The World Bank, 2022)
[3] (World Bank , 2021)
[4] (ADB, Cambodia Energy Sector Assesment, Strategy and Roadmap, 2018)

were not able to access grid electricity and still used old methods to generate electricity, including batteries, firewood, and other fuels. Historically, Cambodia had access to electricity at a rate of less than 1% in 1991, 56% in 2014, and more than 90% in 2019 (World Bank, 2019). Cambodia generated energy domestically at around 73.45% and imported it from neighbouring countries (Thailand, Lao PDR, and Vietnam) at around 26.55%, including non-renewable energy (48.83%) and renewable energy (51.17%) from local generation. In brief, non-renewable energy comprises coal (41.20%) and fuel oil (7.63%). Renewable energy came from hydropower (44.17%), solar power (6.36%), and biomass power (0.64%) in 2021[5].

Hydropower, agriculture biomass, wind energy, and solar energy are significant sources of renewable energy in Cambodia. First, hydropower projects have extended to nine hydropower dams in Cambodia with a capacity of 979 MW installment since 2002, and China has invested US$ 1.6 billion in the construction of hydropower. It is claimed that the government has approved more construction on hydropower facilities since Cambodia projected 4,000 MW of equipped capacity by 2040. Second, agriculture biomass also produced 54,290 MWh of energy from seven biomass generation plants (five plants in 2016 and two plants in 2017). The third source of renewable energy is wind energy. Cambodia can generate around 500 MW from wind based on the speed recorded (5 km/s) in the coastal provinces and the southern part of Tonle Sap Lake. The last source of energy is solar energy. It is found that "the country has solar irradiance measuring on average 1,400-1,800 kWh per square metre per year throughout the country and an average of 6-9 hours of daytime." The government plans to scale up its 3.5% share of total energy by 2030, which is from solar farms (Marabona, 2019).

1.2.2 Infrastructure, Sources, Usage Data, Supply Chain

- Energy Consumption

Cambodia's Total Final Energy Consumption (TFEC) has grown stably around 7.2% in 8 years since 2010. Biomass has still played a very vital role in generating energy for household use, industry, and electricity production. In 2018, the biomass share of TFEC was 25.5%, whereas in 2010, its value was 40.9%, and the rate of oil and electricity trade increased yearly to 8.1% and 18.3%, respectively, as reported by the Ministry of Mines and Energy of Cambodia in 2020. From 2000 to 2008, Cambodia relied heavily on biomass, followed by oil.

[5] (EAC E. , 2021)

For cooking, charcoal and gas are more popularly used in cities than in rural areas because of their easier accessibility and cheaper prices compared with electricity (Mika, et al., 2021), while in rural areas, people use firewood and plants as their primary cooking energy (ADB, 2018). ADB (2018) reported that Cambodians utilised liquefied petroleum gas (31%), charcoal (5%), and electricity (2%) for cooking. It is implied that people can access firewood easily in rural areas for their cooking, followed by gas. The electricity consumption in 2019 was 10.29 billion kWh, and the world average in 2019 based on 189 countries was 125.19 billion kWh[6].

The Ministry of Mines and Energy (2022) concluded that "the country's GDP increased by 7.6% per year between 2000 and 2019, so the energy elasticity of GDP, the percentage change in energy consumption to achieve one percent change in national GDP, towards the TFEC (2000–2019) was 0.95. If biomass is excluded from the TFEC, the energy elasticity will be around 1.4 since the TFEC without biomass has been growing at 10.5% faster than the GDP. In this regard, a critical energy efficiency and conservation programme must be in place to improve elasticity in the future."

- Energy Demand

In 2040, the industry sector will demand 2.41 Mtoe, followed by the residential and commercial sectors at 5.67 Mtoe, (Kimura and Han, 2019). In 2022, the Ministry of Mines and Energy (MME) projected that the final energy demand would rise at an average rate of 5.3% from 2019 to 2050 and by economic sector from around 5 Mtoe in 2019 to 25 Mtoe in 2050. The main consumers of TFEC will be the industry sector, transportation, and other sectors. The industry sector is projected to be the main commercial, which will soar at an average rate of 6.2% over 2019-2050 annually, or "5.9 times from 0.72 Mtoe in 2019 to 5.04 Mtoe in 2050". Furthermore, the second sector of consumption turns to transportation, which is projected to grow at an annual rate of "5.6% or 4.78 times, from 1.75 Mtoe in 2019 to 10.12 Mtoe in 2050". Other sectors are expected to consume around "4.4%, from 1.81 Mtoe in 2019 to 7.15 Mtoe" in 2050. In 2022, MME projected that coal, electricity, and oil would grow annually at 10.3%, 7.6%, and 5.1%, respectively.

[6] (The Global Economic , 2019)

- Energy Supply

Local energy resources or generations cannot fulfill the growing demand for energy. Cambodia is reported to import electricity, coal, and diesel from neighbouring countries. For example, in 2021, Cambodia's annual power generation was 9,255 GWh, of which 3,345 GWh were imported from Vietnam (1,136 GWh), Thailand (306 GWh), and the Lao People's Democratic Republic (1,904 GWh) (EAC, 2021). Cambodia supplied electricity sales, commercial sector, residential sector, industry sector, and government sector were 31%, 28%, 23%, 16% and 4% respectively. This means that Cambodia needs to increase the supply to sustain the growing demand in the above potential sectors.

1.2.3 Facing Issues of Country, Supporting Programmes/Policies to Tackle the Country's Issue

Cambodia has faced many challenges, including the following: 1) The cost, reliability, and coverage of electricity fell behind those of the neighbouring countries, especially in rural areas; 2) Distance from the grid, connection costs, and low-income consumers hinder some rural households from accessing electricity; 3) Energy limitations hampers the country's economic competitiveness (Marabona, 2019); and 4) Energy insecurity due to the uncertainty of importing energy and climate change is critical for the country's development.

To secure a successful sustainable energy transition, RGC has endorsed policy documents and action plans to develop the energy sector, as below:

- National Energy Efficiency Policy 2022-2030
- National Strategic Development Plan (NSDP), 2014–2018
- Industrial Development Policy (IDP), 2015–2025
- Power Sector Strategy 1999-2016
- Master Plan of the Ministry of Mines and Energy
- The Renewable Electricity Action Plan (REAP) 2002–2012
- The Rural Electrification by Renewable Energy Policy 2006
- The Renewable Energy Development Programme

1.3 Sector Context

- Energy Institutions

The energy sector in Cambodia is governed by MME and the Electricity Authority of Cambodia (EAC) following the 2001 electricity law and subsequent amendments of 2007 and 2015 (EAC, 2018). According to the law, MME is responsible for developing energy policies, strategies, plans, and technical standards, while EAC acts as the electricity regulator with the authority to issue rules, regulations, and procedures on power market operations, award licences, and set tariffs (ADB, 2018).

- Energy Supply and Demand

The total primary energy supply (TPES) of Cambodia increased from 3,350 kilotons of oil equivalent (ktoe) in 2010 to 4,761 ktoe in 2015, at an average annual growth rate of 7.3%. The sources comprised fuel wood and other biomass, which accounted for an estimated 44.4% of TPES; oil and petroleum products for 38.5%; coal for 10.7%; hydropower for 3.6%; and electricity imports for 2.8%. The completion of new coal and hydropower facilities between 2010 and 2015 greatly boosted the amount of coal and hydropower in Cambodia's energy supply; during this time, the share of coal rose from 0.7% to 10.7%, while the share of hydropower rose from 0.1% to 3.6%.

The total final energy consumption (TFEC) in Cambodia was about 3.4 million tons of oil equivalent in 2015, at an average annual growth rate of 6.9% from 2010-2015. The consumption comprised 50.5% petroleum products, 36.0% biomass, 13.1% electricity, and 0.4% coal. Even though the TFEC grew steadily during these years, it was still lower than the Asian average (about 480 kilogrammes of oil equivalent per capita per year in 2016 compared to the Asian economies' average of 740 kilogrammes, according to the statistics from the International Energy Agency).

The country's energy requirements will have doubled as a result of continued urbanisation, economic growth, and population increase (ADB, 2018)[7]. As the nation grows increasingly

[7] (ADB, Cambodia Energy Sector Assesment, Strategy and Roadmap, 2018)

motorised and as the government encourages industrial zones for manufacturing and agro-processing, demand for diesel and gasoline will be the primary drivers of oil consumption. As kerosene is phased out, more liquid petroleum gas is anticipated to be used in the residential sector.

- Energy Resources

Fossil fuel (coal and oil) resources in Cambodia are either small in quantity or untapped (limited exploration, mining, drilling, and processing). As a result, the country imports all the fossil fuels that it consumes. However, Cambodia's oil and gas potential, though not proven, seems promising due to similarities to adjacent areas in Vietnam and Thailand where these resources are being produced. According to the General Department of Petroleum of the MME, the nineteen-block onshore petroleum resources contain three times more potential than the six-block offshore area.

The renewable energy consumption in Cambodia was 65% of the TFEC, of which 46% came from traditional biomass, such as wood, charcoal, and dung; 15% from modern biomass, such as biogas produced from human and animal waste; and 3% from hydropower (Bank, 2018).

- Issues in the Energy Sector

Alongside rapid economic growth, increased electrification rates, and increased energy demand, Cambodia faces many challenges, such as limited capacity in energy planning, energy security, affordability, and environmental sustainability. The Asian Development Bank's (ADB) Cambodia Energy Sector Assessment, Strategy and Road Map (ADB, 2018) calls for a more cohesive energy sector strategy that links policies and physical infrastructure plans; and a well-balanced integration of new renewable power generation with the existing energy mix. The document also addresses the need to develop the capacity of the energy sector's governing bodies (MME and EAC) to cooperate with the private sector (public-private partnerships) to scale up clean energy generation. Another energy challenge is the high price of electricity, which results from a high tariff, causing many of the population to be unserved and constrained economic competitiveness, development, and investment.

1.4 Approach and Scope

In response to the objectives of the National Policy on STI 2020-2030 along with the determination of RGC set forth to become a high middle-income country by 2030 and a high-income country by 2050, enhancing the energy sector is considerably important among other potential sectors of the nation to realise such a vision. Boosting energy supply with environmentally friendly energy harvesting in the country can only be obtained by leveraging STI to identify issues that need to be resolved and fulfilled effectively and comprehensively. This energy technology roadmap was developed using a quantitative approach, including an assessment of Cambodia's energy landscape, data gathering of the country's energy context, and a qualitative approach, including a survey and consultation with relevant bodies involved in the nation's energy sector.

With the emergence of fast acceleration towards "Industry 4.0" in Cambodia, the need for advanced technologies for cleaner energy is more pressing than ever. "Energy technology refers to the combination of hardware, techniques, skills, methods, and processes used in the production of energy and the provision of energy services" (IEA, 2020). This relates to how we proceed with creating, converting, storing, transferring, and utilising energy. While the emerging technologies in terms of technical performance may take years to become effective, Cambodia could see close attention, including but not limited to the current trend of worldwide renewable energy transition, including:

- *Solar technologies* convert sunlight into electrical energy either through photovoltaic (PV) panels or through mirrors that concentrate solar radiation.
- *Wind turbines* transform the kinetic energy of the wind into electricity via the blades and a generator.
- *Hydropower* is the power generated by the natural flow of water.
- *Geothermal energy*, a virtually untapped energy resource derived from the earth's heat, is more vital today than ever—it supplies clean, renewable power, emits little or no greenhouse gases, and takes a very small environmental footprint to develop.
- *Bioenergy technology* includes all technologies that derive energy from biomass. Biomass is an organic renewable energy source that includes materials such as agricultural and forest residues, energy crops, and algae.

- *Hydrogen* can be used in fuel cells to produce electricity through a chemical reaction rather than combustion, with the byproducts being heat and water. It can supply sufficient power for transportation, houses and even commercial buildings.

Numerous technical-level and political-level workshops and meetings were held to construct this strategic document of "Energy Technology Roadmap" with high-level energy officials and experts from relevant ministries under the RGC, under co-creation, multi-stakeholders, and a consensus-building framework.

This technology roadmap introduces and labels enabling factors and major challenges for the development of the energy sector in Cambodia, which is limited capacity of energy supply and generation in the country, and that could be fulfilled by deriving renewable and non-renewable sources, and others.

2 An Analysis of Cambodia's Energy Supply and Demand

This section looks into the country's energy endowment, how it constitutes the national supply of and demand for energy, as well as relevant implications.

2.1 Energy Resources

The country has arguably substantial energy potential that lies in both non-renewable and renewable energy resources. Although it currently imports all fossil fuels, such as coal, oil, and gas, that it consumes, these non-renewable energy resources also exist in the country. Other domestic yet renewable energy resources include biomass, hydropower, solar energy, and wind energy. The following subsections describe each energy resource in detail.

2.1.1 Non-Renewable Energy Resources

The common non-renewable energy resources include coal, oil, and gas. They are mainly imported. Raw crude oil production appears promising. However, it could take some or more efforts to attract investment in or exploration of the local natural fuel.

The availability of coal deposits has long been claimed, but there has been limited exploration of this mineral to confirm its exact location and volume. While there can be more coal in unsurveyed areas, the preliminary estimation of the deposits is over 150 million tons in northern Cambodia. These small deposits can supply enough coal for a 400-megawatt (MW)

coal power plant for thirty years (JDI, 2009). The coal is of the lignite type (ERIA, 2022). Its quality is similar to that of Thai coal, which has a calorific value of 3,000 kilocalories per kilogramme and is suitable for boiler or kiln fuel (JDI, 2009). There has never been any commercial-scale mining for coal in the country to date (ADB, 2018).

On the other hand, the condition of oil and gas is not much different from coal. Seismic data shows that the country has more oil and gas reserve potential in onshore areas than offshore areas. There are 19 onshore petroleum blocks (I-XIX), 6 offshore blocks in the national waters (blocks A-F), and 4 more blocks in the offshore Overlapping Claims Area (OCA) with Thailand for oil and gas exploration. To what extent these areas contain oil and gas has yet to be clearly determined. However, it is estimated that the 27,000 square-kilometre-long OCA may contain around 11 trillion cubic feet of natural gas and 3.6 billion barrels of oil. Block A is also estimated to provide about 30 million barrels of oil over a period of 9 years. The fluctuation in global oil prices, complexity of geological factors, maritime disputes, and long duration of contract negotiations constrain the development of all the onshore and offshore petroleum blocks. Over the years, the government has issued some companies concession licences for oil and gas exploration and extraction activities in a number of those blocks, but they have had the licences terminated merely as a result of their lack of progress. The country thus has oil and gas reserves that remain largely untapped, aside from its non-existent oil refineries. In May 2017, a 2.3 billion USD oil refinery construction project took place on 365 hectares (ha) of land straddling Kampot and Preah Sihanouk provinces. It will be the first-ever refinery in the country, with an annual oil capacity of 5 million tons upon completion (ADB, 2018). This project was originally expected to be completed by mid-2019; however, the deadline has been delayed due to some planning and financial difficulties, according to the spokesman of MME in December 2022.

2.1.2 Renewable Energy Resources

The overview of the profile of renewable energy resources in Cambodia has shown that biomass, hydropower, solar energy, and wind energy could be potential sources of energy supply in the future.

Biomass has been used as an energy supply source both in rural and urban areas. The country has plenty of biomass energy resources that come from rubber plantation forests; tropical trees such as Gliricidia and Acacia, and agricultural residues such as rice husk, rice straw, corn cobs,

wastes from palm oil extraction, cassava stalk, sugarcane bagasse, cashew nut shells; and animal waste. The estimated total theoretical potential of agricultural residues alone is around 15,000 gigawatt hours (GWh) per year, 80% of which is converted from rice residues. By 2017, there were 7 biomass generation power plants in operation, representing roughly 39 MW of installed capacity. The production of biofuels for transport also uses biomass. A joint-venture with a Korean company, MH Bio-Energy Group (ADB, 2018), produces nearly 36 million litters of bioethanol per year from 100,000 tons of dry cassava flour or 400,000 tons of cassava. Other major sources of biofuels include jatropha plantations (1,000 ha), palm oil (4,000-10,000 ha), and sugarcane (20,000 ha). In addition, the country can theoretically produce as much as 2.4 million cubic metres of biogas daily. The fact that most agricultural holdings nationwide are small-scale, however, means that the technical potential can be much lower than the theoretical (ADB, 2015).

Hydropower shows potential as a promising energy source for Cambodia, considering the country's richness in streams and topographical conditions. There are about 63 possible locations across the country for the development of both small and large hydropower projects (MME, 2019), 50% of which are located on the Mekong River basin, 40% on its tributaries, and 10% in the southwestern coastal highlands. Hydropower generation varies according to seasonal changes, such that it is higher in the rainy season than in the dry season. The estimate of the country's technical hydropower potential is 10,000 MW. Currently, only around 980 MW of this capacity has been developed, 400 MW is under construction, and 90 MW is in the feasibility study stage (ADB, 2018). Materialisation of this potential resource is necessary, while consideration of its environmental impact is important.

Solar energy is abundant. The country has a considerably high level of solar irradiation, rendering it rich in solar energy resources. The daily average solar irradiation is around 5 kWh, with the daily average sunshine duration of 6-9 hours (MME, 2019). The Global Horizontal Irradiation (GHI) is valued between 1,644-2,009 kWh per square metre per year, while the Direct Normal Irradiation (DNI) varies between 1,168-1,607 kWh per square metre per year. Most parts of the country have a GHI level of 1,826 kWh per square metre per year or more and a DNI level of 1,314 kWh per square metre per year or more (see Annex 1 and 2). The total suitable land area for solar photovoltaic development is 134,500 squares kilometres. This corresponds to the maximum technical solar energy potential of around 8.1 megawatt-peak

(MWp) or 12 terawatt hours (TWh) per year and the maximum economic solar energy potential of around 7.2 MWp or 10.8 TWh per year (ADB, 2015).

Wind energy appears to be promising in coastal and some high-altitude locations. The country has limited wind energy potential as only 3-5% of its total land area has wind resources of medium intensity viable for utility-scale wind turbines. The annual average wind speed is between 6-9 metres per second in the southern regions of Tonle Sap Lake, the southwestern mountainous areas, and along the coast (ADB, 2018). The theoretical wind potential is 65 GW, with a potential production capacity of 154 TWh per year. The technical wind potential, on the other hand, is 18 MW at the lower limit (5% of grid capacity) or 72 MW at the upper limit (20% of grid capacity) (ADB, 2015).

2.2 Primary Energy Supply

The country's domestic energy only includes hydropower and biomass, as its other energy resources remain underutilised. To meet the local energy needs, Cambodia imports sub-bituminous coal primarily from Indonesia (GGGI, 2018); petroleum from Singapore, Thailand, and Vietnam; and electricity from Laos, Thailand, and Vietnam (ERIA, 2022). Its import dependency ratio[8] was 68% in 2019, levelling up from 35% in 2000. More reliance on energy imports can pose a greater threat to the country's energy supply security (ERIA, 2022).

The total primary energy supply (TPES)[9] increased from 1,956 kilotons of oil equivalent (ktoe) in 2000 to 6,885 ktoe in 2019. In the same period, there was an increase in the supply of petroleum from 670 ktoe to 3,104 ktoe, hydropower from 3 ktoe to 346 ktoe, biomass from 1,279 ktoe to 1,902 ktoe, and imported electricity from 4 ktoe to 263 ktoe. The coal import first started in 2008 at a volume of 14 ktoe and then rose to 1,270 ktoe in 2019. Petroleum now makes up around 45% of TPES, replacing biomass as the most dominant energy supply. The steeper slope of the TPES curve over time indicates that the supply has increased faster than before. Its growth rate was almost two times higher in 2010-2019 than in 2000-2009 as seen in Figure 1.

[8] Import dependency ratio measures a country's reliance on energy imports. It equals energy imports divided by the sum of energy production and energy imports.

[9] From the energy balance table, the total primary energy supply shows the energy available within a country. It equals the sum of indigenous production, imports, exports, international marine bunkers, international aviation bunkers, and stock changes.

This growing trend of primary energy supply can be explained by the propelled need for energy to support the country's rapid economic development, which sees a greater influx of foreign direct investments in the construction of commercial buildings, infrastructure, and economic zones (ERIA, 2022).

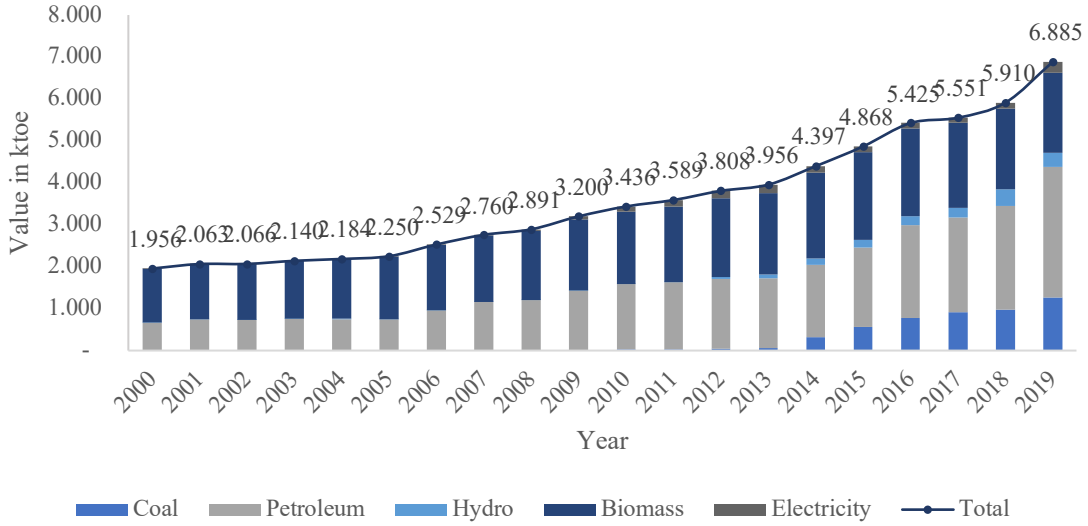

Figure 1: Total Primary Energy Supply (ERIA 2022 and Author's Calculation)

The supplied petroleum products consist of motor gasoline, jet fuel, kerosene, gas or diesel, fuel oil, liquefied petroleum gas (LPG), and others. In 2000, gas or diesel oil was the largest supply with 59%, followed by motor gasoline with 19%, fuel oil with 14%, kerosene with 5%, LPG with 2%, jet fuel with 1%, and the remaining others. The supply of kerosene became obsolete from 2014 onward. In 2019, gas or diesel oil still had the largest share of the total petroleum supply with 54%, while motor gasoline, LPG, fuel oil, and jet fuel accounted for 24%, 13%, 6%, and 2%, respectively, as shown in Figure 2.

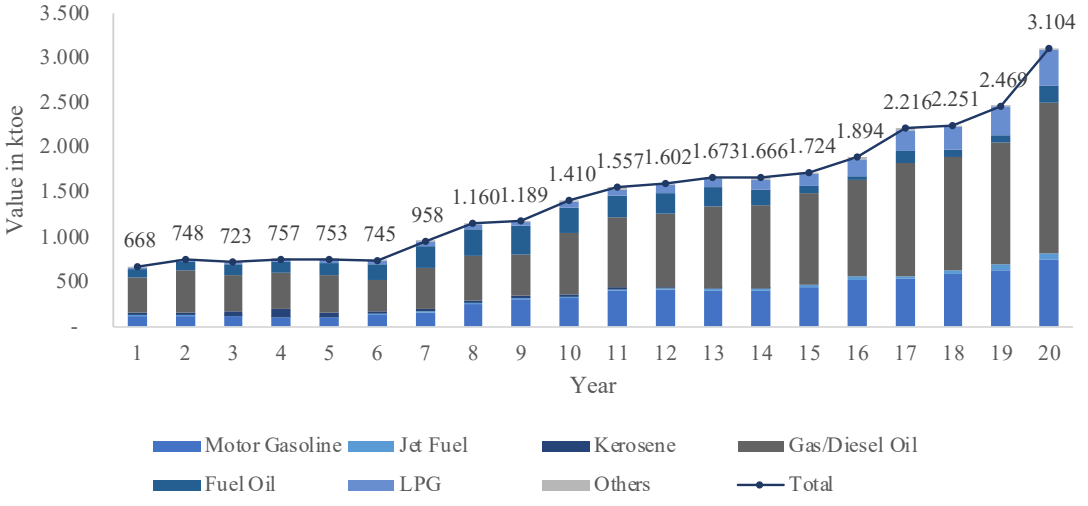

Figure 2: Supply of Petroleum Products (ERIA 2022 and Author's Calculation)

2.3 Final Energy Consumption

The country's total final energy consumption (TFEC)[10] stood at 4,968 ktoe in 2019, a significant increase from 1,325 ktoe in 2000. It covered 137 ktoe of coal, 2,899 ktoe of petroleum, 2,053 ktoe of biomass, and 879 ktoe of electricity. In the last decade, coal consumption grew at the fastest rate of about 55% per annum on average, followed by electricity with 18%, petroleum with 10%, and biomass with 2%, as shown in Figure 3.

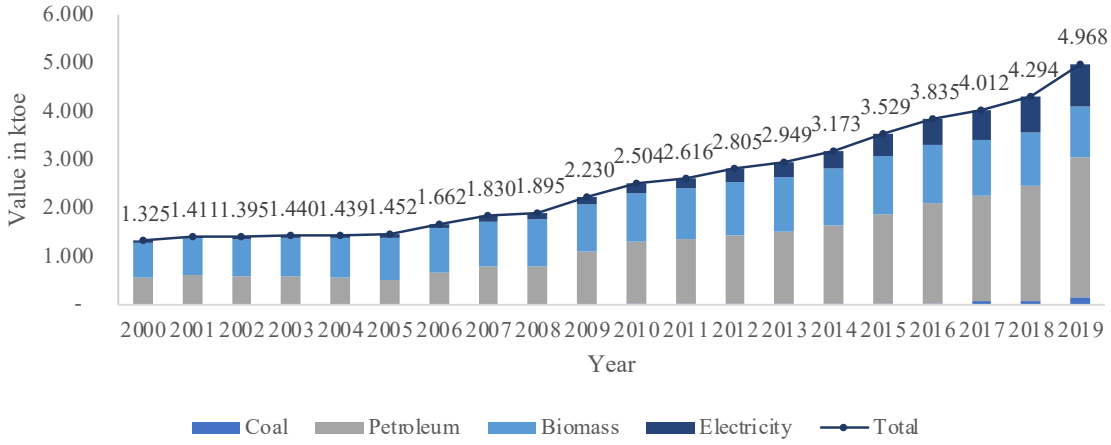

Figure 3: Total Final Energy Consumption (ERIA 2022 and Author's Calculation)

In 2019, the transport sector had the highest final energy consumption (2,103 ktoe), followed by the residential (1,113 ktoe), industry (948 ktoe), commercial (534 ktoe), and other sectors (267 ktoe). The residential sector was the major consumer of biomass. While petroleum consumption was mainly concentrated in the transport sector, the consumption of electricity was almost equally distributed across the industry, commercial, and residential sectors. Coal was consumed only in the industry sector, as shown in Figure 4.

[10] From the energy balance table, total final energy consumption shows how energy is consumed by the final sectors.

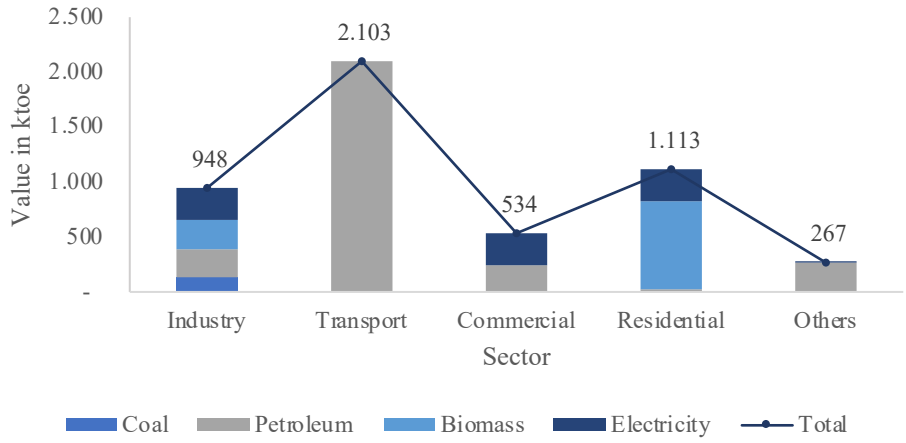

Figure 4:Type of Energy Consumption by Sector (ERIA 2022 and Author's Calculation)

The rise of the TFEC from 2000-2019 was largely driven by the expansion of the industry, transport, and commercial sectors. The average annual final energy consumption growth rates of the industry, transport, commercial, and residential sectors were 8%, 10%, 17%, and 3%, respectively, as shown in Figure 5.

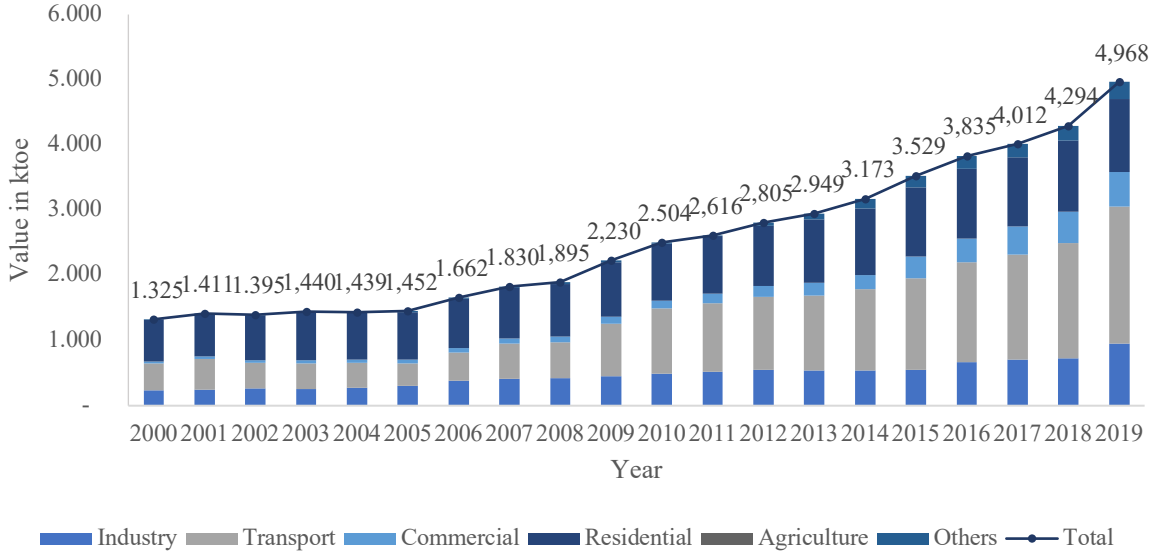

Figure 5: Total Final Energy Consumption by Sector (ERIA 2022 and Author's Calculation)

Besides electricity imports, the country generates electricity from a variety of energy sources, including hydropower, coal, oil, bagasse, and solar. The total electricity generation rose dramatically from 478 GWh in 2000 to 8,675 GWh in 2019. Oil was the primary source of generation until 2013, when more hydro and coal power plants started to operate. By 2019, the share of oil in the generation fell to just 8%, while hydropower and coal accounted for 46% and 43%, respectively. Bagasse and solar had a share of 1% each, as shown in Figure 6.

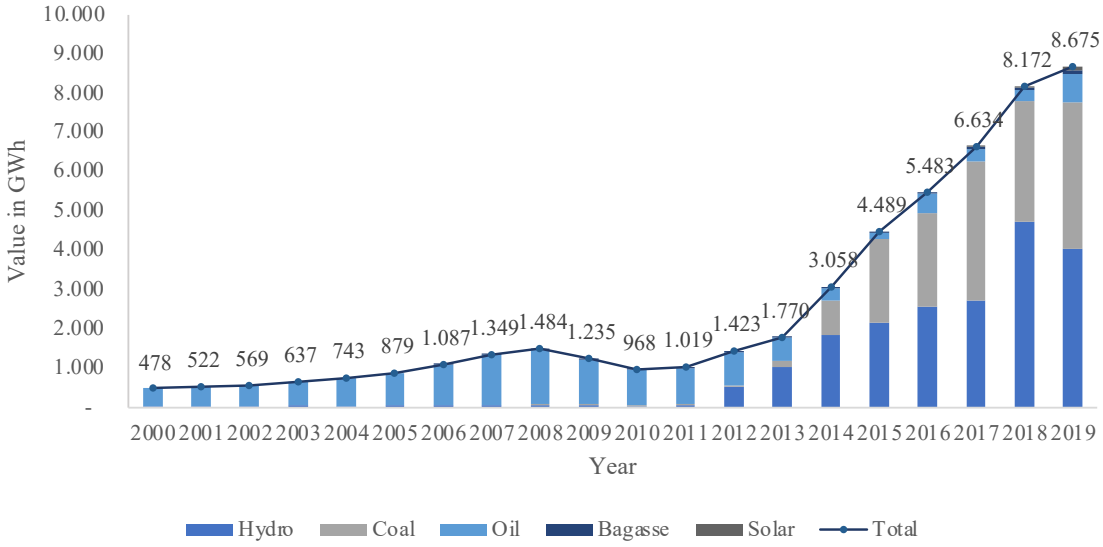

Figure 6: Power Generation (ERIA 2022 and Author's Calculation)

3 Cambodia's Policy and Regulatory Framework

Energy consumption in Cambodia has been significantly increasing in the last few decades. Energy has been placed in a strategic role to support Cambodia's economic development. In fact, RGC has considered four paramount pillars, including water, road, electricity, and human, as the national strategic capital for sustainable development embedded since the triangle strategy of the 1st legislation of the national assembly up until the rectangular strategy phase four of the 6th legislation and beyond. Thus, RGC has formulated and implemented many energy-related policies and regulatory frameworks, including, inter alia:

Rectangular Strategy Phase IV has been set up for national growth by the RGC and was applied to the sixth term of the National Assembly, 2013–2018[11]. The National Strategic Development Plan (NSDP), 2018–2023, is the primary policy strategy guiding efforts towards the national development agenda, which was endorsed by the National Assembly on June, 26 2014[12]. The NSDP targets the achievement of the Cambodia Millennium Development Goals,[13] successful integration into the Association of Southeast Asian Nations economic community, reduction

[11] Government of Cambodia. 2013. Rectangular Strategy Phase III, 2013–2018. Phnom Penh. The government has drafted the new Rectangular Strategy Phase IV, 2018–2023, which will guide the development of the NSDP, 2019–2023.

[12] Government of Cambodia. 2014. National Strategic Development Plan, 2014–2018. Phnom Penh.

[13] The United Nations Sustainable Development Goals came into effect in January 2016, replacing the Millennium Development Goals, which were to be achieved by 2015. Cambodia is currently developing localised Cambodia Sustainable Development Goals, which will be integrated into future plans and policies, including the NSDP, 2019–2023.

of poverty to about 13% by 2018, and the long-term goal of graduation to upper middle-income country status by 2030. Regarding the energy sector, Cambodia's National Energy Sector Development Policy, established in 1994[14], stipulates the government's main goals for an adequate, affordable, and sustainable energy supply in support of economic development.

The NSDP, 2014–2018, emphasises that although progress has been made in electricity expansion, tariff reduction, and institutional strengthening, further development of the energy sector is essential for increased competitiveness and sustained economic growth. The NSDP consists of eight key energy policy objectives, as follows:

i. Further expand the capacity to generate low-cost and high-tech electricity, especially from new and clean energy sources, along with the continued development of relay networks at all levels to strengthen energy security and ensure high efficiency, safety, high-quality, reliable, and affordable electricity supply and distribution to respond to development needs;
ii. Further incentivise the private sector to invest in electricity generation, transmission, and distribution infrastructure that focuses on technical and economic efficiency and mitigating environmental and social impacts;
iii. Increase the implementation of the electricity strategy to meet the goal that all villages in Cambodia will have access to electricity from the national grid or other sources by 2020;
iv. Further support the Rural Electrification Fund (REF) to help achieve equitable electricity access for the population through funds from the Electricite du Cambodge (EDC) and other government budget allocations, as well as funding support from development partners;
v. Continue rational measures for the use of electricity by reducing energy costs during part-time hours to serve production and irrigation systems in order to increase agricultural productivity and accelerate the development of industry and handicrafts;
vi. Step up the exploration and commercialisation of the oil and gas sector, which has enormous potential for ensuring energy security and will provide valuable resources for Cambodia's economic development in the long term;

[14] Government of Cambodia. 2015. Cambodia Industrial Development Policy, 2015–2025: Market Orientation and Enabling Environment for Industrial Development. Phnom Penh.

vii. Further build institutional capacity, human resources and energy sector planning and management; and
viii. Continue active involvement in energy cooperation under the Greater Mekong Subregion GMS regional framework.

In the same manner, Cambodia has embraced the new 2030 Agenda for Sustainable Development. Eradicating poverty in all its forms and dimensions is at the core of the new 2030 Agenda, adopted in September 2015 by 193 world leaders at the UN Sustainable Development Summit in New York.

The benefits of energy efficiency under Sustainable Development Goal 7 are the following:

- Access to energy: Energy efficiency can increase the services delivered by each kilowatt of electricity and improve energy access;
- Air quality: Energy efficiency can reduce both indoor and outdoor concentrations of air pollutants;
- Asset values: Energy efficiency can increase asset values for homeowners, businesses and utilities;
- Economic benefits: Cost-effective energy efficiency improvements can have positive macroeconomic impacts, boosting economic activities;
- Emissions savings: Energy efficiency reduces GHG emissions, both direct emissions from fossil fuel, and indirect emissions from electricity generation;
- Employment: Energy efficiency can induce job creation, improve productivity, and decrease employee absenteeism;
- Energy prices: Energy efficiency can lower energy prices by reducing the need to add new power generation or transmission capacity and by reducing pressure on energy resources;
- Energy savings: Energy efficiency reduces the amount of energy used to provide a service;
- Energy security: Energy efficiency can reduce the reliance on energy imports and reduce the risks of supply interruptions;
- Health and wellbeing: Energy efficiency supports physical and mental health with healthy temperatures, humidity, noise, and air quality;

- Household savings: Energy efficiency can enable higher disposable income by lowering energy bills and other households' costs;
- Productivity: Energy efficiency leads to productivity gains by lowering maintenance issues and optimising processes.
- Public budgets: Energy efficiency delivers financial benefit to public budgets through increased income and decreased expenses.

Energy Demand and Supply of Cambodia 2010–2018, rolled out in 2019[15], one of the energy research reports of the Economic Research Institute for ASEAN and East Asia (ERIA), has been studied the energy demand and energy landscape of Cambodia. The report indicated that total final energy consumption (TFEC) grew at 7.2% per annum in 2010–2018. However, its elasticity over gross domestic product (GDP) was because of the 7.2% growth rate of GDP in the same period. The TFEC includes biomass, whose share was significant in Cambodia (biomass share over the TFEC was still 25.5% in 2018). The growth rates of commercial energy, such as oil and electricity, in 2010–2018 were 8.1% and 18.3% per year, respectively, which were much higher than that of TFEC. In the future, biomass's 25.5% share in the TFEC will surely be replaced by commercial energy sources, such as oil and electricity. Energy efficiency and conservation (EEC) policies and programmes to limit and check commercial energy consumption shall be in place. Unfortunately, the EEC programme was not formulated. Consequently, the General Department of Energy (GDE) of the Ministry of Mines and Energy and ERIA came up with the EEC Master Plan for Cambodia. The following five EEC policies and programmes were focused: (i) energy service companies (ESCO), (ii) growing of energy managers, (iii) standard and labelling system, (iv) education and campaigns, and (v) preparation of energy efficiency indicators (EEIs). ERIA also prepared a 5-year roadmap (2020–2025) for each EEC policy and programme mentioned above.

Similarly, the government's Industrial Development Policy (IDP) recognises that insufficient coordination and investment in physical infrastructure, including electricity and clean water, are holding back the adoption of manufacturing and other value-added industries. In line with the IDP's 2018 target, the government has reduced the price of electricity for specific industrial

[15] Ministry of Mines and Energy, Cambodia and ERIA (2019), Energy Demand and Supply of Cambodia 2010–2018. Jakarta: ERIA. Available at: https://www.eria.org/publications/energy-demand-and-supply-of-cambodia-2010- 2018/

zones and expanded transmission networks to improve the reliability of supply. The IDP also calls for a review of the forecast of long-term electricity demand and energy supply options to better align with the country's goals for economic and industrial development. Cambodia does not yet have a comprehensive energy strategy. Instead, the government has adopted, or is preparing, various sector strategies and action plans. The MME's PDP, which was prepared in 2007 for the period 2008–2020 and updated in 2015 for the period 2015–2030[16], includes investment plans for generation and transmission expansion. With regard to distribution expansion and rural electrification, the MME, in cooperation with the Electricity Authority of Cambodia (EAC) and REF, sets the goals.

In 2019, Cambodia rolled out and implemented a Basic Energy Plan[17] to guide the development of the energy sector in Cambodia. The plan outlines the country's energy policy objectives, targets, and strategies for the period up to 2030. Some key policies in this plan include:

- Energy Mix Diversification: The plan places a strong emphasis on the necessity of changing Cambodia's energy mix in order to lessen its reliance on imported fossil fuels and boost the proportion of renewable energy sources. This involves encouraging the development of technologies for biomass, solar, wind, and other renewable energy sources.
- Power Generation Expansion: To address the rising demand for energy, the strategy aims to improve Cambodia's capacity for electricity production. To maintain a consistent supply of electricity across the nation, this calls for the construction of additional power plants—conventional and renewable—as well as the expansion of the transmission and distribution networks.
- Rural Electrification: As a major section of the population still lacks access to dependable power, the strategy places a high priority on initiatives to increase energy access in rural areas. Along with promoting off-grid renewable energy options and lending support to community-based electrification projects, it involves attempts to expand the grid infrastructure.

[16] Chugoku Electric Power Co., Inc. 2015. The Project on Revision of Cambodia Power Development Master Plan. Presentation prepared for the Government of Cambodia. Phnom Penh. September. Unpublished.

[17] Cambodia Basic Energy Plan. 2019

- Energy Efficiency: The plan takes into account how important energy efficiency is for lowering energy costs, boosting energy security, and reducing greenhouse gas emissions. It draws attention to the necessity of energy-saving measures, the use of energy-efficient technologies, and the encouragement of energy-efficient behaviours across diverse industries.
- Cross-Border Energy Trade: Cambodia targets to improve cross-border energy trade prospects and regional energy cooperation. To maximise energy resources and advance regional energy security, this also involves potential electricity imports and exports with nearby nations.

Apart from generally encouraging the use of renewable energy and setting aspirational goals for rural electrification through renewable sources, Cambodia has not yet set a clear national renewable energy target. However, the National Policy, Strategy, and Action Plan on Energy Efficiency in Cambodia were developed by consultants funded under the EU Energy Initiative Partnership Dialogue Facility and were expected to be adopted by the end of 2018[18]. A strategy and action plan for the promotion of renewable energy, including a target percentage of renewable energy in the energy mix, is to be undertaken as part of the MME's CCAP, 2016–2018[19]. In addition, Cambodia's Nationally Determined Contribution targets a 24% reduction in emissions from renewable energy and energy efficiency initiatives[20]. The preparation of the Nationally Appropriate Mitigation Actions required to meet this target and establish an emissions management approach for the sector is also part of the MME's CCAP.

Moving forward, the government will need to formulate a consolidated energy sector strategy and implementation plan that specifies sector priorities, timelines, and responsible agencies for different initiatives and activities. Consolidating the various thematic strategies and plans should facilitate more organised and efficient development of the energy sector, including the development of physical infrastructure and the required legal, regulatory, and institutional frameworks.

[18] A National Policy, Strategy, and Action Plan on Energy Efficiency in Cambodia.
[19] Government of Cambodia, MME. 2015. Climate Change Action Plan for Mines and Energy Sectors, 2016–2018. Phnom Penh.
[20] Government of Cambodia. 2015. Cambodia's Intended Nationally Determined Contribution. Phnom Penh.

4 Technology Roadmap Development Process

This part details the process of developing the Energy Technology Roadmap (EnergyTech Roadmap), which is a document that serves as a guideline for the development of key technologies to be implemented until 2030 to achieve the common vision. This EnergyTech Roadmap has been built on a multi-stakeholder and co-development framework that engages experts in diverse fields from line-ministries, universities, and research institutes, as well as the private sector working on energy. For this reason, the national committee for technology roadmap development and sub-committee for energy technology roadmap have been established on the Prakas 153 MISTI/2022 by the Minister of Industry, Science, Technology & Innovation (See the annex 3). Additionally, this roadmap gives government, private sector, and academic institutions the investment priorities and guiding principles for the technologies listed in it. According to background knowledge, the primary objectives of the EnergyTech Roadmap are:

- To establish a technology roadmap to support the National Policy on STI 2020–2030 implementation strategy;
- To provide a strategic direction on technology for energy development in Cambodia;
- To pursue the Industrial Revolution 4.0 goal of RGC.

The following phases make up the process of developing this EnergyTech Roadmap:

1- The first step is to define the vision and goals for the energy sector in Cambodia for the next eight years, as well as the essential technologies required to develop this sector globally, particularly to contribute to and help accelerate the growth of the national economy.

2- The second step includes an in-depth analysis that takes into consideration social, technological, economic, environmental, and political concerns. Then, depending on the drivers, the opportunities and threats in the energy sector are evaluated.

3- The third step involves determining potential functions, strategic products and services. Following that, the expert committee scores the priority products and services to determine the final selection.

4- The identification of key technologies comes in at fourth place. The expert committees then rank the important technologies to choose as the priority key technologies.

5- Finally, the technology roadmap is charted with timeframes ranging from short to long term.

Figure 7 Depicts the summary of EnergyTech Roadmap development process.

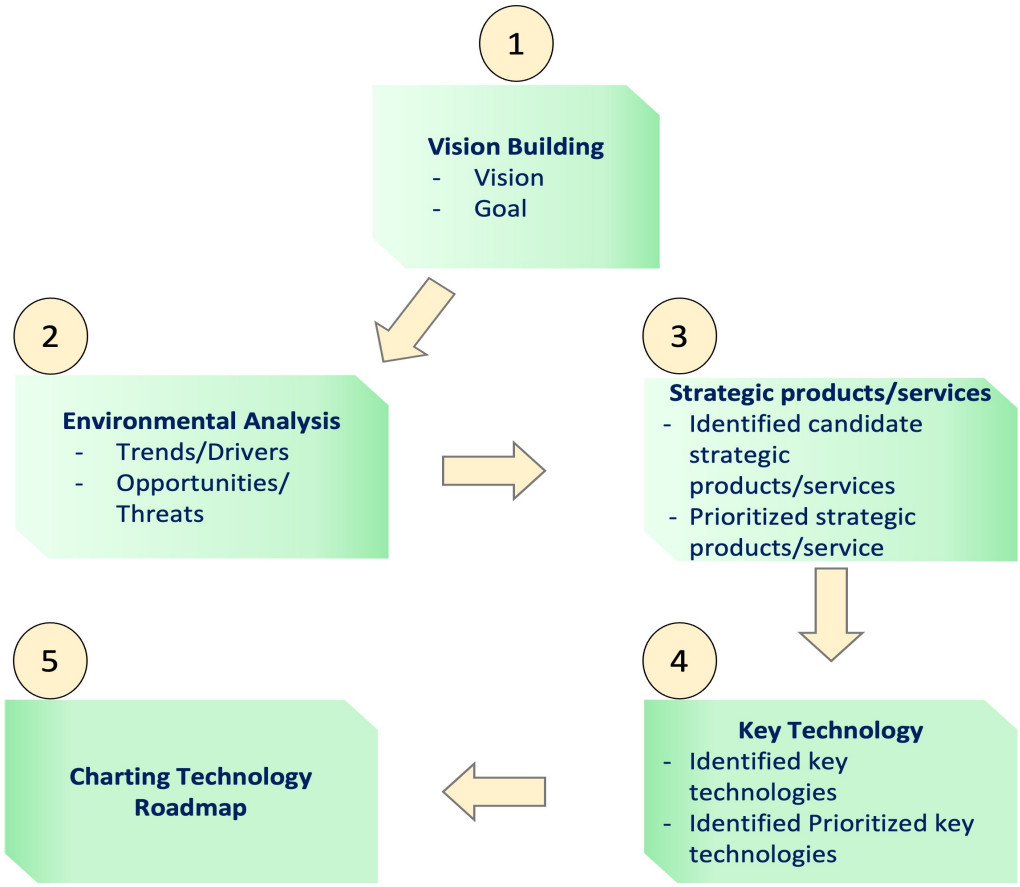

Figure 7: National energy technology roadmap development process

5 Energy Technology Roadmap Development

5.1 Vision and goals

This EnergyTech Roadmap is developed to achieve the vision: ***"To become an energy self-sufficient nation through the deployment of technology and innovation, and leveraging renewable energy sources for sustainable development by 2030"***

In order to achieve the vision above, the roadmap has the following goals:

1. To increase the local energy generation capacity with the support of science, technology and innovation;
2. To increase the share of renewable energy in national consumption and its storage capacity for sustainable development;
3. To leverage energy efficiency for domestic usage and in the industrial sector.

5.2 STEEP analysis

To realise the vision and goals above, the STEEP analysis is conducted to effectively identify the main drivers necessary for this roadmap's development. STEEP analysis looks thoroughly into Social, Technological, Economic, Environmental and Political aspects of the current situation in energy by consulting with experts from different institutions and in a wide range of fields. On the social side, Cambodia has a good demographic dividend, meaning that the majority is young and is likely to be early adopters of new technologies. More importantly, the growth rate is still in good momentum, and civic engagement as well as energy awareness are seen to be in a positive trend. From a technological point of view, renewable and clean energy sources like solar, biomass, and wind are in the top spot, and most people are likely to adopt the new and emerging technologies, including sensors, automation, big data, smart homes, and so forth. From an economic viewpoint, Cambodia enjoyed an average annual growth rate of about 7%. Productivity has also been seen to have proportionately increased while investment flow has increased, despite the temporary economic downside posed by the COVID-19 pandemic. However, there are also some drawbacks, such as the instability of oil prices caused by some geopolitical and trade wars in recent years. The competition with foreign companies in energy is still a negative point that needs to be taken into account for support. From an environmental perspective, despite public awareness of climate change and environmental-related issues, Cambodia is still relatively vulnerable to climate change, environmental

pollution, and resource depletion due to development. Hence, Cambodia shall increase its adaptation and resilience capacities. Last but not least, political stability remains assured, and political commitment and support for energy are still ceaselessly continued despite the impacts caused by external forces such as political and geographical crises and war. From a political standpoint, good governance and regional and global partnership are ensured. Having understood all of these drivers from the holistic view of STEEP analysis, opportunities and threats are then identified by experts based on Cambodia's context. The opportunities in Cambodia's energy sector range from favourable conditions for renewable energy sources to political support both technically and financially, as well as good momentum in research and development, while the threats range from climate change to price instability due to geopolitical competition and the global trade war. Table 1 depicts the STEEP analysis of the current situation, opportunities, and threats to energy in the Kingdom of Cambodia.

Table 1: Vision, goals and opportunities and threats of energy in Cambodia

Vision	***"To become an energy self-sufficient nation through the deployment of technology and innovation, and leveraging renewable energy sources for sustainable development by 2030"***				
Goals	1. To increase the local energy generation capacity with the support of science, technology and innovation; 2. To increase the share of renewable energy of national consumption and its storage capacity for sustainable development; 3. To leverage the energy efficiency for domestic usage and in an industrial sector.				
Drivers	**Social:** • Young population • Population growth • Increasing energy using • Community engagement or public acceptance to government's initiatives • Limited supplies • Covid-19 • Increasing job opportunities	**Technological:** • Clean energy • Solar energy/sunlight • Digital control • Biomass • Remote sensing • Automation • Energy storage system • R&D for new invention • Wind energy • Internet of Things • Big data analysis • Artificial Intelligence (AI) • Robotics • Mobile technology • Sensor technology • Increasing battery storage price • Smart home	**Economical:** • Growing economy • Productivity increase • Large enterprise • Community development and fund • Investment attraction • Financial support • Fuel price • Oil crisis • Competition with foreign firms • Price instability	**Environmental:** • Environment pollution • Climate change • Resource dependent • Production environment impact • Natural disaster (responding system) • Vulnerability • Environmental concern	**Political:** • Political stability • Support (technical and financial) from the government • Political and geography crisis • War causing price instability • Partnership and cooperation • Political will and commitment

		• Tech startups • Technology transfer • Hydropower • Grid development	• Investment on energy industry		
Opportunities & Threats	**<u>Opportunities</u>** • Favourable conditions for renewable energy sources (Hydropower, Solar energy, biomass energy) • Willingness to adopt renewable energy • Fast pace of technological development • Technology adoption tendency • Environmental and pollution awareness • Smart home adoption tendency • Political will and commitment on energy sectors • Investment attraction plan on energy industry • Partnership and cooperation • Financial support from government and relevant agencies • Availability of community development and fund • Existing capacity building scheme • Good momentum in energy research and development • Grid development • Environmental social governance regulation by the European Union		**<u>Threats</u>** • Climate change • Oil crisis and overpriced • Increasing battery storage price • Environmental impact of production • Natural disaster (responding system) • Limited supplies • Resources dependency • High vulnerability especially in rural areas • Lack of community involvement or public acceptance • Energy insecurity especially in rural areas • Environmental and emission concerns • Price instability caused by war and geopolitical instability • Spread of the COVID-19 pandemic • Competition with foreign firms • Energy instability • High price	

6 Products and Services

The structure of the EnergyTech Roadmap, including its vision, goal identification, direction setting, function, strategic products, and key technologies, is shown in Figure 8. Three main directions that are strongly oriented are necessary to support the vision and achieve the goals by 2030. They are to increase the local energy generation capacity with the support of STI, increase the share of renewable energy in national consumption and its storage capacity for sustainable development, and leverage energy efficiency for domestic usage and the industrial sector. Strategic products and services are determined within these three directions by committee members, along with drivers from STEEP analysis, and eight strategic products and services were chosen as priorities based on scoring, including fossil energy, renewable energy, new source energy, storage capacity, power stability, power transportation and distribution, efficiency, and conservation and consumption.

From the opportunities and challenges identified in the previous section, the participants, involving experts, researchers, and relevant stakeholders from the public and private sectors, reached consensus on eight products/services that Cambodia needs to focus on to achieve its self-sufficiency and sustainable development goals, including fossil fuel, renewable energy, new source energy, storage capacity, power stability, power transportation, power distribution, power efficiency, and power conservation. With the 8 key technology areas, all expert participants are also asked to make an evaluation and assessment in terms of strategic importance, economic impact, and the potential for success in the current status and context of Cambodia. Figure 8 shows the key technology areas with the criteria mentioned above. From the figure, fossil energy will still be the primary source of energy, at least in the not-too-distant future. It is very strategically important with its high economic impact and high potential for success. Renewable energy also stands at the second highest position among other key technology areas due to the favourable conditions in Cambodia. Power efficiency and conservation are also among the highest proponents for consideration, as they have a high score in the three criteria. Explore the new energy sources and power stability, which received a relatively low score compared to other candidates but are still in the acceptable range (Figure 8).

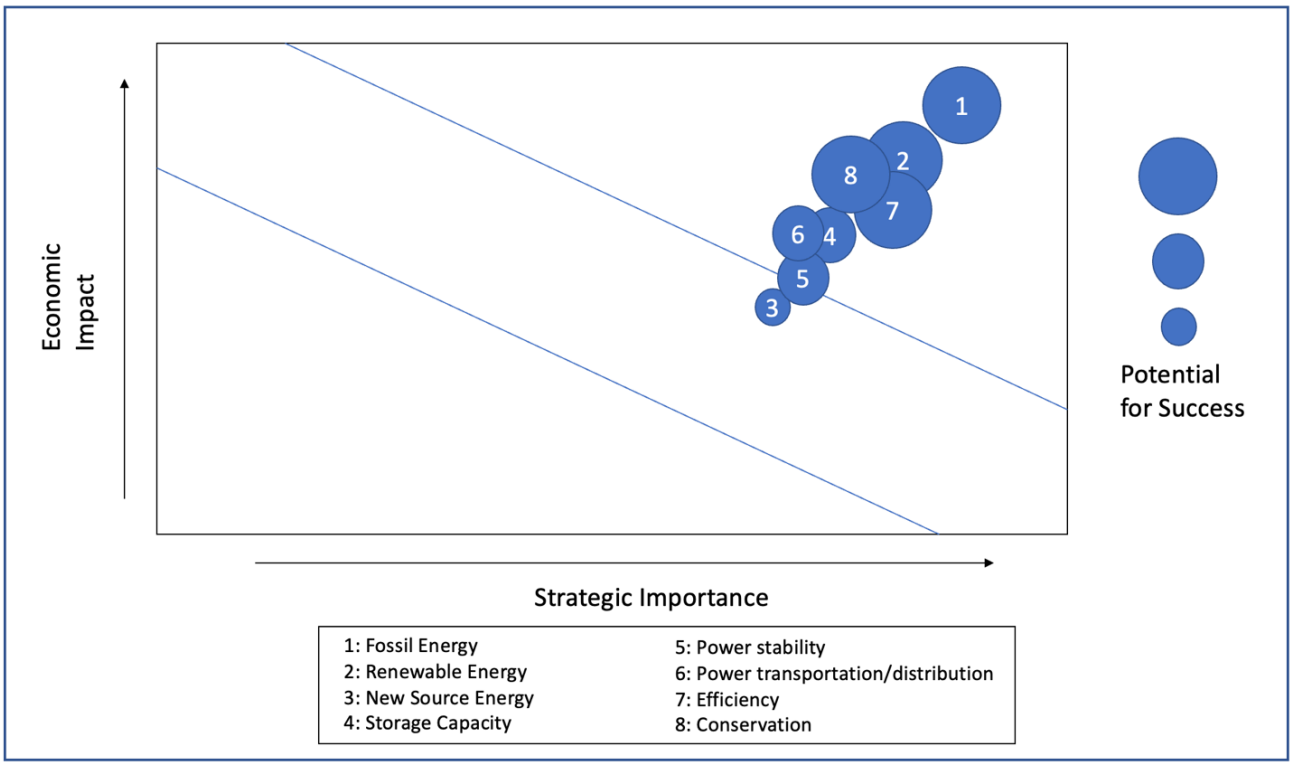

Figure 8: Products and services evaluation

Figure 9 shows the key technologies derived from the products and services illustrated in the above session. The experts and relevant institutions have identified 54 key technologies for Cambodia to embrace in the future to achieve her ambitious vision to become an energy self-sufficient and a sustainable development nation. These 54 key technologies were then scored based on the evaluation criteria shown in Annex 2 and the summaries in the figure 9 below. The strategic product's key technology is more important when the line is thicker. The 54 important technologies serve to support the potential strategic products and services, identified in figure 8. To emphasise its importance, each key technology is given a score based on its strategic importance, economic impact, potential for success with the vision, and how viable it will be in the short, medium, and long terms. Given that they are regarded as priority key technologies, the selected key technologies were added to the figure 9 chart.

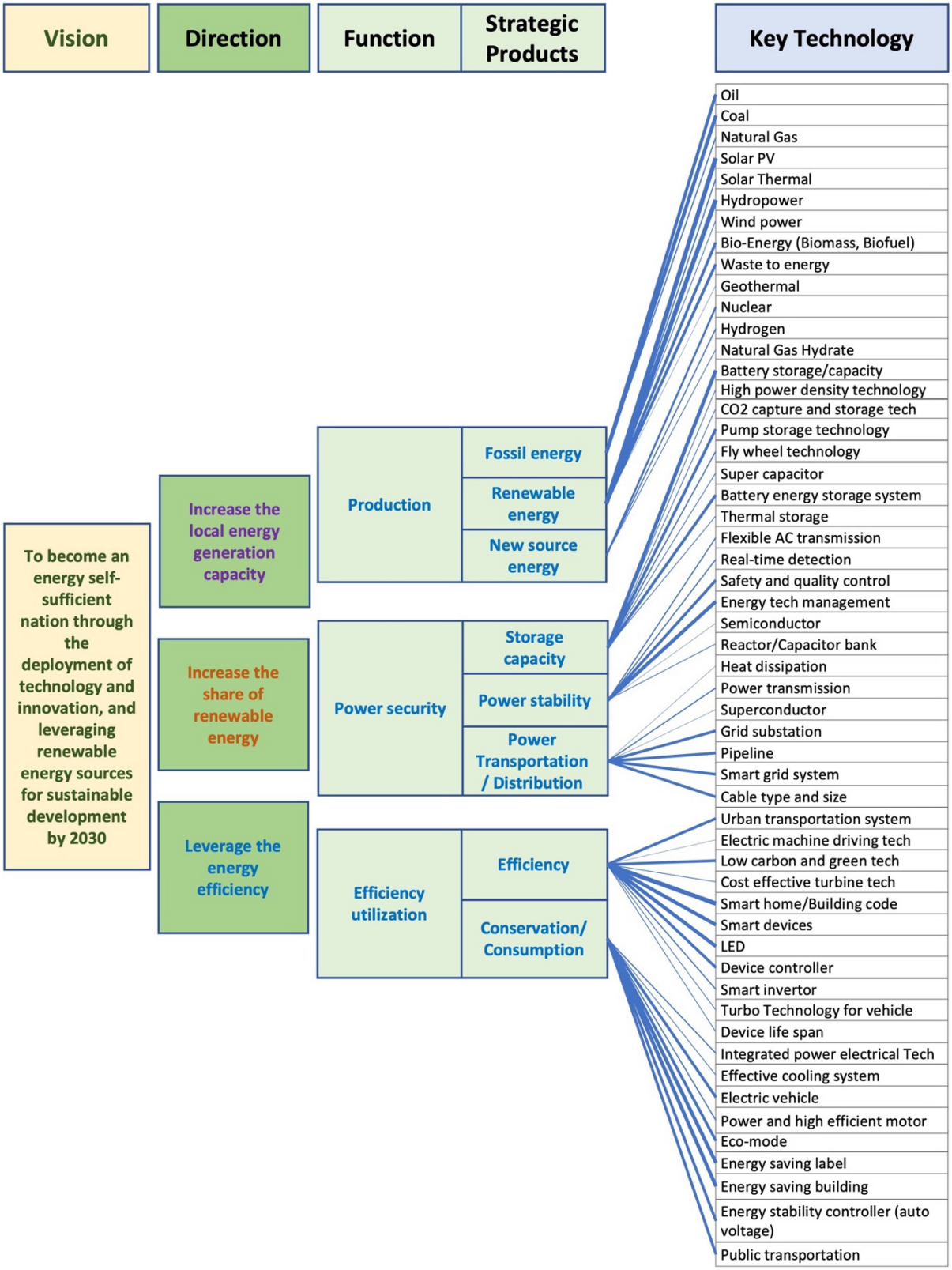

Figure 9: Key Technologies

7 Technology Roadmap Charting

Figure 10 below shows the charting of the EnergyTech Roadmap. This roadmap depicts key technologies, illustrated in Figure 8, for which the score band is high, to be implemented in the short, medium, and long term until 2030 for Cambodia to embrace to achieve the above-set vision of becoming an energy self-sufficient nation through the deployment of technology and innovation and leveraging renewable energy sources for sustainable development by 2030. To fully realise this vision, efforts must be ceaselessly put into the introduction of energy structural changes and focus on five main categories: energy production, power security and stability, power storage, energy transportation and distribution, energy efficiency, and energy conservation. In the short term, Cambodia shall prioritise energy self-sufficiency to achieve national energy security and ensure that reliable energy coverage reaches the last mile of the country. In the medium term, more attention should be paid to renewable energy sources such as solar power, hydropower, and wind power, all of which are clean energy sources that are favourable to the environment.

Production source is identified as the top priority for the energy sector as it is the prerequisite condition. Even though it is not really a technology in itself, due to its importance, it is agreed to be on this charting roadmap. Up to the present time, fossil fuels remain the main source for energy production. The use of petroleum, natural gas, and coal as energy sources dates back several centuries. Likewise, Cambodia has also heavily relied on fossil fuels for energy consumption. Hence, in the short term, energy from oil will still play an important role as an energy source for consumption. However, the concerns associated with fossil fuel energy consumption have increased in recent decades, especially the concern over the depletion of the world's fossil fuel reserves in the near future, and the energy crisis is becoming more serious for the economic well-being of every nation on the globe. In addition, the large-scale development and utilisation of fossil fuels pose several problems to the environment; one among them is climate change and ecological deterioration, which in turn directly impact human health and the sustainability of humankind. To this end, clean, renewable, pollution-free energy sources have been introduced and adopted as strategic energy plans by many countries in the world to replace conventional fossil fuel-based energy sources. As with the favourable conditions, Cambodia shall embrace hydropower as a power source in the short and medium term. While energy from solar power shall be adopted for

the long-run energy strategy to achieve Cambodia's sustainable development goal and be a carbon-neutral country.

To achieve the realised energy provision, it is crucial to ensure the stability and security of energy operation, particularly for long-distance transmission. Cambodia shall constantly deploy and develop the technologies to achieve an optimally effective power grid for energy management as well as safety and quality control in the short to medium term. For the medium to long run, technologies like real-time perception and detection through sensing technologies shall be paid attention to, as they can monitor and detect the power grid situation and transfer this data instantly via digital and information technologies to centralised and any decentralised control centres or to users directly. Flexible transmission technology is another spectrum that can improve the stability and capacity of energy transmission over long distances and enhance the quality and stability of energy in the medium to long run.

Power storage is another aspect to be taken into account. Because the renewable sources are scattered in many areas and the energy generation capability is not available at all times (for example, solar energy could only be produced during the day), storage technology is a necessity to ensure the stability and security of renewable energy sources. Battery energy capacity is strategically important to store surplus energy and can serve as an alternative source for energy generation once needed. Increasing the high-power density cell capacity shall be adopted in the short to medium term. Pump storage could be another technology used in the hydropower system. Increasing the storage capacity, especially of the battery, will be a priority in the medium term.

Effective transportation and distribution shall be improved to ensure energy security and stability because long-distance transmission could pose problems such as energy leakages and losses, and renewable energy sources like solar and hydropower sources require transportation from suitable areas to the city and urban areas. Grid substations and smart grid systems shall be in place in the short to medium term and in the medium to long term, respectively. Power transmission and superconducting technologies shall be the technologies to enhance energy and power

transportation and distribution, as they could minimise the energy resistance, which could in turn cause the energy resistance losses. They should be considered over a medium-to-long time span.

Energy efficiency is another aspect that needs to be included in the strategic plan for achieving energy security and sustainability. Smart homes and smart devices powered by sensor technologies, IOT, information technologies, AI, and others shall help enhance the efficiency of energy utilisation at home and in buildings as it minimises the energy wastage due to unnecessary usage as these technologies could deliver the energy and power just in time and immediately disconnect once unnecessary. Technologies like light-emitting diodes (LED) could save a lot of energy and provide better quality in personal building and industry consumption, and as a result, we should consider implementing and promoting their utility in the short and medium run. Low-carbon and green technologies could not only improve the efficiency of energy consumption but also be environmentally friendly, which could be good for the environment and help boost the realisation of sustainable development and the carbon neutral goal in the long run. Urban transportation could also help reduce energy consumption on the one hand and carbon emissions on the other. Hence, these technologies are deployed in this strategic roadmap for energy as a long-term goal for Cambodia to embrace in the next decade.

Energy conservation cannot be decoupled from energy efficiency. To achieve sustainable development, integrated electrical technology shall be deployed to replace fossil fuel consumption entirely, and power and high-effect motor technology shall replicate and could even go far beyond what traditional fossil fuel is capable of with the current speed of development of technologies in recent years. Energy-saving buildings are another effective strategy to be implemented for energy conservation. These technologies are in use these days but will be encouraged in the near future. The energy-saving label is very effective and is used worldwide for energy-conservative consumption, as it could provide the correct information to consumers about energy usage. The energy label, coupled with the incentive scheme from the government, is among, if not the most

effective, ways to promote energy conservation in a country. This practice will be consistently promoted from now on to raise public awareness nationwide.

Two additional directions for this EnergyTech Roadmap have been proposed due to the current megatrend around the globe: Electrical Vehicles (EV) and New Possible Sources of Energy. The use of electrical vehicles is becoming very popular to reduce, if not completely replace, the reliance on fossil fuel-driven vehicles, as it not only saves a lot of money economically but is also good for the environment. Import tax incentives, together with promoting electric machine driving technology, could promise the success of electrical vehicles. Searching for possible new sources of energy could solve the problems of the current energy situation Cambodia is facing today and accelerate the successful realisation of its energy strategy and vision. Nuclear and Hydrogen-fueled energy sources are clean energy sources that should not be completely ruled out without a thorough study and feasibility study about these two new possible sources of energy production.

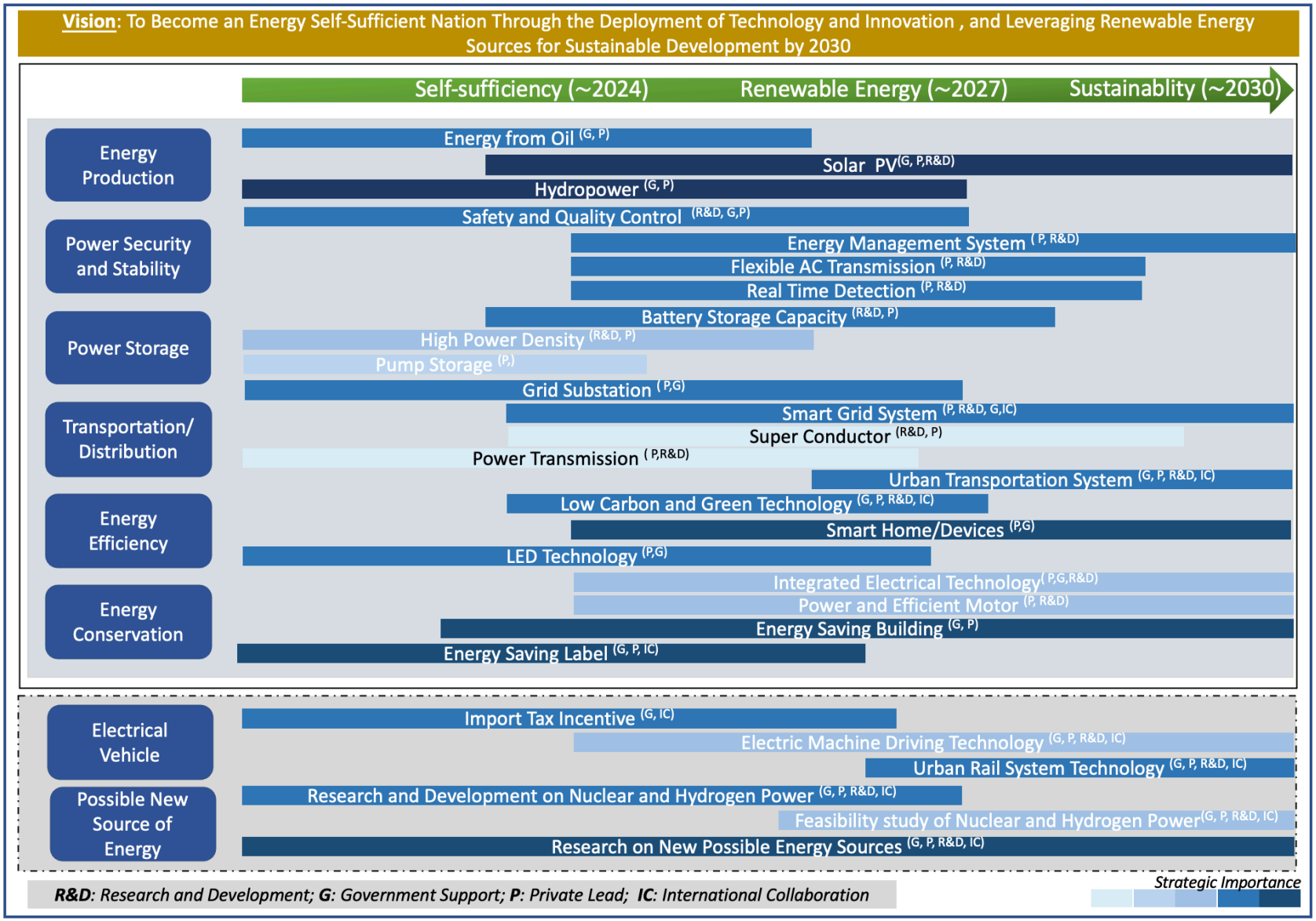

Figure 10: Energy technology roadmap chart

8 Conclusion

Energy is a mandatory resource required for human survival and societal advancement. Energy is not only crucial for economic development; it is also crucial from a political and strategic perspective. One country, without energy security, could not fully develop if it relied on energy sources from outside. The development of energy production has a direct impact on the development and security of a nation. The needs of the nation's economic and social development require an increasingly enormous amount of energy consumption each year as civilisation and national development progress. The lack of energy hampered urban and economic growth as well as population expansion.

Because of the emergency of an energy crisis, the environmental impact, and the fear of the depletion of fossil fuels, the energy structure has changed over time. It was previously dominated by fossil fuels such as petroleum, natural gas, and coal and now transitions into the use of renewable energy sources like solar, wind, ocean, biomass, and geothermal energy, as well as new possible sources such as nuclear and hydrogen. This pattern could lead to a significant energy technology evolution. As a result, STI is the key factor in the advancement of energy technology and, in turn, will bring about radical changes in socioeconomic growth. Economic development in human history has been associated with energy transitions from human labour to steam engines to electricity, as we see today. Humans transformed from an agrarian society into an industrial civilisation, thanks to energy evolution and scientific and technological progress.

Cambodia shall have a clear strategic plan, such as this roadmap, to utilise STI to ensure energy security for future economically prosperous development as well as sustainable and inclusive growth. This EnergyTech Roadmap has identified the technologies that Cambodia needs to adopt for its developmental and sustainable future in order to realise the vision to become an energy self-sufficient nation through the deployment of technology and innovation and leveraging renewable energy sources for sustainable development by 2030 based on the evaluation of the current condition, the strengths, weaknesses, opportunities, and threats by identifying the drivers, and in turn, determining the strategic products and functions with a clear and specific timeframe.

Last but importantly, below are some policy implications to be considered for the implementation of achieving energy security:

- The government's policies and incentive scheme are mandatory to meet the needs for energy security and sustainable development;
- Progress in STI is crucial for a country's development in all sectors; the energy sector is one of them. Hence, investing in STI shall be indispensable for Cambodia to be an energy-self-sufficient and sustainable nation;
- Talents are central to this energy roadmap as well as other energy strategic plans to be realised. Investing in human capital development is of important for long term achievement;
- Research and Development in energy-related areas shall be invested in and prioritised as it can strengthen scientific-based and technological capabilities and bring out innovation;
- A training and education system on energy science and technology capability shall be promoted to keep up with the trend of the global energy sector;
- Collaboration is a key factor in promoting knowledge and technology transfer, knowledge creation, as well as the solutions to tackle the societal need for energy security and sustainable development;
- The energy strategy and policy study shall be continued to leverage the national innovation capabilities;
- Good governance and coordination among key stakeholders in the ecosystem are the keys to success and are compulsory.

To achieve the optimal result, a monitoring and evaluation framework shall be in place, and this roadmap shall be reviewed and upgraded every three to five years with the consultancy of relevant stakeholders to ensure that it guides the right direction in energy technology development for Cambodia to achieve the goals.

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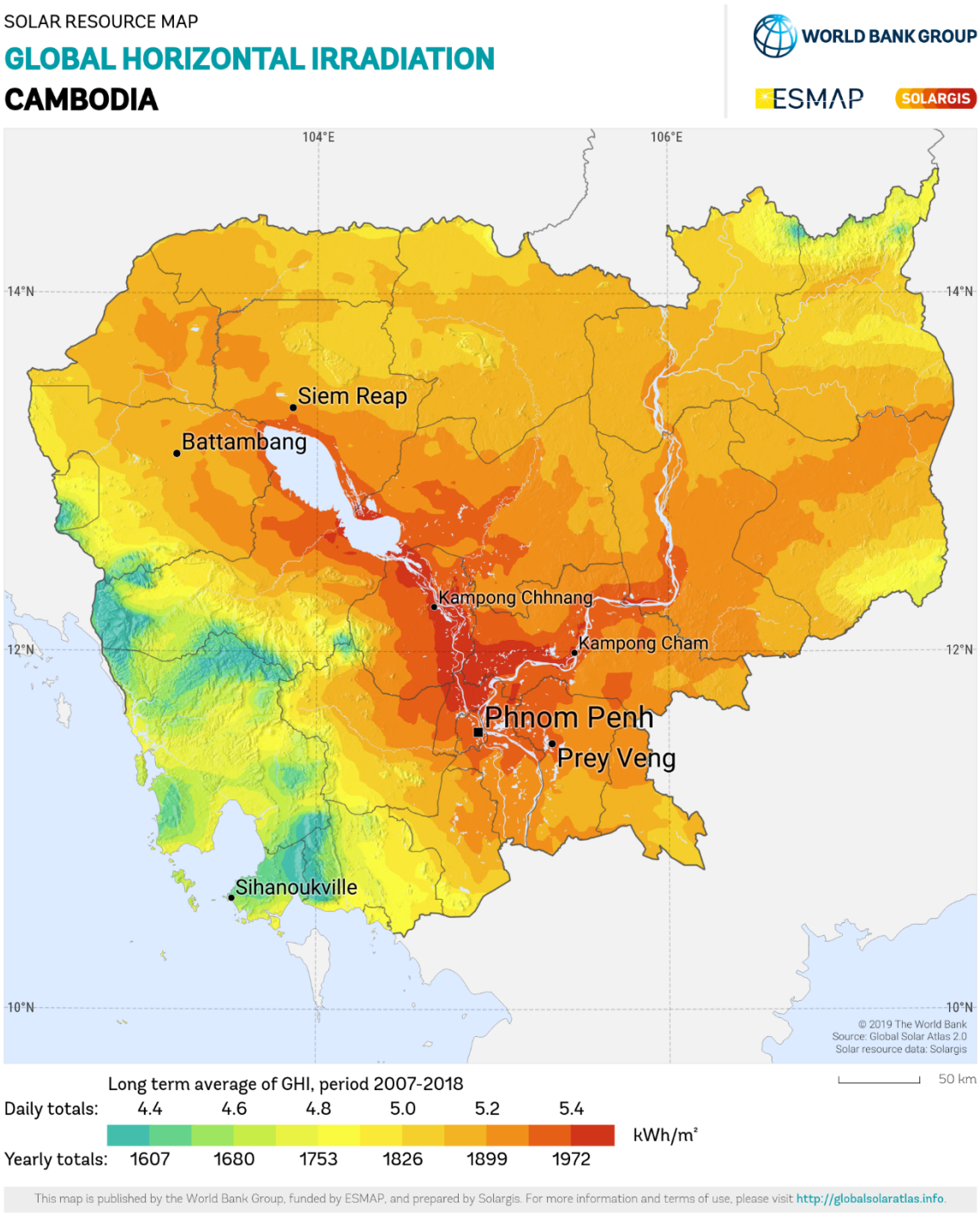
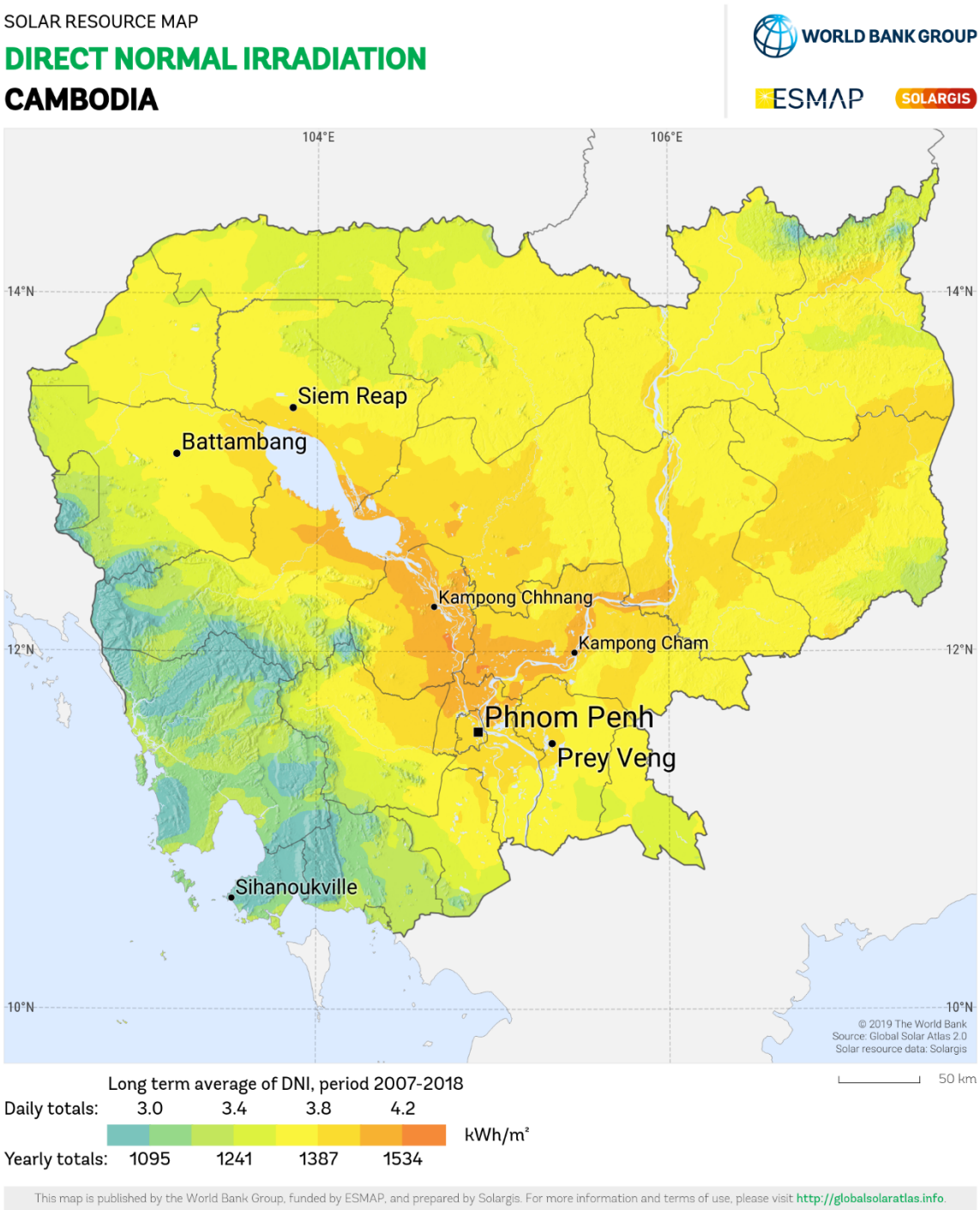
Annex 1: Global Horizontal Irradiation



Annex 2: Direct Normal Irradiation



Annex 3: Committee Members

ព្រះរាជាណាចក្រកម្ពុជា
ជាតិ សាសនា ព្រះមហាក្សត្រ

ក្រសួងឧស្សាហកម្ម វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍
Ministry of Industry, Science, Technology & Innovation
លេខ: ១៧៣ MISTI / ២០២២

២. ឯកឧត្តមបណ្ឌិត **ហ៊ិល សៀងហេង**	អគ្គនាយកនៃអគ្គនាយកដ្ឋានវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍ នៃក្រសួងឧស្សាហកម្ម វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍	អនុប្រធាន
៣. ឯកឧត្តមបណ្ឌិត **កង ច័ន្ទតារាវត្ត**	អនុរដ្ឋលេខាធិការក្រសួងប្រៃសណីយ៍ និងទូរគមនាគមន៍	សមាជិក
៤. ឯកឧត្តម **ណៃប សាមុត**	អគ្គនាយកនៃអគ្គនាយកដ្ឋានគ្រប់គ្រងឧស្សាហកម្ម ទេសចរណ៍នៃក្រសួងទេសចរណ៍	សមាជិក
៥. លោក **ជា ណារិន**	អគ្គនាយករងនៃអគ្គនាយកដ្ឋានថាមពល នៃក្រសួងរ៉ែ និងថាមពល	សមាជិក
៦. លោកបណ្ឌិត **ទ្រី សុផល**	អគ្គនាយករងនៃអគ្គនាយកដ្ឋានវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍ នៃក្រសួងឧស្សាហកម្ម វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍	សមាជិកអចិន្ត្រៃយ៍

ប្រការ២.-

គណៈកម្មការដឹកនាំ និងសម្របសម្រួលដល់ការអនុវត្តគម្រោង មានតួនាទី និងភារកិច្ចដូចតទៅ៖

- ធានានូវការសិក្សារបស់គម្រោង ត្រូវបានបន្សុំ និងគិតគូរច្បាស់លាស់ជាមួយនឹងយុទ្ធសាស្ត្រពាក់ព័ន្ធនានា
- ធានានូវការសិក្សារបស់គម្រោង និងប្រើប្រាស់ធនធានបានយ៉ាងល្អនិងគ្រប់គ្រងជ្រោយ រាប់ទាំងមូលដ្ឋានចំណេះដឹងក្នុងប្រទេស និងក្នុងតំបន់
- ផ្តល់យុទ្ធសាស្ត្រក្នុងការអនុវត្ត និងជួយដោះស្រាយបញ្ហានិងហានិភ័យនានាក្នុងពេលអនុវត្តគម្រោង
- ពិនិត្យនូវវឌ្ឍនភាព និងសម្របសម្រួលជាមួយថ្នាក់ដឹកនាំជាន់ខ្ពស់ និងក្រសួង-ស្ថាប័នពាក់ព័ន្ធនានា
- ពិនិត្យ និងផ្តល់យោបល់លើ សេចក្តីព្រាងកម្រងសំណួរសម្រាប់ការធ្វើអង្កេតនិងលទ្ធផលដែលទទួលបាន
- ពិនិត្យ និងផ្តល់យោបល់លើវិធីសាស្ត្រនានាដែលជាក់ឱ្យប្រើប្រាស់ក្នុងគម្រោង
- ណែនាំអំពីឱកាសដើម្បីទទួលបានប្រយោជន៍ និងសារៈសំខាន់ជាអតិបរិមាពីលទ្ធផលនៃការសិក្សាគម្រោង។

ប្រការ៣.-

ត្រូវបានបង្កើតអនុគណៈកម្មការ**ចំនួន៣** ដើម្បីទទួលអនុវត្តគម្រោងខាងលើតាមបច្ចេកវិទ្យា ដូចមានសមាសភាពខាងក្រោម៖

ក. អនុគណៈកម្មការអភិវឌ្ឍផែនទីបង្ហាញផ្លូវសម្រាប់បច្ចេកវិទ្យាថាមពល៖

១. លោក **ជា ណារិន**	អគ្គនាយករងនៃអគ្គនាយកដ្ឋានថាមពល នៃក្រសួងរ៉ែ និងថាមពល	ប្រធាន
២. ឯកឧត្តម **នុត អ៊ុនរ័ណារ៉ា**	អគ្គលេខាធិការរងគណៈកម្មការវិនិយោគកម្ពុជា នៃក្រុមប្រឹក្សាអភិវឌ្ឍន៍កម្ពុជា	សមាជិក
៣. លោកស្រីបណ្ឌិត **គ្រី ណាល់លីស**	អគ្គនាយករងនៃអគ្គនាយកដ្ឋានវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍	សមាជិក
៤. លោក **តាំង ម៉ែងអៀង**	ប្រធាននាយកដ្ឋានសេដ្ឋកិច្ចបៃតង នៃអគ្គនាយកដ្ឋានគោលនយោបាយនិងយុទ្ធសាស្ត្រ នៃក្រសួងបរិស្ថាន	សមាជិក

៥. លោកបណ្ឌិត **ស្រ៊ុន បញ្ញារិទ្ធិ**	ប្រធាននាយកដ្ឋានគោលនយោបាយវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍ នៃអគ្គនាយកដ្ឋានវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍	សមាជិកអចិន្ត្រៃយ៍
៦. លោកស្រីបណ្ឌិត **លី សុខនី**	ប្រធាននាយកដ្ឋានសហប្រតិបត្តិការវិស័យវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍ នៃអគ្គនាយកដ្ឋានវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍	សមាជិក
៧. លោកបណ្ឌិត **ជាតិ សុផល**	ប្រធាននាយកដ្ឋានតាមដាន ត្រួតពិនិត្យ និងវាយតម្លៃការអនុវត្តគោលនយោបាយវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍ នៃអគ្គនាយកដ្ឋានវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍	សមាជិក
៨. លោក **ស៊ាន រិទ្ធី**	ប្រធាននាយកដ្ឋានស្ដីទី នៃនាយកដ្ឋានបណ្ដុះបណ្ដាលវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍ នៃវិទ្យាស្ថានជាតិវិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍	សមាជិក
៩. លោក **វ៉ាន់ សីហៈគីរី**	នាយករង ផែនការយុទ្ធសាស្ត្រ និងគម្រោងការ នៃអគ្គិសនីកម្ពុជា	សមាជិក
១០. លោកបណ្ឌិត **ជ័យ ចាន់អឿន**	ព្រឹទ្ធបុរសរងមហាវិទ្យាល័យវិទ្យាសាស្ត្រ នៃសាកលវិទ្យាល័យភូមិន្ទភ្នំពេញ	សមាជិក
១១. លោក **តេង សារឿន**	អនុប្រធាននាយកដ្ឋានសេវាកម្មផលិតកម្ម នៃអាជ្ញាធរអគ្គិសនីកម្ពុជា	សមាជិក
១២. លោក **ឈាង លីហួរ**	ប្រធានផ្នែកគ្រប់គ្រងការអភិវឌ្ឍថាមពលថ្មីនៃក្រុមហ៊ុន TOTAL ENERGY កម្ពុជា	សមាជិក
១៣. លោកបណ្ឌិត **អ៊ូ ចំរុង**	ប្រធានផ្នែកគ្រប់គ្រងទូទៅនៃនាយកដ្ឋានបច្ចេកទេសជាន់ខ្ពស់ នៃក្រុមហ៊ុន SCHNEITECH CO.,LTD	សមាជិក
១៤. លោក **ជឿន គ្រឹម**	ប្រធានផ្នែកលក់ នៃក្រុមហ៊ុន VP-SMART TECHNOLOGY	សមាជិក
១៥. លោក **ច្រិង ការូឌីន**	និយោជិត នាយកដ្ឋានផែនការយុទ្ធសាស្ត្រ និងគម្រោងការ នៃអគ្គិសនីកម្ពុជា	សមាជិក

ប្រការ៤.-

អនុគណៈកម្មការអភិវឌ្ឍផែនទីបង្ហាញផ្លូវបច្ចេកវិទ្យាទាំង៣នេះ មានតួនាទី និងភារកិច្ចដូចតទៅ៖

- ទទួលអនុវត្តការងារទៅតាមទិសដៅដែលបានដាក់ចេញដោយគណៈកម្មការដឹកនាំ និងសម្របសម្រួលដល់ការអនុវត្តគម្រោង
- សម្របសម្រួល ប្រមូល និងផ្តល់ជាតុចូលនានាតាមក្រសួង-ស្ថាប័ន ឬអង្គភាពសាមីដែលពាក់ព័ន្ធនឹងការសិក្សារបស់គម្រោងទៅតាមរបៀបវារៈនៃការអនុវត្ត
- ជានាទូវសង្គតិភាពព័ត៌មាន និងទិន្នន័យដែលទទួលបាន និងផ្តល់ជូន និងទទួលស្គាល់ដោយក្រសួង-ស្ថាប័ន ឬអង្គភាពសាមី
- សម្របសម្រួលការងារទាំងបច្ចេកទេស និងរដ្ឋបាលនៅតាមក្រសួង-ស្ថាប័ន ឬអង្គភាពសាមី
- ពង្រឹងសមត្ថភាពបន្ថែមលើវិស័យ តាមរយៈសិក្ខាសាលា និងវគ្គបណ្តុះបណ្តាលនានា ដែលរៀបចំដោយគម្រោង

ក្រសួងឧស្សាហកម្ម វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍
៤៥ មហាវិថីព្រះនរោត្តម សង្កាត់ផ្សារថ្មី៣
ខណ្ឌដូនពេញ ភ្នំពេញ ១២២០៥ (ព្រះរាជាណាចក្រកម្ពុជា)

ខុទ្ទកាល័យឯកឧត្តមកិត្តិសេដ្ឋាបណ្ឌិត ទេសរដ្ឋមន្ត្រី
ទូរស័ព្ទលេខ៖ (៨៥៥) ២៣ ២១១ ៧៧៥
អ៊ីមែល: misti.smcabinet@gmail.com

- ជាមន្ត្រីបង្គោលតាមក្រសួង-ស្ថាប័ន ឬអង្គភាពសាមីសម្រាប់ការអនុវត្តសកម្មភាពនានារបស់គម្រោង
- ទទួលអនុវត្តការកិច្ចផ្សេងទៀតដែលបានដាក់ចេញដោយគណៈកម្មការដឹកនាំ និងសម្របសម្រួលគម្រោង។

ប្រការ៥...

ពេលប្រធានគណៈកម្មការដឹកនាំ និងសម្របសម្រួលដល់ការអនុវត្តគម្រោង អវត្តមាន ឬមានករណីចាំបាច់ ប្រធានគណៈកម្មការដឹកនាំនិងសម្របសម្រួលដល់ការអនុវត្តគម្រោង អាចផ្តល់សិទ្ធិជូនអនុប្រធាន ដើម្បីដឹកនាំការប្រជុំតាមការប្រគល់សិទ្ធិពីប្រធាន។

ប្រការ៦...

សមាជិកគណៈកម្មការ និងអនុគណៈកម្មការនីមួយៗ ត្រូវចូលរួមប្រជុំតាមការអញ្ជើញរបស់ប្រធាន និងទទួលខុសត្រូវតាមបន្ទុកការងារដែលបានបែងចែក។ ប្រធានអនុគណៈកម្មការនីមួយៗ ត្រូវរាយការណ៍ការងារជាប្រចាំ និងតាមការចាំបាច់ ជូនប្រធានគណៈកម្មការដឹកនាំ និងសម្របសម្រួលដល់ការអនុវត្តគម្រោង។

ប្រការ៧...

នាយកខុទ្ទកាល័យ អគ្គនាយក អគ្គាធិការ ប្រធានមជ្ឈមណ្ឌល គ្រប់អង្គភាពពាក់ព័ន្ធ និងសាមីខ្លួន ត្រូវទទួលបន្ទុកអនុវត្តសេចក្តីសម្រេចនេះ ចាប់ពីថ្ងៃចុះហត្ថលេខាតទៅ។

ថ្ងៃ ច័ន្ទ ៧ កើត ខែអាសាឍ ឆ្នាំខាល ចត្វាស័ក ព.ស.២៥៦៦
ធ្វើនៅរាជធានីភ្នំពេញ ថ្ងៃទី ១៨ ខែ កក្កដា ឆ្នាំ២០២២
ទេសរដ្ឋមន្ត្រី
រដ្ឋមន្ត្រីក្រសួងឧស្សាហកម្ម វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍ ត.ជ

កិត្តិសេដ្ឋាបណ្ឌិត **ចម ប្រសិទ្ធ**

កន្លែងទទួល៖
- ទីស្តីការគណៈរដ្ឋមន្ត្រី
- គ្រប់ក្រសួង-ស្ថាប័នពាក់ព័ន្ធ
- គ្រប់ថ្នាក់ដឹកនាំក្រសួងឧស្សាហកម្ម វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍
- ដូចប្រការ៧
- ឯកសារ-កាលប្បវត្តិ

ក្រសួងឧស្សាហកម្ម វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍
៤៥ មហាវិថីព្រះនរោត្តម សង្កាត់ផ្សារថ្មី៣
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ខុទ្ទកាល័យឯកឧត្តមកិត្តិសេដ្ឋាបណ្ឌិត ទេសរដ្ឋមន្ត្រី
ទូរស័ព្ទលេខ: (៨៥៥) ២៣ ២១១ ៧៧៥
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Annex 4: Key technologies scoring from committee members

Key Technologies for Energy Technology Roadmap							
Technology Group	Sources/Key technologies	Evaluation Criteria			Important level		
		Strategic Importance	Economic Impact	Potential for Success	Short term	Medium term	Long term
Fossil energy	Oil	65	75	63	77	68	50
	Coal	59	67	60	65	59	41
	Natural Gas	49	50	44	36	37	43
Renewable energy	Solar PV	78	61	73	67	69	75
	Solar Thermal	48	42	45	41	44	49
	Hydropower	74	69	78	64	70	81
	Wind power	51	57	42	29	36	63
	Bio-Energy (Biomass, Biofuel)	59	56	52	47	50	56
	Waste to energy	68	57	42	40	49	65
	Geothermal	20	29	20	19	21	27
New Source energy	Nuclear	45	57	29	21	29	37
	Hydrogen	53	44	38	23	26	51
	Natural Gas Hydrate	31	31	31	15	27	35
Storage Capacity	Battery storage/capacity	70	65	63	47	60	64
	High power density technology	39	32	33	22	33	43
	CO2 capture and storage tech	44	43	42	18	36	44
	Pump storage technology	55	47	54	38	45	62
	Fly wheel Technology	47	47	47	28	39	43
	Super capacitor	48	43	50	31	47	48
	Battery energy storage system	58	49	50	33	50	57
	Thermal storage	42	40	43	32	42	44
Power Security/Stability	Flexible AC transmission	46	42	46	38	48	53
	Real-time detection	48	43	46	36	46	54
	Safety and quality control	59	52	51	44	49	56
	Energy technology management	66	57	57	44	50	66
	Semiconductor	22	20	24	19	21	21

	Reactor/Capacitor bank	43	41	44	41	44	47
Power/Energy Transportation/ Distribution	Heat dissipation	29	27	27	19	25	30
	Power transmission	49	45	49	32	37	44
	Superconductor	35	33	25	20	29	39
	Grid substation	61	56	59	38	48	61
	Pipeline	56	55	42	27	37	56
	Smart Grid system	62	53	59	39	48	62
	Cable type and size	51	47	51	30	42	45
Efficiency	Urban transportation system	54	51	54	32	45	52
	Electric machine driving technology	43	38	31	26	33	43
	Low Carbon and green technology	61	52	47	36	44	64
	Cost effective turbine tech	43	41	32	25	36	47
	Sensor technology	68	60	68	53	59	69
	Smart home/Building code	77	68	63	43	56	74
	Smart devices	65	57	63	40	50	64
	LED	65	57	66	56	63	71
	Device controller	55	48	51	39	46	54
	Smart invertor	51	47	50	42	50	57
	Turbo technology for vehicle	40	42	39	32	40	45
	Device life span	44	44	43	34	43	46
Conservation/ Consumption	Integrated power electrical tech	42	45	47	37	43	51
	Effective cooling system	44	46	45	35	41	48
	Electric vehicle	65	53	55	35	55	63
	Power and high efficient motor	41	38	38	30	40	47
	Eco-mode	59	55	54	43	53	63
	Energy saving label	62	55	61	48	55	67
	Energy saving building	54	47	49	35	44	59
	Energy stability controller (auto voltage)	54	47	48	37	50	52
	Public transportation	71	63	66	58	65	66

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