Initiative for Climate Action Transparency – ICAT

MEASUREMENT, REPORTING AND VERIFICATION SYSTEM FOR RENEWABLE ENERGY POLICY IN CAMBODIA

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DELIVERABLE 2: MEASUREMENT, REPORTING AND VERIFICATION FRAMEWORK FOR RENEWABLE ENERGY POLICY IN CAMBODIA (including the data and metrics of RE sector and its policies, BAU scenario(s), ex-ante estimation of selected policy GHG impact, existing barriers and gaps in current reporting mechanisms and MRV system design)

DISCLAIMER

This publication has been produced as part of a component of the Initiative for Climate Action Transparency project (ICAT) implemented by the UNEP DTU Partnership (UDP). The views expressed in this publication are those of Consultants, and do not necessarily reflect the views of the GSSD or UDP.

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The Royal Government of Cambodia (RGC), being a Party to the United Nations Framework Convention on Climate Change (UNFCCC) ratified the Convention in 1995 and the Paris Climate Agreement to limit global warming in 2017. The country also submitted its Nationally Determined Contributions (NDCs) to the UNFCCC in 2017.

Increasing the share of renewable electricity, especially through the introduction of grid-connected solar PV systems, is one of the mitigation actions proposed by the RGC in its NDC to the UNFCCC. Having an internationally recognized and transparent system for the Measurement, Reporting and Verification (MRV) in order to evaluate the Greenhouse Gas (GHG) effect of such mitigation actions is an essential requirement.

UNEP DTU Partnership is providing technical assistance to the RGC under this ICAT project. The aim of this assignment is to design an MRV system for a selected renewable energy policy in Cambodia, which will help improving transparency and capacity building in the country. A Team of National Experts, and International Experts of Climate Smart Initiatives (Pvt) Ltd (ClimateSI) was selected to support the Cambodian team for this project.

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- General Secretariat of the National Council for Sustainable Development

List of Acronyms

ADB	Asian Development Bank
BOT	Build, Operate, Transfer
BTR	Biennial Transparency Report
BUR	Biennial Update Report
COPs	Conference of the Parties
DMS	Data Management System
EAC	Electricity Authority of Cambodia
EDC	Electricite du Cambodge
ERs	Emission Reductions
ETF	Enhanced Transparency Framework
GSSD	General Secretariat of the National Council for Sustainable Development
GHGs	Greenhouse Gases
GST	Global Stock Take
IEA	International Energy Agency
IRENA	International Renewable Energy Authority
INC	Initial National Communication
INDC	Intended Nationally Determined Contribution
IPPs	Independent Power Producers
LCOE	Levelized Cost of Electricity
LDCs	Least Developed Countries
LNG	Liquefied natural gas
MEF	Ministry of Economy and Finance
MoE	Ministry of Environment
MME	Ministry of Mines and Energy
MoP	Ministry of Planning
MRV	Measurement, Reporting and Verification
NAMA	Nationally Appropriate Mitigation Actions
NCSD	National Council for Sustainable Development
NDCs	Nationally Determined Contributions
NIS	National Institute of Statistics
PDP	Power Development Plan

PPA	Power Purchase Agreement
RE	Renewable Energy
REEs	Rural Electricity Enterprises
REF	Rural Electrification Fund
REREP	Rural Electrification by Renewable Energy Policy
RFO	Residual Fuel Oil
RGC	Royal Government of Cambodia
SNC	Second National Communication
TNC	Third National Communication
UDP	UNEP DTU Partnership
UN DESA	United Nations Department of Economic and Social Affairs
UNFCCC	United Nations Framework Convention on Climate Change
VAT	Value-added tax

Glossary of Terms

Activities	The administrative activities involved in implementing the policy (undertaken by the authority or entity that implements it), such as permitting, licensing, procurement, or compliance and enforcement
Assessment period	The time period over which GHG impacts resulting from a policy are assessed
Assessment report	A report, completed by the user, that documents the assessment process and the GHG, sustainable development and/or transformational impacts of the policy
Barrier	Any obstacle to develop and deploy renewable energy (RE) potential that can be overcome or attenuated by a policy, programme or measure
Baseline scenario	A reference case that represents the events or conditions most likely to occur in the absence of a policy (or package of policies) being assessed
Causal chain	A conceptual diagram tracing the process by which the policy leads to impact through a series of interlinked logical and sequential stages of cause-and-effect relationships
Emission factor	A factor that converts activity data into GHG emissions data
Ex-ante assessment	The process of estimating expected future GHG impacts of a policy (i.e. a forward-looking assessment)
Ex-post assessment	The process of estimating historical GHG impacts of a policy (i.e. a backward-looking assessment)
Expert judgment	In the absence of unequivocal observational evidence, a carefully considered, well-documented qualitative or quantitative judgment made by a person or persons who have a demonstrable expertise in the given field (IPCC 2006)
Feed-in tariff	The price per unit of electricity that a utility or a power supplier has to pay for distributed or renewable electricity fed into the grid by non-utility power producers
GHG assessment boundary	The scope of an assessment in terms of the range of GHG impacts that are included there in
GHG impacts	Changes in GHG emissions by sources, that result from a policy

Electricity grid (grid)	A network consisting of wires, switches and transformers to transmit electricity from power sources to power users. A large, intermediate voltage (1-50 kV) to high-voltage (above 50 kV to MV) transport subsystems. Interconnected grids cover large areas up to continents. The grid is a power exchange platform enhancing supply reliability and economies of scale
Grid access	Refers to the acceptance of power producers to deliver to the electricity grid
Impact assessment	The estimation of changes in GHG emissions or removals resulting from a policy, either ex-ante or ex-post
In-jurisdiction impacts	Impacts that occur inside the geopolitical boundary over which the implementing entity has authority, such as a city boundary or national boundary
Independent policies	Policies that do not interact with each other, such that the combined effect of implementing the policies together is equal to the sum of the individual effects of implementing them separately
Inputs	Resources that go into implementing the policy, such as financing
Intended impacts	Impacts that are intentional based on the original objectives of the policy. In some contexts, these are referred to as primary impacts.
Interacting policies	Policies that produce total effects, when implemented together, that differ from the sum of the individual effects had they been implemented separately
Intermediate effects	Changes in behavior, technology, processes, or practices that result from the policy, which leads to GHG impacts
Jurisdiction	The geographic area within which an entity's (such as a government) authority is exercised
Key performance indicator	A metric that indicates the performance of a policy indicator
Levelized Cost of Electricity LCOE)	The unique cost price of the outputs (cUS/kWh or USD/GJ) of a project that makes the present value of the revenues (benefits) equal to the present value of the costs over the lifetime of the project
Long-term impacts	Impacts that are more distant in time, based on the amount of time between implementation of the policy and the impact

Monitoring period	The time over which the policy is monitored, which may include pre-policy monitoring and post-policy monitoring in addition to the policy implementation period
Negative impacts	Impacts that are perceived as unfavorable from the perspectives of decision makers and stakeholders
Net metering	The practice of using a single meter to measure consumption and generation of electricity by a small generation facility (such as a house with a wind or solar photovoltaic system). The net energy produced or consumed is purchased from or sold to the power producer, respectively.
Non-policy drivers	Conditions other than RE policies, such as socioeconomic factors and market forces, that are expected to affect the emission sources included in the GHG assessment boundary
Own use of electricity	Consumption of the electricity for the direct support of the power plants
Out-of-jurisdiction impacts	Impacts that occur outside the geopolitical boundary over which the implementing entity has authority, such as a city boundary or national boundary
Overlapping policies	Policies that interact with each other and that, when implemented together, have a combined effect less than the sum of their individual effects when implemented separately. This includes both policies that have the same or complementary goals (such as national and subnational energy efficiency standards for appliances), as well as counteracting or countervailing policies that have different or opposing goals (such as a fuel tax and a fuel subsidy).
Parameter	A variable such as activity data or emission factors that are needed to estimate GHG impacts
Policy or action	An intervention taken or mandated by a government, institution, or other entity, which may include laws, regulations, and standards; taxes, charges, subsidies, and incentives; information instruments; voluntary agreements; implementation of new technologies, processes, or practices; and public or private sector financing and investment, among others

Policy implementation period	The time period during which the policy is in effect
Policy scenario	A scenario that represents the events or conditions most likely to occur in the presence of the policy (or package of RE policies) being assessed. The policy scenario is similar to the baseline scenario except the fact that it includes the policy (or package of policies) being assessed.
Positive impacts	Impacts that are perceived as favorable from the perspectives of decision makers and stakeholders
Power purchase agreement (PPA)	A contract between an electricity (power) producer and an electricity utility/consumer/distributor. Historically, PPAs have been frequently signed between utilities and independent power producers as a way for the utility to procure additional generation. In recent years, PPAs have been used as a way for power consumers to purchase electricity, often from solar systems, from a third-party power producer
RE addition	The additional installation of renewable energy capacity or electricity generation from renewable sources realized via the policy, expressed in megawatts (MW) or megawatt-hours (MWh) respectively
Reinforcing policies	Policies that interact with each other and that, when implemented together, have a combined effect greater than the sum of their individual effects when implemented separately
Renewable energy	Any form of energy from solar, geophysical or biological sources that is replenished by natural processes at a rate that equals or exceeds its rate of use. Renewable energy is obtained from the continuing or repetitive flows of energy occurring in the natural environment and includes low-carbon technologies such as solar energy, hydropower, wind, tide and waves and ocean thermal energy, as well as renewable fuels such as biomass.
Renewable portfolio standard	A legal mandate that require utilities to procure a certain percentage or flat amount of renewable electricity or power based on their total generation. Utilities can procure the renewable energy via direct ownership or the purchase of renewable energy

Short-term impacts	Impacts that are nearer in time, based on the amount of time between implementation of the policy and the impact
Solar energy	Energy from the sun that is captured either as heat, as light that is converted into chemical energy by natural or artificial photosynthesis, or by photovoltaic panels and converted directly into electricity
Stakeholders	People, organizations, communities or individuals who are affected by and/or who have influence or power over the policy
Sustainable development impacts	Changes in environmental, social, or economic conditions that result from a policy, such as changes in economic activity, employment, public health, air quality, and energy security
Transmission and distribution	The network that transmits electricity through wires from where it is generated to where it is used. The distribution system refers to the lower-voltage system that delivers the electricity to the end consumer.
Uncertainty	1. Quantitative definition: Measurement that characterizes the dispersion of values that could reasonably be attributed to a parameter. 2. Qualitative definition: A general term that refers to the lack of certainty in data and methodological choices, such as the application of non-representative factors or methods, incomplete data, or lack of transparency.
Unintended impacts	Impacts that are unintentional based on the original objectives of the policy. In some contexts, these are referred to as secondary impacts.
Utility	An entity in the electric power industry that engages in electricity generation and distribution-of electricity for sale, generally in a regulated market
Weighted average cost of capital (WACC)	The rate that a company is expected to pay on average to all its security holders to finance its assets, including the fraction of each financing source in the company's capital structure

Source: ICAT Renewable Energy methodology, 2020

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Executive Summary

The Royal Government of Cambodia (RGC), being a Party to both the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Climate Agreement, needs to comply with the international reporting requirements in order to strengthen the global response to climate change. Under the Paris Agreement (PA), the Parties agreed to limit the rise in global temperature well below 2 degrees Celsius above pre-industrial levels, and pursue efforts to limit the increase in temperature even further, to 1.5 degrees Celsius. The RGC, in response to the UNFCCC requirements, has already submitted two national communications in 2002 and 2015. Further, the RGC, in response to the PA, submitted the first Nationally Determined Contributions (NDCs) in 2017. Currently, the First Biennial Update Report (BUR) and the revised NDCs of the country are under preparation.

As Article 13 of the Paris Agreement relies on a robust transparency and accounting system to provide clarity on action and support by the Parties, the Initiative for Climate Action Transparency (ICAT) is providing support through UNEP DTU Partnership (UDP) to build capacity in order to establish a Measurement, Reporting and Verification (MRV) system in Cambodia through this project. The Cambodian team, after consultation with stakeholders, selected Renewable Energy (RE) policy in Cambodia for development of an MRV system. This will help tracking contribution of the RE to Cambodian NDCs and also to prepare Biennial Transparency Report (BTR). Grid connected solar power generation was selected as the priority within the RE sector to develop an MRV system. Further, reverse auction policy (a type of competitive bidding), which is one of the three types of policies that can be applied under ICAT RE methodology, was selected as the RE policy to be assessed.

As per the ex-ante GHG impact assessment, implementation of grid connected solar power generation under the reverse auction policy can lead to an annual emission reduction between 529,490 tCO_2e and 582,866 tCO_2e by 2030.

This report includes the list of parameters required to be measured, reported and verified, and existing barriers and gaps in current reporting mechanism. Most of the data are gathered as part of regular data collection efforts by the institutions involved in the current reporting system. This report also proposes an institutional arrangement for implementing the MRV system, including roles and responsibilities of the relevant institutions as well as a data management system to collect relevant data.

The proposed data management system, which was developed based on information gathered from existing institutions, includes details on what, when and how data are to be collected, and also who the reporting agencies are. The institutional arrangement includes working group at ministry level to compile, process and verify the data gathered from different entities. Three teams have been proposed to establish within the existing working group for data collection, QA/QC, and technical work like calculations and report generation. The QA/QC team will be responsible for ensuring the quality of the collected data and the proposed MRV expert team will verify the calculations conducted by the working group. Developing overall guidance and providing approval for the reports will be a responsibility of the proposed MRV coordination unit at the General Secretariat of the National Council for Sustainable Development (GSSD). Approved reports will be submitted to the UNFCCC through the Ministry of Environment (MoE).

This report also provides recommendations for the successful implementation of the MRV system. Main recommendations are: revising regulatory framework; improving human capacity; conducting awareness building events; getting high level support; and improving institutional coordination.

Summary of Chapters

Chapter 1

Arrangements for national reporting have evolved throughout the history of the UNFCCC and the Kyoto Protocol, into a comprehensive Measurement, Reporting and Verification (MRV) framework. At the twenty-first session of the COP to the UNFCCC, the Paris Agreement was adopted and it entered into force on 4th November 2016. Article 13 of the Paris Agreement established an Enhanced Transparency Framework (ETF) for action and support in order to build mutual trust and confidence among the Parties and to promote the effective implementation of the Paris Agreement. Key elements of the ETF include National Communications (NCs), Biennial Update Reports (BURs), Biennial Transparency Reports (BTRs) and Nationally Determined Contributions (NDCs). Out of the above, Cambodia has experience on NCs and NDCs as it has already submitted initial and second national communications, and first set of NDCs. At present, the country is preparing the third national communication, first BUR and the second version of NDCs. This assessment will support the country in the preparation of the BTR as this study assesses the impact of the policies on GHG reduction. It also proposes capacity building to construct an MRV system for RE policies with an ultimate aim of helping the achievement of NDCs.

Limitations to the assessment were: unavailability of specific RE policies, a clear base year and specific source-wise emission reduction targets to the RE sector.

A Complete MRV system including an MRV framework, procedures, protocol and institutional arrangement was developed through consultations with relevant stakeholders.

Chapter 2

This chapter provides an overall picture of the energy sector in Cambodia.

Main source of electricity in Cambodia is hydro power, which covers more than 50% of the generation, followed by coal power. Apart from these sources, fuel oil and renewable energy also contribute to electricity generation. Further, some industries and licensees generate electricity domestically for their own use. Annual electricity demand of the country has increased from 7,175 GWh to 12,015 GWh from 2016 to 2019 respectively. Approximately 80% of the demand is met by electricity generation within the country while the balance is imported from Thailand, Vietnam and Lao. As per the first National Communication, GHG emissions attributed to the domestic energy generation is 385 GgCO_2e. Further, the country expects to reduce the GHG emissions of energy industry by 16% (3,100 GgCO_2e) by the year 2030 as per the NDCs. Mitigation actions and policies will be implemented to achieve this target within the intended period. Chapter two lists relevant mitigation policies available in Cambodia. As the ICAT RE policy can only be applied to feed-in tariff, tax incentive and competitive bidding related policies; considering the data availability, requirement and future plans of the country, and through consultations with UNEP DTU Partnership and the local expert team; competitive bidding was selected as the RE policy to be studied. Grid connected solar power generation has already been prioritized to develop the MRV system in a study carried out by local experts as part of this ICAT project. Reverse auction has been used in two occasions for a National Solar Park project, and local experts consider it likely to be continued. Therefore, reverse auction policy implemented to promote grid connected solar power generation will be used as an example to apply the proposed MRV system.

Chapter 3

This chapter explored the application of ICAT Renewable Energy Methodology for the Cambodian competitive bidding policy (reverse auction policy) for grid connected solar power generation. The assessment boundary, potential GHG impacts, causal chain and calculation methods have been identified in the chapter. Furthermore, baseline calculations, and ex-ante and ex-post calculations have been included in the chapter based on data currently available in the country.

Baseline scenario was established based on the circumstances of power sector as at 2016 (the base year). The ex-ante baseline scenario emissions for the year 2030 worked out to be 6,776,214.2 tCO_2e.

The unhindered initial technical potential of grid connected solar power for ex-ante assessment came out as 822 MW, which was estimated based on the future technical potential of solar power generation until year 2022, and a 5 - 10% share of grid connected solar power generation in the electricity mix from 2023 until 2030. However, the technical potential was reduced due to the identified barriers, such as: design characteristics of the reverse auction policy, financial feasibility of the projects, and other barriers to implement projects. The technical potential of grid connected solar power projects ("the projects") was reduced from 822 MW to 658 MW after accounting for design characteristics of the reverse auction policy. It was lowered to 526 MW after considering the financial feasibility of the projects. After taking into account other barriers for the projects the potential was identified to be between to 447 MW (lower end) and 492 MW (upper end). Accordingly, the ex-ante emission reductions by 2030 were estimated to be between 529,490 tCO_2e (lower end) and 582,866 tCO_2e (upper end) under the reverse auction policy.

Ex-post emission reductions were calculated for the 10 MW solar power plant established under reverse auction policy in the year 2017. The calculated annual emission reductions by 2017 was 3,274 tCO_2e under the emission trajectory method and 3,330 tCO_2e under the grid emission factor method.

Chapter 4

Measured parameters need to be reported to respective institutions to identify the impact of the RE policy on GHG reduction. This section will discuss what, when and how data need to be collected and who the reporting agencies would be.

Parameters that need to be measured according to the methodology are listed. Data Management System was developed indicating who to measure, where to record, how to process data, whom to report and when the report is to be presented.

Data required to assess the impact of the RE policy need to be gathered from different entities. Therefore, it is important to have a working group to collect, process, report and verify data in a manner complying with international standards. Current study proposes to allocate these responsibilities to the existing working group at the ministry. These groups will consist of teams for the data collection, QA/QC and technical support. Roles and responsibilities of each team in compiling and processing the data are described. QA/QC process is described in detail by referring to the IPCC guidelines for National Greenhouse Gas Inventories. Results of the calculations and other requested data will be provided into the MRV coordination unit, which is proposed to be established at the GSSD. Roles and responsibilities of the unit include: providing guidance and training to stakeholders on accurate collection, recording, reporting and analysis of data; and calculating the GHG impact of policies or actions. Calculations will be provided to the MRV expert committee for the verification. Composition of the committees and their roles and responsibilities are also described in this chapter.

Finalized reports will be submitted to the MoE and NCSD through the GSSD. Approved report will be submitted to the UNFCCC by GSSD.

Chapter 5

This chapter compiles the verification activities required at different stages of the proposed process. It includes the verification of authenticity of data collected at each level, verification of the calculations by the MRV expert committee, etc.

Chapter 6

Recommendations for successful implementation of the MRV system are given under this chapter, which includes:

i) incorporating proposed institutional arrangement for successful implementation of the MRV system;
ii) revising regulatory framework to address the data gaps;
iii) ensuring proper institutional coordination, capacity and awareness building of the stakeholders;
iv) strengthening the human capacity of the proposed units; and
v) providing high level supports to the data providers are the main recommendations.

Summary of the proposed MRV framework

NDC	Mitigation action	Measurement		Reporting	Verification
		Methodology	Annual emission reduction tCO_2e (2030)		
educe 16% GHG emissions in 2030 from Energy Industries compared to the baseline emissions	Reverse auction policy to promote grid connected solar power generation	ICAT Renewable Energy Methodology	Ex-ante: 529,490[1] CO_2e (lower end) and 582,866 tCO_2e (upper end)	1. MME 2. EDC 3. EAC 4. IPPs 5. MoP	1. Data Verification – existing working group at the MME 2. Calculation - MRV expert committee

[1] According to the NDC, expected GHG emission reductions of energy industry is 1,800 $GgCO_2e$ in the year 2030. The highest annual emission reductions attributed to reverse auction policy was estimated as 582, 866 tCO_2e. Therefore, share of GHG emission reductions attributed to reverse auction policy compared to total total expected GHG emission reduction is around 32.4% in upper case while it will be around 32.4% in the lower case.

1 Introduction

Reporting obligations

The objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to combat climate change by achieving stabilization of greenhouse gas concentrations in the atmosphere at a safe level through various agreements and legal instruments that the Parties may adopt. Reporting requirements to achieve the objective of the UNFCCC include national communications and biennial update reports (BURs) for developing countries with additional flexibility given to LDCs. The Parties are required to submit reliable, transparent and comprehensive information on GHG emissions, climate action and support. The arrangements for national reporting for the UNFCCC and its Kyoto Protocol have evolved into a comprehensive measurement, reporting and verification (MRV) framework. Measures to significantly enhance transparency of action and support under the convention were adopted as part of the Bali Action Plan at COP 13 and elaborated in decisions adopted at subsequent Conferences of the Parties (COPs). At the twenty-first session of the COP to the UNFCCC, the Paris Climate Agreement was adopted, and it entered into force on 4th November, 2016. Main aim of the Paris Agreement is to strengthen the global response to the threat of climate change by keeping a global temperature rise well below 2° Celsius above pre-industrial levels, and to pursue efforts to limit the temperature increase even further, 1.5° Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change (UNFCCC, 2020c).

Article 13 of the Paris Agreement established an Enhanced Transparency Framework (ETF) for action and support in order to build mutual trust and confidence among the Parties and to promote the effective implementation of the Paris Agreement. The ETF is designed with built-in flexibility, which takes into account Parties' different capacities and builds upon the collective experience of transparency under the Convention. Its implementation is pursued in a facilitative, non-intrusive, non-punitive manner that is respectful of national sovereignty and is designed to avoid placing an undue burden on the Parties. The purpose of the ETF for transparency of action is to:

- Provide a clear understanding of climate change actions in light of the objective to limit global warming to well below 2°C and to pursue efforts to limit warming to 1.5°C; and

• Provide clarity and track progress towards achieving Parties' NDCs (Article 4) and Parties' adaptation actions (Article 7) in order to inform the Global Stock Take (GST) (Article 14). (Maso, Canu, & Antonio, 2019).

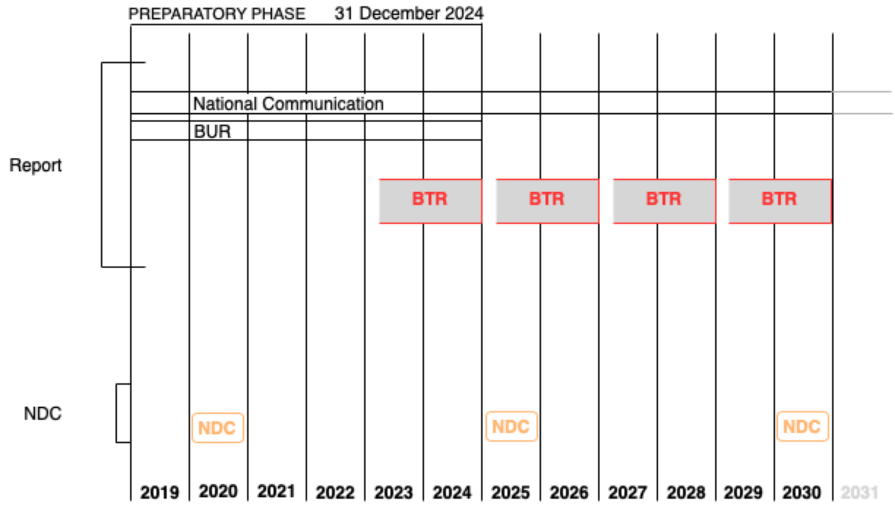

Figure 1.1 Key elements of Enhanced Transparency Framework

Source: DTU, 2019

As illustrated in Figure 1.1, the countries that are Parties to the Paris Agreement should submit its first Biennial Transparency Report (BTR) at the latest by 31st December 2024. At the same time, the countries that are Parties to both the Convention and the Paris Agreement, should also submit the last Biennial Update Report (BUR), which is the reporting element under the Convention, at the latest by 31st December 2024. In this way, for the Parties to the Paris Agreement, the BTR will supersede the BUR at the latest by end of 2024. Furthermore, the countries should submit their revised Nationally Determined Contributions (NDCs) by 2020 (Maso et al., 2019).

Country Experience

Kingdom of Cambodia is a party to the Paris Agreement as well as to the UNFCCC (United Nations Treaty Collection, 2020). Therefore, aligning with the requirements of the UNFCCC, the country has submitted two National Communications (NCs) in 2002 and 2016 respectively (UNFCCC, 2020b). Intended Nationally Determined Contribution (INDC) were submitted in 2015 (Kingdom of Cambodia, 2015) while Nationally Determined Contributions (NDCs) were submitted in 2017 (Kingdom of Cambodia, 2017). Cambodia has not submitted its first BUR yet (UNFCCC, 2020a). However, country is in the process of developing the Third National Communication (TNC) and the first BUR.

National Communications

Results of the Initial National Communication (INC) indicate that in 1994, Cambodia emitted 59,708 $GgCO_2e$ and removed 64,850 $GgCO_2e$ from the atmosphere. Therefore, Cambodia was a net carbon sink country in 1994 with a net total carbon removal of 5,142 $GgCO_2e$. The main source of carbon dioxide emission was the Land-Use Change and Forestry (LUCF) sector (97%), followed by the energy sector (3%) (MoE, 2002).

Second National Communication (SNC) of the country indicates the GHG emissions at 47,709 $GgCO_2e$ in 2000, and removal at 48,166 $GgCO_2e$. The net removal was thus estimated at 457 $GgCO_2e$. Hence, Cambodia remained a net sink in the year 2000 as well. LUCF was the main emission source of the country (49%) followed by agriculture (44%) and energy (6%) sectors (Ministry of Environment, 2015).

Nationally Determined Contributions

Cambodia has communicated its goal for climate change mitigation (and adaptation) via NDCs to UNFCCC in 2017 (Kingdom of Cambodia, 2017). As per its NDCs, the focus will be on two main sectors for climate change mitigation - energy and forestry, with the following targets:

I. Cambodia expects to reduce 3,100 $GgCO_2e$ from the energy sector emissions compared to baseline emissions of 11,600 $GgCO_2e$ by 2030 (GSSD, 2015)[2].

II. Cambodia intends to undertake voluntary and conditional action to achieve the target of increasing forest cover to 60% of the national land area by 2030.

As per the energy sector NDCs, Cambodia has highest ambitions for GHG emission reductions (ERs) from the energy industries, having an emission reduction target of 16% by the year 2030. Manufacturing industries and transport have targets of 7% and 3% respectively (Kingdom of Cambodia, 2017). Summary of the NDCs is given in the Annex I.

Biennial Transparency Report

First Biennial Transparency reports are to be submitted in the year 2024. Proposed MRV system on RE policies in Cambodia will help the RGC to report the required data on mitigation policies and measures for the BTR.

[2] Baseline emissions for energy sector have been projected using LEAP model with default emission factors as per second national communication of Cambodia (https://unfccc.int/resource/docs/natc/khmnc2.pdf).

Annex II provides the list of information needed to be provided in the BTR.

Measurement, Reporting and Verification Framework

Showcasing the transparency of the implemented mitigation activities and following the international reporting requirements, Cambodia has designed and implemented few national level MRV frameworks (IGES, 2019).

- MRV system for REDD program (MoE, 2017)
- NAMA on Energy Efficiency in the Garment Industry (UNDP, 2015)

In addition to above mentioned activities, current study is developing an MRV system for renewable energy policy in Cambodia with the support from ICAT and UNEP DTU Partnership (UDP).

What is an MRV?

According to the Bali Action Plan, which defined MRV in the context of climate change, mitigation actions - mainly GHG emission reductions, shall be implemented in a measurable, reportable and verifiable manner. Measurement, Reporting and Verification (MRV) are key elements for:

a) Ensuring greater transparency, accuracy and comparability of information with regard to climate change in order to identify good practices, foster a learning process, and allow international benchmarking;
b) Recognition and visibility of mitigation achievements to raise ambitions of countries;
c) Attribution of quantified impacts to policies;
d) Accounting national and international progress;
e) Identifying gaps and international support needed; and
f) Creating access to international public and private finance

"MRV" includes three independent, but related, processes of measurement or monitoring (M), reporting (R), and verification (V) (Ninomiya, 2012). MRV of mitigation includes the following steps (Dagnet & Waskow, 2015):

Measure or monitor (M) data and information on emissions, mitigation actions, and support. This may entail direct physical measurement of GHG emissions, estimating emissions or emission reductions utilizing activity data and emission factors, calculating changes relevant to sustainable development, and collecting information about support for climate change mitigation.

Report (R) by compiling this information and including in GHG inventories and other standardized formats to make it accessible to a range of users and facilitate public disclosure of information.

Verify (V) by periodically subjecting the reported information to some form of review or analysis or independent assessment to establish completeness and reliability. Verification helps to ensure accuracy and conformance with any established procedure, and can provide meaningful feedback for future improvement.

Types of MRVs

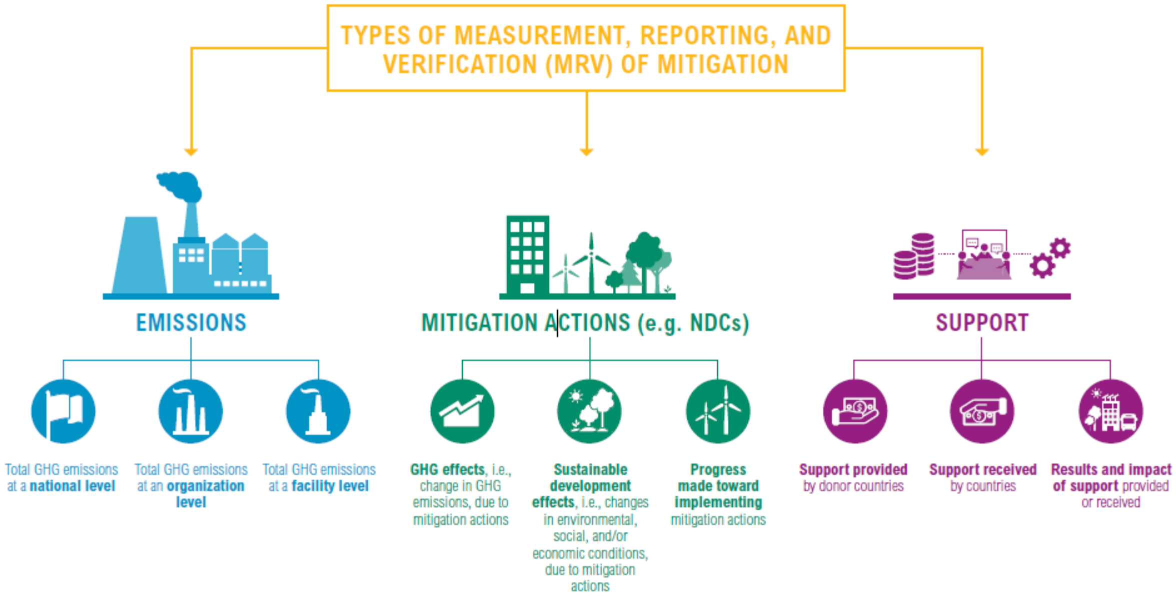

Figure 1.2 Types of Measurement, Reporting and Verification of Mitigation

Source: MRV 101: Understanding measurement, reporting, and verification of climate change mitigation by WRI, 2016

MRV of GHG emissions

This refers to measuring, reporting, and verifying actual emissions over a defined period of time. This type of MRV can be performed at national level, or by organizations and facilities. For example, national GHG inventories include an account of emissions from a country for a particular period, are reported to UNFCCC, and undergo some form of review (Singh, Finnegan, & Levin, 2016).

MRV of mitigation actions

This involves assessing (ex-ante or ex-post) GHG emission reductions and/or sustainable development (non-GHG) effects of policies, projects, and actions, as well as monitoring their implementation progress. It also involves assessing progress towards achieving mitigation goals. An example would be a national government estimating the GHG and job growth-related impacts of its home insulation subsidy program. While MRV of GHG emissions measures actual emissions, MRV of mitigation actions estimates the change in emissions and other non-GHG variables that results from those actions (Singh et al., 2016).

MRV of support

Focuses on monitoring the provision and receipt of financial flows, technical knowledge, and capacity building, and evaluating the results and impact of support. An example of this kind of MRV would be, developing countries tracking climate-specific finance received through bilateral or multi-lateral channels (Singh et al., 2016).

1.1 Overall Objectives and Outcomes of the Assignment

The main objective of this assignment is to build capacity to design an MRV system for a selected policy / action in Cambodia that helps meet the NDC commitments. It is coordinated by the General Secretariat of the National Council for Sustainable Development. The assignment only recognizes the impact of an individual policy according to the main objective of the assessment. Therefore, an individual assessment was undertaken for the selected policy.

The main objectives of this assignment are to:

- Task 1: Review of the Guidance Material and Methodologies Developed Under the ICAT Pillar 1 Relevant to a Selected Policy
- Task 2: Design of the MRV System, Establishment of Roles and Responsibilities
- Task 3: Conduct Workshops and design an Implementation Plan.

  Task 1 was completed and a report has been submitted. Task two includes four main components which are MRV framework, Procedures, Protocol and the Implementation plan.

1.2 Objective and outcomes of this deliverable

Scope of this report is to produce an MRV framework, which will demonstrate: a) the measurement of GHG impacts of implementing reverse auction policy to promote grid connected solar power generation (M); b) the establishment of institutional arrangement including the roles and responsibilities, designing templates and data management system to report and verify GHG impacts, GHG related activity data, emission factors, and other information needed to estimate GHG impacts (RV). It also includes development of an implementation plan. This framework can be applied for other similar RE policies to assess GHG impacts after making necessary adjustments.

1.3 Limitations

1.3.1 **Selection of a Policy**

The ICAT Renewable Energy (RE) methodology can be used to evaluate the impact of a policy on the reduction of GHG emissions only for three kind of policies - namely, Feed-in tariff, Auction/Tender, and Tax incentives.

Cambodia has experienced a variety of RE policies, but currently Cambodia does not appear to have a specific target exclusively intended for renewable energy development. Therefore, RE auction policy, which has been adopted for the upcoming ADB supported 100 MW solar park, was selected after consulting the relevant stakeholders in order to estimate its impact on renewable energy development and GHG emissions. However, data on the policy is limited as it has been applied for only two solar PV projects (10 MW Solar PV project in 2017 and 100 MW Solar PV project in 2019) (ADB, 2019) on pilot basis.

1.3.2 **Selection of Base Year**

Selection of the base year is a vital factor in the design of an MRV system. Cambodia has developed the first set of NDCs based on the Second National Communication. However, the base year for the NDCs was not specifically mentioned there. Year 2016 appears to have been considered as the base year in Cambodian first Biennial Update Report (BUR). The same base year has been opted by the relevant national stakeholders. Based on these circumstances, 2016 was considered as the base year for this assessment. As Cambodia is in the process of revising its NDCs, it is also recommended as prudent that revised NDCs may refer the same base year.

1.3.3 **Targets for different Renewable Energy Technologies**

The energy industry has a target to reduce the GHG emissions by 1,800 tCO_2e (16%) by 2030 using Solar energy, hydropower, biomass and biogas compared to the baseline emissions in accordance with the NDCs. However, specific emission reduction targets are not set for different renewable energy technologies.

1.4 Methodology

In order to support achieving its emission reduction targets, the RGC expects to establish an internationally recognized MRV System to assess the effectiveness of their mitigation activities. Deliverable 1 of this assignment indicates selection of reverse auction for grid connected solar power as the policy[3], for which ICAT RE methodology will be used to quantify the GHG impacts and the development of an MRV framework for Cambodia. The rationale for selection of the policy is included in that report.

Ex-ante impact of the reverse auction policy on the GHG emissions of the energy sector was assessed using the ICAT RE methodology with data gathered by national experts, from the national institutions and other agencies. Parameters needed for applying the methodology and monitoring when an MRV system is implemented, were identified.

Institutional arrangement including roles and responsibilities were developed to measure, report and verify the GHG impacts, activity data, emission factors and other relevant information. Further, a database structure was developed to store relevant data needed to estimate the GHG impacts of RE policy. The data management system (DMS) required for implementing the MRV system was designed based on the identified parameters and the existing DMS. The proposed institutional arrangement including the roles and responsibilities, and data management system was discussed and agreed with the relevant stakeholders. Further, MRV Protocol, which includes all the instructions and templates to implement the proposed MRV system, will be developed as part of the next deliverable. Finally, MRV procedures will be developed for each institution involved in the proposed data management system to collect relevant activity data in relevant data collection templates.

[3] Cambodia confirmed that the use of reverse auctioning policy to establish an MRV system for RE sector is appropriate as part of the first deliverable of this assignment. Further information is available in the report.

Data Collection and Processing for the Assessment under the Methodology:

ICAT RE Methodology recommends to use country-specific data from the sources such as national institutions related to energy industry (e.g. Ministry of Mines and Energy) and international agencies (e.g. International Energy Agency or the International Renewable Energy Agency).

Most of the data and information for this assessment were collected from the national institutions. ClimateSI, the international consultant for the assignment, was supported by the national team in Cambodia to collect the relevant data. Furthermore, the national team provided their expertise wherever it was needed. The following procedure was followed for data collection.

1. List of questionnaires were prepared by ClimateSI requesting necessary data and information.
2. Questionnaires were sent to the team of national experts.
3. National team approached the national institutions such as MME, EAC and EDC directly, to collect the requested data and information.
4. Collected information and data were aggregated and verified by the national team and sent to ClimateSI.
5. ClimateSI reviewed the received data and prepared a list of data that need to be clarified before applying into the assessment. Then the list was sent to the national team for further clarification.
6. Clarifications were received by ClimateSI from the national team of experts.

When the country-specific data were not available for requested parameters, estimates were made following the methodology with the input from experts. Expert judgments and assumptions are acceptable in the ICAT RE Methodology for the assessment. Therefore, ClimateSI used their own expert judgment too for selecting suitable values or a range of values for the assessment after inspecting and analyzing the data received a from the national experts. However, expert judgments can be associated with high level of uncertainty. Therefore, constructed judgments were validated through broader consultations with stakeholders.

2 Electricity sector

2.1 Electricity Demand and Generation

Cambodian domestic electricity generation, like in most of the developing countries, has increased gradually over years. Though a major part of the electricity demand is met by domestic electricity generation, Cambodia also imports electricity from neighboring countries. Increase of the electricity demand during the period 2016-2019 is shown in Figure 2-1.

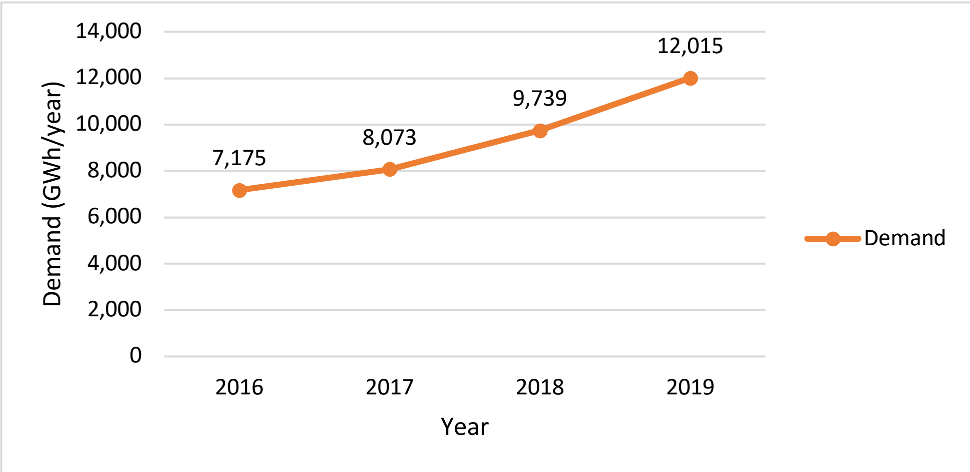

Figure 2-1 Energy demand of Cambodia

Source; EAC, 2091

As illustrated in Figure 2-1, electricity demand has increased almost by 67% in 2019 compared to the base year 2016. The growth of total domestic generation during the same period is shown in Table 2-1

Table 2-1 Domestic Electricity Generation by source

Power Sources	2016 (GWh/year)	2017 (GWh/year)	2018 (GWh/year)	2019[4] (GWh/year)
Coal	2,394	3,569	3,211	3,390
Hydro	2,568	2,711	4,511	4,626
Fuel Oil	478.3	259	180	425
Renewable Energy	42.4	56	42	73
Generation by Industries & Licensees		38	9	8
Total Domestic Generation	5,483	6,634	7,954	8,522

* Source: EAC, 2019; Estimated for 2019

[4] Figures for 2019 were estimated based on the trends of domestic generation from 2016-2018.

As shown in Table 2-1, domestic electricity generation has increased gradually compared to the base year. From Table 2-1, it can be seen that between 41% to 57 % of the electricity demand was generated by hydro power. Further, domestic electricity generation fulfilled between 77% to 85% of the electricity demand and the rest was imported from neighboring countries namely Thailand, Vietnam and Lao (EAC, 2019).

2.2 GHG Emissions in electricity sector

GHG emissions in Cambodian electricity sector (energy industry) were 385 GgCO_2e in year 2000, which is around 14% of energy sector emissions in that year (2,767 GgCO_2e) as per the SNC (Ministry of Environment, 2015).

GHG emissions attributed to electricity sector are to be reduced by 1,800 GgCO_2e by the year 2030. This accounts for 16% of GHG emission reductions compared to the baseline GHG emission (11,600 GgCO_2e) (Kingdom of Cambodia, 2017).

The corresponding NDC of Cambodia indicated that this target will be achieved by:

- National grid connected renewable energy generation (Solar energy, hydropower, biomass and biogas), and connecting decentralized renewable generation to the grid;
- Off-grid electricity such as solar home systems, hydro (pico, mini and micro); and
- Promoting energy efficiency by end users.

2.3 Renewable Energy Policies

Number of renewable energy policies were drafted and implemented during the past few years to promote the low emission initiatives within the country. A detailed analysis of the national policies and strategies has been conducted under another ICAT supported project - National low emission policies and GHG MRV system (MME & GSSD, 2019). A summary of that assessment is given in Annex III.

ICAT Renewable Energy Methodology (ICAT, 2019) can be applied to quantify the GHG impact of three types of renewable energy (RE) policies: 1) Feed–in tariff (including feed-in premiums); 2) Auction policies (including tender policies); and 3) Tax incentives.

Table 2-2 summarizes the RE policies in Cambodia, which have a bearing on the development of renewable energy resources and are compatible with ICAT RE Methodology.

Table 2-2 Summary of RE policies in Cambodia that are compatible with ICAT RE methodology

Policy	Source	Year	Action
Feed-in tariff policy	The Environment And Natural Resources Code Of Cambodia (Draft)	2017	One-year pilot for a feed-in-tariff system, in which the government offers a fixed rate for solar energy fed into the grid
Tax incentive	The Environment And Natural Resources Code Of Cambodia (Draft)	2017	Businesses, which use sustainable energy sources, shall be eligible for a 10% reduction to the income tax rate for 5 years since they start reporting profits.
	The master plan study on rural electrification by renewable energy in the kingdom of Cambodia	2006 & 2009-2020	Tax exemption on the import of RE equipment (15% of custom tax and 10% of VAT). Value of this tax exemption has been estimated to be $13 million from 2009 to 2020.
Competitive Bidding (Reverse Auction policy)	Asian Development Bank, National Solar Park Project	2019	Reverse auction has been used by EDC for the first phase of 60 MW and received the lowest bid for solar power (First phase of 100 MW National Solar Park).

Source: GSSD, 2020

Cambodian national team, after considering the authenticity of the source material of the policy, determinants of the policy and progressiveness or recentness of the policy, selected "Reverse Auctioning Policy" (a type of competitive bidding) for the solar power development as the most appropriate RE policy for development of MRV framework under this ICAT project. Even though, the MRV framework has been designed based on the reverse auction policy, it can be adopted to any kind of competitive bidding policy and modified to use for any feed-in tariff or tax incentive.

2.3.1 Competitive Bidding – Reverse Auction policy

Reverse auction policy for solar power generation has been selected as the RE policy to develop an MRV system after the process of desk review and discussions with national experts.

A reverse auction policy is a type of auction where sellers who meet minimum eligibility criteria submit non-negotiable price bids and the buyer selects winning sellers based on the lowest price. The starting price and bid decrement can be announced before start of reverse auction. The objective of the reverse auction is to obtain the maximum benefit in cost saving through competitive bidding.

At the moment in Cambodia, reverse auction policy has been enforced on pilot basis for 10 MW Solar PV project in 2017 and phase one (60 MW) of solar project in 2019 (ADB, 2019). As EDC has received the lowest tariff through this process, it can be reasonably expected to be continued. As the project is financed by ADB, their guidelines on monitoring and reporting the progress of the project would be followed. Therefore, collection of data required for the MRV system will be convenient. The power purchase agreement has a validity period of 25 years. Therefore, electricity generation and other relevant data would be collected and stored for calculating payments. That data and any additional information could be used for the MRV system as well.

The reverse auction policy has a high potential to continue as it allows to receive the lowest possible tariff through a competitive process for solar power production with a guaranteed long-term contract.

Information available on the reverse auction policy is indicated in Table 2.3.

Table 2-3 Detailed information relevant to reverse auction policy

Information	Remarks
Title of the policy or action	Reverse auction policy for solar power projects (between 2017 – 2030) based on the 10MW pilot and the100 MW National Solar Power Park.
Type of the policy or action	Reverse auction
Description of specific interventions	The specific intervention is the application of reverse auction policy to select an independent power producer for the 10MW pilot project and the 60 MW Solar Park, which is the phase 1 of the ADB National Solar Park Project of 100MW capacity. Phase one of 60 MW has been bid

	out to independent power producers with support of ADB's Office of Public–Private Partnership working as a transaction advisor to assist EDC to design and conduct an open and competitive bidding process. In the project arrangement, EDC provided the land and transmission access, while the private sector provides power generation capacity based on a long-term power purchase agreement with EDC.
Status of policy	Pilot (new policy)
Date of implementation	13th Feb – 17th May, 2019 (1st phase) Pilot 10 MW project was commissioned in October, 2017
Date of completion of auction period (if relevant)	29th Aug 2019 (for phase 1 of solar farm) However, future potential capacity from 2020 to 2030 is also considered for the evaluation of the impacts of the policy.
Implementing entity/ies	Electricite du Cambodge (EdC)
Objectives and intended impacts or benefits of the policy	The pilot project is intended to support the construction of solar photovoltaic (PV) power plants in Cambodia, and addresses the country's need to: (i) expand low-cost power generation, (ii) diversify the power generation mix; (iii) increase the percentage of clean energy in its generation mix in line with its stated GHG reductions targets; and (iv) expand the use of competitive tenders and other global best practices in the sector. With the reverse auction, it is expected to enhance transparency and attract more solar investors to the country.
Level of the policy	This policy is piloted for utility solar scale for 70 MW capacity at present. It may be applied for the phase II (40MW) and other future projects as well.
Geographic coverage	Kampong Chhnang province
Sectors targeted	Energy industry – utility solar
Greenhouse gases targeted	CO_2
Other related policies/ actions	-
Intended level of GHG mitigation to be achieved and/or other target level of other indicators	Not available

Title of establishing legislation, regulations, or other founding documents	ADB's Office of Public-Private Partnership (OPPP) has supported EDC to design and conduct a competitive tender for procurement of a pilot utility solar. No legislation or regulation is established so far as it is still in the pilot phase.
Monitoring, reporting and verification procedures	Performance of solar electricity is usually monitored by the plant owner and sent to EDC for their records and payments. Currently, the plant is under construction.
Enforcement mechanisms	Not available
Reference to relevant documents	https://www.adb.org/projects/51182-001/main#project-pds
The broader context/significance of the policy	Competitive bidding process provides a convincing argument to EDC in promoting transparent auction exercises which will attract private investors to invest more in the RE sector of the country.
Outline of sustainable development impacts of the policy or action	Application of reverse auction policy to promote solar parks can also support the achievement of Sustainable Development Goals (SDGs) in Cambodia as this intervention can lead to: increase renewable energy share in the generation mix (SDG7); generate quality job opportunities (SDG8); and to reduce GHGs (SDG13). Further, promoting clean energy is in line with the country's national strategic development plan (NSDP) too.
Key stakeholders	MME, EAC, ADB, private developers,
Other relevant information	Cambodia's NDCs intend to reduce 16% of GHG emissions from energy industry by 2030. It encourages more adoption of grid-connected renewable energy generation through solar energy and other renewable sources. The reverse auction policy clearly and effectively demonstrates its impact by achieving the lower electricity tariff through a competitive bidding process. Further, the reverse auction policy spends minimal amount of government budget compared to other incentive-based instruments such as subsidies or feed-in tariff.

Source: Expert team of Cambodia

3 Measurement

3.1 Scope of the applicability

Specific intervention: The specific intervention is to introduce reverse auctioning policy ("the policy") to promote grid connected solar power generation in Cambodia. The policy has been adopted by the EDC in in 2017 for the 10MW pilot project and in 2019 for the phase one (60 MW grid connected solar power project) of the ADB assisted National Solar Park Project of 100 MW. This project is also listed under the Power Development Plan (2020 – 2030) of the Ministry of Mines and Energy, Cambodia.

By introducing the reverse auction policy to the solar energy projects, it is expected to: expand low-cost power generation, diversify the power generation mix; increase the share of clean energy in its generation mix in line with its stated greenhouse gas emission reduction targets; and expand the use of competitive tenders and other global best practices in the sector.

Therefore, this specific intervention will reduce the GHG emissions from new fossil fuel power plants that would have been built in the absence of the intervention. Also, this will support to achieve the NDC target set by the country to reduce the GHG emissions by 16% through promoting renewable energy generation. In addition, the specific intervention will support to reduce the cost of electricity in Cambodia and increase the private sector investment in grid connected solar power generation.

Applicability of the ICAT RE Methodology: ICAT RE methodology is applicable to the selected policy (an auction policy), as it is one of the three policies (Feed-in tariff policies including feed-in premiums, auction policies including tender policies, and tax incentive policies) to which the ICAT RE methodology can be applied at the national level during the implementation of the policy. ICAT RE methodology can be applied at planning as well as implementation stages. Therefore, ICAT RE methodology is applicable to the policy.

3.2 Causal Chain for reverse auctioning policy

Figure 3.1: Causal chain for the Reverse Auction policy

Source: GSSD, 2020

, which was sourced from first deliverable under the assignment to develop an MRV system for RE sector in Cambodia (GSSD, 2020), provides a conceptual diagram tracing the process by which the policy leads to GHG impacts through a series of interlinked and sequential stages of cause-and-effect relationships. Figure 3-1 illustrates the intermediate effects (grey color boxes) and GHG impacts of the policy (green box).

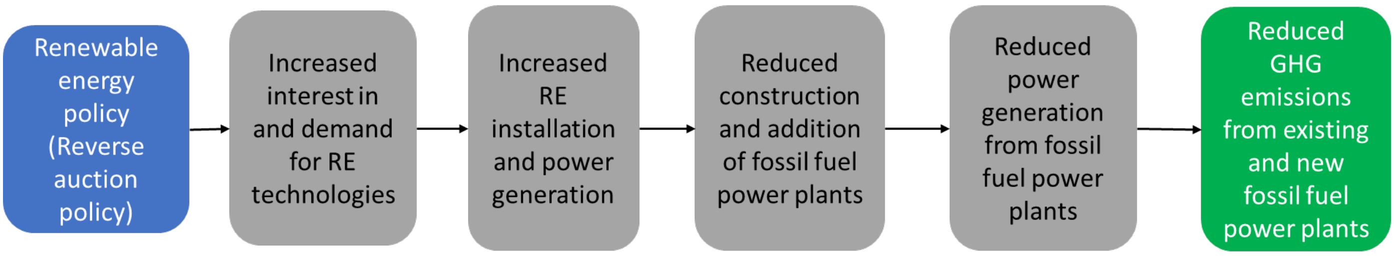

Figure 3.1: Causal chain for the Reverse Auction policy

Source: GSSD, 2020

Increased interest and demand: The reverse auction (competitive bidding) provides better transparency and competitiveness which would attract more private sector investment. Furthermore, land, access to the transmission and long-term power purchase agreement supplied by EDC provides assurance to developers on the long-term stability of their projects. This increases the interest for solar energy technologies in the country.

On the other hand, competitive bidding would result in a lower tariff to the end consumer and increase the demand for the electricity generated from solar power plants.

Increased RE installation: Increased interest and demand for solar power generation can lead to increase the installation of RE in the national grid.

Reduced fossil fuel power installation and generation: As more investors turn to green energy, the demand for fossil fuel generated electricity would decrease. Therefore, the reverse auction policy will encourage GHG emission reductions from existing and new fossil fuel power plants in Cambodia.

Reduced GHG emissions: As the installation of new grid connected solar power plants are likely to reduce/replace the installation/operation of fossil fuel power plants, it will lead to reduce GHG emissions which would have occurred due to the burning of fossil fuel in the absence of grid connected solar PV installations.

3.3 Define the GHG assessment boundary, type of GHG impacts and the assessment period

Assessment boundary

The GHG assessment boundary defines the scope of the assessment in terms of the range of GHG impacts. As per ICAT RE methodology, only one GHG impact (reduced GHG emissions from existing and new fossil fuel power plants) is likely to be significant for most RE policies. This is due to the fact that for most RE policies it is the only GHG impact that is categorized as both very likely and of a major magnitude. As such, reduced GHG emissions from existing and new fossil fuel power plants is included in the assessment boundary for the reverse auction policy for grid connected Solar power generation as shown in Table 3-1. However, Table 3-1 also provides GHG impacts of reverse auction policy excluded from the assessment boundary as well.

Identification of type of GHG impacts and source categories

Table 3-1 describes the potential GHG impacts of the policy and associated GHG source categories.

Table 3-1 Types of GHG impacts

Type of GHG impact	Description	Example of GHG impact
Positive impact vs. negative impact	Impacts that cause decrease or increase in GHG emissions	*Positive*: Reduced GHG emissions from new fossil fuel power plants *RE equipment are imported from other countries. Hence, there is no considerable negative impact*

Intended impact vs. unintended impact	Impacts that are both intentional and unintentional based on the original objectives of the policy	*Intended:* Reduced GHG emissions from new fossil fuel power plants *Assessment boundary is within the geopolitical or national boundary. RE equipment is imported from other countries which are outside the assessment boundary. Hence, unintended impacts will not be considered.*
In-jurisdiction impact vs. out-of-jurisdiction impact	In-jurisdiction impacts are those that occur inside the geographic area over which the implementing entity has authority, such as a city boundary or national boundary. Out-of-jurisdiction impacts occur outside of the geopolitical boundary	*In-jurisdiction*: Reduced GHG emissions from electricity generation using RE *As explained before, assessment boundary is within the national boundary. Hence, only in-jurisdiction impacts are considered.*
Short-term impact vs. long-term impact	Impacts that are both nearer and more distant in time, based on the amount of time between implementation of the policy and the impact	*Short-term*: Reduced GHG emissions from fossil fuel power plants that would have been built *Long-term*: Reduced emissions from energy use due to increased share of the RE *Both impacts are applicable for the assessment.*

Source: Author's work based on ICAT RE methodology

Introducing competitive bidding (reverse auction) policy to select solar power producers leads to only positive impacts (reduced GHG emissions from new fossil fuel power plants) in the country as the country imports its RE equipment from other countries outside the assessment boundary. Hence the intended impact due to the policy is GHG emissions reduction from new fossil fuel power plants as provided by the ICAT RE methodology. Implementation of the policy encourages both short term and long-term impacts for the country given the fact that the competitive bidding (reverse auction) will be used for the selection of power producers in the future for solar power projects until 2030.

Table 3-2 GHG source categories

Source category	Description	Emitting entity or equipment	Relevant GHGs

Grid-connected electricity generation	CO_2 emissions from electricity generation in fossil fuel fired power plants that are displaced due to the project activity	Fossil fuel fired power plants	CO_2
Water reservoirs of hydro power plants	CH_4 and CO_2 emissions from reservoirs	Decaying organic matter in reservoirs	CH_4, CO_2
Fugitive emissions of geothermal power plants	Fugitive emissions of CH_4 and CO_2 from non-condensable gases contained in geothermal steam	Steam from power plant	CH_4, CO_2
Emissions from fossil fuel combustion in renewable energy plants	CO2 emissions from combustion of fossil fuels for electricity generation in solar thermal power plants and geothermal power plants	Solar thermal and geothermal power plants	CO2

Source: Author's work based on ICAT RE methodology

Grid-connected electricity generation is the GHG source category associated with the GHG impacts of selected policy. The relevant GHG for the assessment is CO_2.

Cambodia does not generate electricity from geothermal power plants. Hence there is no fugitive emission from geothermal power plants associated with the GHG impact. Currently, policy focuses only on the power generation directly from solar PV without transforming into heat before electricity generation. Hence, GHG impact is not associated with the emissions from the fuel combustion in solar thermal power plants and geothermal power plants. Finally, the policy only focuses on the solar energy addition without expectation to replace or change the condition of the water reservoirs of hydro power plants.

Table 3-3 GHG impacts and source categories included/excluded in the GHG assessment boundary

GHG impact	GHG	Likelihood	Relative magnitude	Included?	Explanation
1.Reduced GHG emissions from new	CO_2	Very Likely	Major	Included	The main GHG impact of RE policies

fossil fuel power plants					
2.Reduced emissions from mining of fossil fuels	CH_4	Possible	Minor	Excluded	Considered insignificant for most RE policies, and is conservative to exclude
3.Increased emissions from the manufacturing of RE equipment	CO_2, CH_4, N_2O	Possible	Minor	Excluded	Considered insignificant for most RE policies and is offset by decreased emissions from construction of fossil fuel power plants
4.Reduced emissions from construction of fossil fuel power plants	CO_2, CH_4, N_2O	Possible	Minor	Excluded	Considered insignificant for most RE policies, and is offset by increased emissions from construction of RE power plants
5.Leakage emissions to other jurisdictions	CO_2, CH_4, N_2O	Possible	Minor	Excluded	Considered insignificant for most RE policies

Source: Author's work based on ICAT RE methodology

Note: GHG impacts 6-9, which are related to reduced emission due to lower energy use, fugitive emissions of CH_4 and CO_2 from geothermal power plants, emissions of CH_4 and CO_2 from water reservoirs of hydro power plants, and emissions associated with agriculture and land-use change in biomass power plants respectively, were not discussed under Table 3-3 as these technical areas will be not part of the reverse auctioning policy.

Ex-post assessment was conducted for the 10 MW solar power project, which was the country's first ever utility-scale solar project tendered by the government using reverse auction policy. This is the pilot project of National Solar Power Park Project in the country.

The initial technical potential for the project scenario was calculated under the sub topic "3.4.1Estimating capacity addition of grid connected solar power generation under the reverse auction policy ex-ante". Initial potential for the assessment is 822 MW according to the estimation described under the sub-topic.

Base year

In line with the upcoming BUR, 2016 has been selected as the base year for the study (GSSD, 2020).

Assessment period

The assessment period, which is defined as the time period over which GHG impacts resulting from the policy as per ICAT RE methodology, covers both ex-ante and ex-post for the reverse auctioning policy.

Ex-ante assessment period[5]

As per ICAT RE methodology, ex-ante assessment period, which is determined by the longest-term impact included in the GHG assessment boundary, can be "longer than the policy implementation period, and should be as long as possible to capture the full range of significant impacts based on when they are expected to occur".

Cambodia expects to achieve the emission reduction targets within the 2021-2030 period as per the NDCs submitted to the UNFCCC. As such, NDC target period (2021-2030), which seems to be the longest term for the reverse auctioning policy impact, can be considered as ex-ante assessment period.

Ex-post assessment period[6]

[5] The ex-ante technical potential has been estimated as 822 MW (from the year 2021 until the year2030), which was indicated as 210 MW earlier (from the year 2021 until the year 2030 in the deliverable 1). This change is based on the latest information received from the national experts.

[6] 10 MW has been taken as the ex-post capacity for solar power generation based on solar power project commissioned in 2017. The information was given by the national experts for this study.

As per ICAT RE methodology, ex-post assessment period can be "the period between the date the policy is implemented and the date of the assessment or it can be a shorter period between those two dates".

Reverse auctioning policy, a competitive bidding, was first introduced in 2016, for a 10 MW grid connected solar power project, which has been commissioned in 2017. Therefore, ex-post scenario was developed for the period 2017 to 2019.

3.4 Assessing ex-ante GHG impacts

3.4.1 Estimating capacity addition of grid connected solar power generation under the reverse auction policy ex-ante

Step 1: Estimate grid connected solar PV technical potential for the assessment period of the reverse auctioning policy

Technical potential is the amount of renewable energy output obtainable by full implementation of demonstrated technologies or practices as per ICAT RE methodology and IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation[7]. As per ICAT RE methodology, there can be three distinct policy cases, which can be applied to quantify the technical potential for the assessment period:

(i) policy with a capacity cap over the entire period of assessment;
(ii) policy without capacity cap over the period of assessment; and
(iii) policy with capacity cap over a partial period of assessment (Figure 7.2, page 42 of ICAT RE methodology).

As shown in Table 3-5, the Ministry of Mines and Energy (MME) intends to add 264.3 MW and 414.3 MW of grid connected solar PV in 2021 and 2022 respectively (sources: MME Revised PDP, 2015; MME, 2019). Though the MME has not defined the grid connected solar PV capacity addition from 2023 to 2030, they have indicated that solar could meet between 5-10% of predicted electricity demand in the base case, which is shown in Table 3-5. Thus, MME's grid connected solar capacity addition plan for 2021 and 2022 can be considered as a cap for grid connected solar for these years. MME has also indicated the possible share of grid connected solar PV power in the total electricity demand as 5-10% from 2023 to 2030. Upper limit of this grid connected solar power (10%) and corresponding solar capacity is similarly treated as a cap on grid connected solar capacity. Following the above policy case (i), corresponding solar capacity required to meet 10% of the total electricity demand planned by Cambodia is referred to as the “Technical Potential” of the policy, according to the ICAT RE Methodology. It was assumed that this solar power generation capacity will be installed using

[7] Available at: https://www.ipcc.ch/report/renewable-energy-sources-and-climate-change-mitigation/

the reverse auction policy. In summary, was assumed that the reverse auctioning policy is a policy with a capacity cap from 2021 to 2030 though it is not certain that EDC will continue to use the reverse auctioning policy. Therefore, case (i) approach was applied to quantify the technical potential of the grid connected solar PV potential from 2021 – 2030.

Expected grid connected solar PV capacity addition from 2023 to 2030 was estimated based on the following assumptions: i) 10% of electricity demand forecasted in base case in Table 3-4 will be met by grid connected solar PV[8]; and ii) expected plant load factor of solar power is 19% (which varies between 18% - 20% as per information received from MME). Then, following formulae were applied to calculate the estimated annual solar power capacity addition from 2023 onwards.

Equation 1: Calculating the annual capacity addition

$$CA_{sp} = S_{se} \times ED_{Forecasted} \div (AH \times PLF_{solar})$$

CA_{sp} = Annual capacity addition of grid connected solar PV in MW

S_{se} = Annual share of solar energy in electricity demand forecasted (%)

$ED_{forecasted}$ = Annual electricity demand forecasted in GWh

AH = Annual hours (8,760 hrs)

PLF_{solar} = Annual plant load factor of grid connected solar PV in % (19%)

Table 3-5 gives a summary of the estimated annual grid connected solar PV potential from 2023 to 2030 after applying Equation 1, and the cumulative grid connected solar PV capacity addition from 2021 to 2030.

Table 3-4: The electricity demand forecast from 2020 to 2030 (GWh/year)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
High case	8,566	9,406	10,328	11,340	12,452	13,673	14,951	16,349	17,878	19,550	21,378
Base case	7,881	8,589	9,360	10,200	11,115	12,113	13,135	14,244	15,446	16,749	18,162
Low case	7,261	7,837	8,458	9,129	9,853	10,634	11,428	12,281	13,197	14,182	15,240

Source: (MME, 2015)

[8] The proposed share of solar PV addition to the grid from 2023-2030 was based on a discussion with the national experts. As per information provided by them, solar PV share from 2023-2030 could be between 5-10% as per a study under preparation.

Table 3-5: Estimating capacity requirements from 2023 to 2030 for grid connected solar power

	Pre-2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Electricity Demand (ED) forecasted (GWh)					10,200	11,115	12,113	13,135	14,244	15,446	16,749	18,162
Solar Electricity Demand (SED) forecasted (GWh)					1,020	1,112	1,211	1,314	1,424	1,545	1,675	1,816
Estimated CAsp to generate SED forecasted (MW)					613	668	728	789	856	928	1,006	1,091
Current and under implementation CAsp	94.3[9]	174.3[10]	264.3[10]	414.3[10]	0	0	0	0	0	0	0	0
Cumulative CAsp	94.3	268.6	532.9	947.2	947.2	947.2	947.2	947.2	947.2	947.2	1,006	1,091

Source: Author's work based on available data

As per Table 3-5, the estimated capacity addition requirements for the grid connected solar PV to meet the planned solar power generation for the assessment period (2021 to 2030) is 822 MW. Note: Available capacity in 2020 (268.6 MW) was subtracted from the capacity required in 2030 (1,091 MW). Following the earlier discussions, it is assumed that the required capacity addition of 822 MW is planned to be achieved using the reverse auction policy and referred as "Technical Potential". This calculation was made in line with the RE methodology, to illustrate the impact of various factors on this technical potential. Therefore, capacity addition that can be realized from the above technical potential was determined by considering the policy design characteristics, financial feasibility and other barriers that have impacts on the establishment of solar power projects under the reverse auction policy.

9 (EAC, 2019)(Data and data source were provided by the national experts)

10 (MME, 2015)(Data and data source were provided by the national experts)

Step 2: Account for the design characteristics of reverse auctioning policy

There are several design characteristics common to auction policies (e.g.: the reverse auction policy) that influence their impact, such as the scope of eligibility, differentiation between technologies, payment structure, longevity of financial support, and complexity of regulatory and legal procedures as shown in Table 7.8 of ICAT RE methodology. Table 3-6 explains the design characteristics of the reverse auctioning policy and account for their effect on the expected addition to grid connected solar PV under the policy during the assessment period.

Table 3-6: Summary of the design characteristics of reverse auction policy's influence on technical potential of grid connected solar PV from 2021-2030

Design Characteristic	factors	Reverse auction policy for solar power project	Impact (%)	Adjustment (MW)	Adjusted Capacity Addition MW
Auction demand and auction design	Volume of competitive bidding, design conditions, and pre-analysis of the conditions	Planned grid connected solar PV capacity additions by EDC are 264.3 MW and 414.3 MW in 2021 and 2022 respectively. Assumed grid connected solar PV capacity additions by EDC are 1,091 MW. As per step 1, expected grid collected solar PV technical potential is 822 MW. Reverse auctioning policy is a technology - specific standalone auctions, and completeness of the documents will be checked during the pre-analysis. As per the information gathered, it seems that auction design and pre-analysis on the conditions may not affect the capacity additions of the grid connected solar PV.	0	0	822
Longevity of the power purchase agreement (PPA)		25 years. Since the PPA can be signed for 25 years, it is unlikely to have an impact in the solar PV potential.	0	0	822
Qualification requirements	Eligibility requirements to participate: qualifications; financial requirements; resources required	There can be some difficulties to demonstrate the similar experience and technical capabilities for some of the bidders; Some of the bidders may face financial barriers such as difficulties to: demonstrate tangible net worth of at last USD 10 million; raise financing equivalent to the debt component required for	10%	-82	740

Design Characteristic	factors	Reverse auction policy for solar power project	Impact (%)	Adjustment (MW)	Adjusted Capacity Addition MW
		a 5MW power plant; and produce Bid Security in an amount equal to USD 500,000. Availability of resources such as land can also be a barrier for some of the bidders. Considering all these aspects, qualification requirements appear to have an impact on the grid connected solar PV potential. In the absence of a quantitative method to estimate the impact share, the impact share indicated in Table 7.10 of ICAT RE methodology was applied.			
Winner selection process	Bidding procedures, requirements for minimal competition, winner selection criteria, clearing mechanism, and payment to the winner	Though the reverse auction policy has been designed with the support from the ADB and winner selection criteria appears to be transparent, there can be some barriers on the clearing mechanism and payment to the winner. However, this impact seems to be not significant compared to previous design characteristic. As such, the impact of this design characteristic was considered as half of the impact of previous characteristic.	5%	-41	699
Sellers' contractual liability requirements	Commitments to contract signing, contract schedule, remuneration profiles & financial risks, nature of liability, and settlement rules, delays, and institutional & regulatory framework	Though the MME will give long term PPA and tariff assurance, it is not clear what sort of damages will be covered by the MME. Land too belongs to EDC and the selected winner may need to negotiate with EDC. As such, impact has been considered as 5% given the fact that the impact level appears to be as same as the impact level of previous characteristic.	5%	- 41	658

Source: Author

Estimates given in Table 3-6 indicate that the technical potential of the policy reduces to 658 MW from 822 MW after assessing the design characteristics of the policy. Thereafter, the effect on the financial feasibility needs to be estimated.

Step 3: Account for effect on financial feasibility of grid connected solar power generation

Step 3.1-3.3: Compare Levelized cost of electricity (LCOE) and consider other costs

The reverse auction policy offers cost savings to governments, results in lower cycle times, and at the same time enhances transparency leading to boost in supplier participation.

Levelized cost of electricity (LCOE) to the EDC after de-risking for grid connected solar power generation is 8.7 cUS$ /kWh[11], which is higher than the wholesale market price[12] of electricity (ceiling price) set for grid connected solar power projects under the reverse auction policy in Cambodia (7.6 cUS$/kWh)[13] and the agreed electricity tariff for grid connected solar power under the reverse auction policy for 60 MW grid connected solar power project in 2020 (3.877 cUSD /kWh)[14].

When LCOE is higher than electricity tariff (paid to producer) provided by the policy, the technology is likely to diffuse only in niches where end user electricity price is more than the LCOE plus other costs (such as transmission and distribution costs). Since both the electricity price for the high voltage industrial consumers (at least 11.70 cUS$/kWh[15]) and low-voltage residential consumers (18.25 cUS$/kWh) are higher than the LCOE, grid connected solar power is likely to diffuse in these categories.

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[11] LCOE value 8.7 cUS$/kWh was provided by the national experts from "CAMBODIA: De-risking Renewable Energy Investment" (UNDP collaboration with NCSD, 2019) based on serval assumptions especially coal + hydro as baseline technologies.

[12] The wholesale market price is the price power producers receive for selling electricity to the grid.

[13] 7.6 cUS$/kWh value is provided by the National Experts.

Indicated source: VDB article "CAMBODIA ANNOUNCES TENDER FOR 100MW SOLAR PLANT" (http://www.vdb-loi.com/kh_publications/cambodia-announces-tender-for-100mw-solar-plant/)

[14] 3.877 cUSD/kWh value is confirmed by the national experts.

Source: ADB article "ADB-Supported Solar Project in Cambodia Achieves Lowest-Ever Tariff in ASEAN" released in 2019 (https://www.adb.org/news/adb-supported-solar-project-cambodia-achieves-lowest-ever-tariff-asean)

[15] 11.7 cUS$/kWh & 18.25 cUS$/kWh values are provided by the National Experts.

Source: (EAC, 2019)

Therefore, it can be concluded that the LCOE along with other costs may restrict the achievement of full technical potential of the grid connected solar power generation.

Step 3.4: Consider effects of other policies in the sector

Most RE technologies are rather new and not well understood in developing countries. There are concerns about the reliability of the equipment and a general hesitation to accept an unfamiliar technology. Enabling policies can play an encouraging role to promote RE technologies under this situation.

Cambodia has the following incentive policies:

1. Tax incentives on import duties - Import of equipment and spare parts are exempted from tax for one year. Tax exemptions granted on the imports of RE equipment are 15% of custom tax and 10% of VAT. (Value of tax exemption on imports of RE equipment was estimated to be $13 million from 2009 to 2020); and
2. Tax holidays established to encourage investors to invest in power sector - Tax holidays are granted to investors for 9 years, in compliance with Cambodia Investment Law.

Tax incentives on RE equipment reduce the financial burden of the developers. This increases the confidence of developers as the perceived risk is lowered. Tax incentives reduce the capital cost and therefore cost of power generation is reduced. This, combined with the tax holiday for 9 years improves the cash flow to attract more developers for RE.

Therefore, other policies in the sector have no adverse impact on the technical potential of solar power generation. Therefore, the attainable potential remains at 658MW.

Step 3.5: Consider effect of sectoral trends

Global LCOE for solar power generation continues to decrease as shown in

while global share of coal power generation continues to decrease as shown in **Error! Reference source not found.**. **Error! Reference source not found.** indicates that RE share needs to increase in order to meet IEA Sustainable Energy Scenario by 2030.

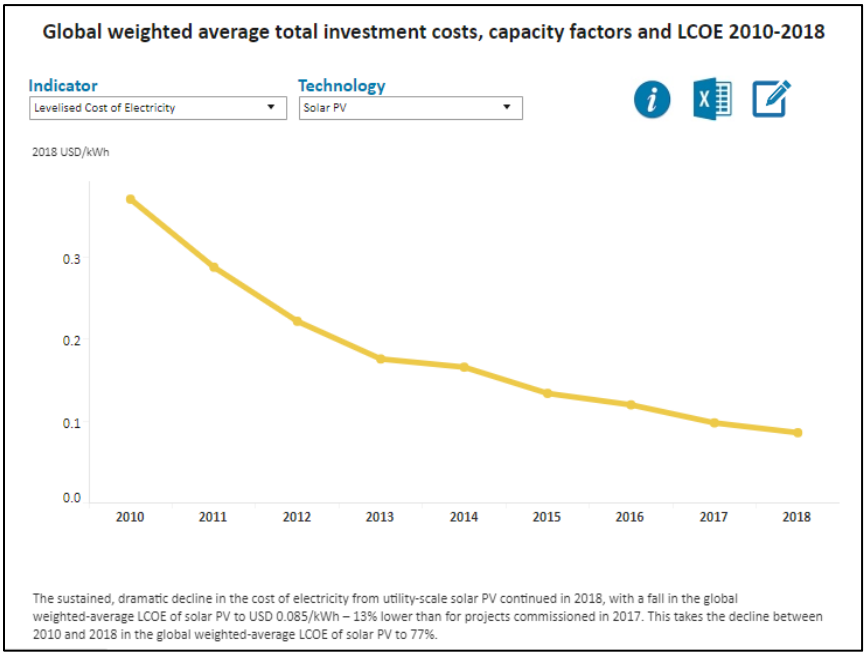


Figure 3.2: Global LCOE value fluctuation for solar PV 2010 – 2018
Source: (IRENA, 2019)

The cost of solar PV has dropped by almost 75% during the period 2010 -2019 as shown in Figure 3.2 above.

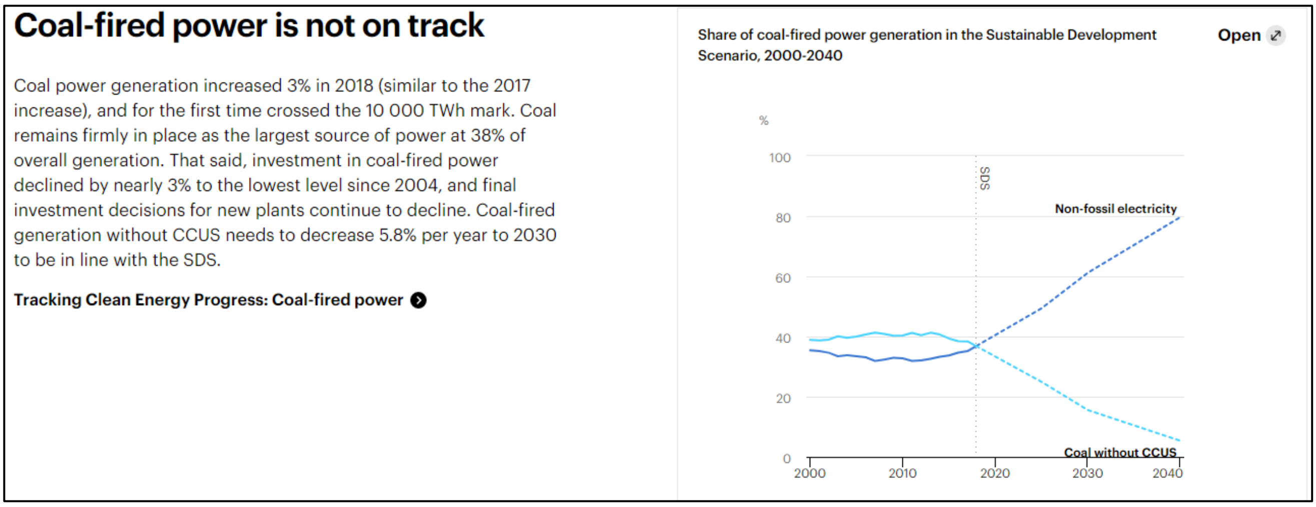


Figure 3.3:Global coal power generation in the Sustainable Development Scenario 2000 – 2040,
Source: (IEA, 2020a)

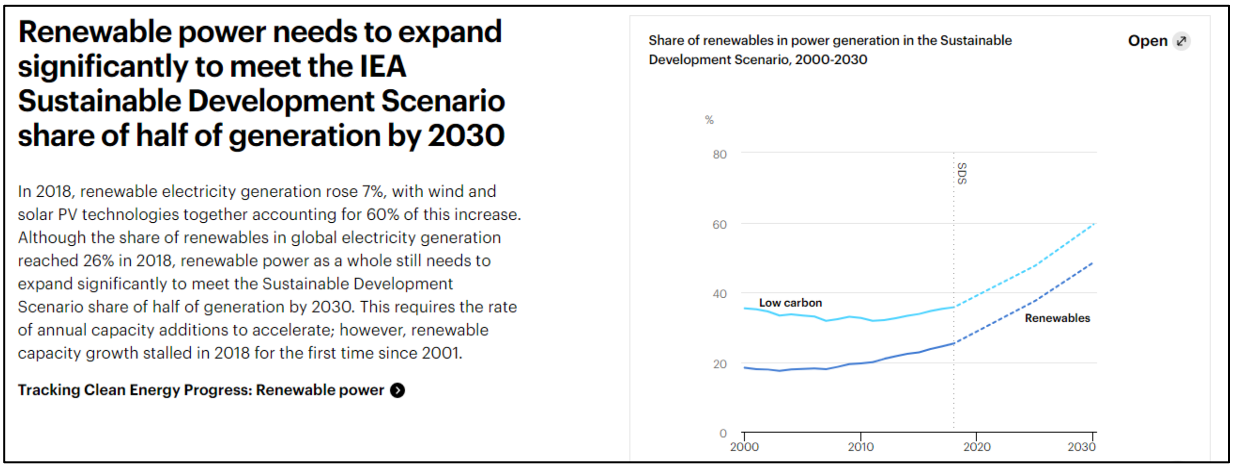


Figure 3.4: Share of renewables in power generation in the Sustainable Development Scenario, 2000-2030,
Source: (IEA, 2020b)

According to the global trends illustrated in **Error! Reference source not found.** and **Error! Reference source not found.** above, it can be concluded that renewable energy generation is on an increasing trend while coal power generation is on a decreasing trend.

However, Cambodian decision to build some coal power plants and also to import electricity from Lao PDR, whose electricity generation is mostly dependent on coal power generation, can decrease the installation of grid connected solar power generation. On the other hand, although Cambodia had more thermal power plants at the beginning, many hydro plants were added later. These will allow integration of more variable RE including solar energy to the grid.

Overall, it can be concluded that the sectoral trends may adversely impact the technical potential of the grid connected solar power generation.

Based on the assessment of steps 3.1 to 3.5, it is assumed that the overall negative impact of various factors on financial feasibility may lead to reduction of 20% of grid connected solar power generation technical potential. This is also comparable with share of technical potential reduction indicated under the financial feasibility study step of ICAT RE methodology (page 67).

Therefore, it is estimated that the achievable potential of grid connected solar power generation reduces from 658 MW to 526 MW.

Step 4: Account for other barriers

First, other barriers in the country were identified. They are listed in Table 3-7.

Table 3-7: Identification of other barriers

Barrier Category	Barrier sub category	Barriers in Cambodia
Technical and infrastructure	Lack of technical standards, technology providers, and T&D infrastructure	Lack of information on solar power potential, lack of technology providers (suppliers – 3, installation and maintenance – 8, civil works 10-15), and lack of clarity on grid absorption capacity for RE, are considered as key technical and infrastructure barriers for solar power generation.
Regulatory and policy uncertainties. Institutional and administrative barriers	Insufficient clarity and transparency in existing regulations/ development of new policies. Lack of institutional capacities and procedures for RE planning, approval and development	Under-developed policy and regulatory framework for energy and RE development, non-alignment of the government support or investment incentives with the NDC support activities, and a lack of stakeholders involvement in the power development plan are considered as the main regulatory and policy uncertainties. Inadequate institutional capacities on RE technology planning, implementation and maintenance, and weak capacity at provincial-level stakeholders to manage energy issues have been identified as the key institutional capacity issues.
Market	Inconsistent pricing structures, and market information. Fossil fuel subsidies. Lack of access to market. High price of electricity	The high electricity price has undermined the competitiveness of Cambodian industries as it has become the main obstacle to doing business in the country, which aims to diversify from apparels to other industries such as commercial rice farming, other agribusinesses, tourism, and manufacturing.

Financial	Inadequate and expensive funding and financing products	Limited access to investment capital and affordable financing/loans is a key financial barrier to expand solar power generation.
Public acceptance, awareness, and environmental concerns	Lack of research into interactions between RE and environment. Competition with other interests in the geographic area. Lack of general information on RE deployment	There is not much research into the interaction between RE technologies and environment in Cambodia. This leads to a lack of correct information, resulting in public opposition to RE deployment. In addition, there are multiple interests for land which can be used for solar power generation (e.g. for agriculture) Limited availability of information on RE, and lack of public awareness on renewable energy sources are other key issues for solar power generation.

Source: Cambodian national team

Table 3-8 indicates the impact of each barrier identified in Table 3-7 based on the information gathered from national experts and the information available in ICAT RE methodology.

Table 3-8: Impact of each barrier on assessing technical potential[16]

Barriers	Upper case	Lower Case	Reasoning
C1: Technical & Infrastructure	0%	0%	Impact of technical and infrastructure barriers seems to have been considered in determining the estimated technical potential under step 1. Further, EDC has agreed to provide land for grid connected solar power generation, and it will also lead to remove this barrier. In addition, ADB has granted a loan to enhance electricity transmission network and substation in order to increase the absorption capacity of renewable energy, and also to reduce the cost of grid connection. Therefore, this barrier may not have an impact on the estimated technical potential of grid connected solar power generation.
C2: Regulatory	0%	0%	In order to address regulatory barriers, EDC has introduced reverse auction policy to select grid connected solar power developers. This

[16] Expert judgments were used to determine the percentage factor during the barrier analysis. The pairwise comparison method was used for the initial analysis. However, the percentage factors achieved through this analysis were implausible. Therefore, simultaneous rating method was used. (Experts were asked to give a score out of 100 to each individual barrier according to its significance and the average for each barrier were used for the analysis.)

and Institutional			is assumed to be continued. Therefore, it is assumed that this barrier may also not have an impact on the estimated technical potential of grid connected solar power generation.
C3: Market	2%	5%	Market barriers have been partially addressed by providing grid access and lands for the RE developers. However, barriers due to fossil fuel subsidies will prevail. Therefore, it is assumed that this barrier may lead to reduce the estimated solar power potential between 2% to 5%, which is in line with ICAT RE methodology.
C4: Financial	2.5%	5%	As per ICAT RE methodology, access to finance barriers will lead to a reduction of 5% to 10% of RE technical potential. However, ADB has granted a loan to enhance the grid access and build substation for grid connected solar power generation. As such, it will partially address the financial barriers, though access to finance for building solar power plant still remains a barrier. This is estimated to lead to a reduction in technical potential by 2.5% to 5%.
C5: Public awareness & acceptance	2%	5%	It is assumed that this barrier will also lead to a reduction in the estimated solar power generation potential by 2% to 5%
Total impact	6.5%	15%	

Source: Author

Next step is calculating the reduction in technical potential from the barriers discussed above (Step 4).

Estimated grid connected solar power potential after accounting for financial feasibility in step 3 was 526 MW. Reductions due to the above barriers in the upper and lower cases are 35 MW and 80 MW respectively. Therefore, the estimated grid connected solar power potential after accounting for other barriers is between 447 MW and 492 MW. Summary of the analysis of overall technical potential is shown in Table 3-9 below.

Table 3-9: Summarized results

Step	RE Addition	Adjustment	% Reduction
Step 1: Estimated technical potential	822		
Step 2: Account for policy design characteristics	658	-164	20 %
Step 3: Account for financial feasibility	526	-132	20%

Step 4: Account for other barriers	447 to 492	-79 to -34	6.5% to 15%

Source: Author

3.5 Ex-ante Estimation of GHG Impacts of the RE Policy

ICAT RE methodology provides two approaches to calculate the GHG impact of RE policies ex-ante.

1. Trajectory method

2. Grid emission factor method

An approach can be selected considering the I) impact on the energy system II) Timeframe of the intervention and III) Objective of the assessment.

Impact on the energy system

Current share of solar power generation in Cambodia is less than 5%. In the absence of wind power in the electricity mix, Cambodian variable renewable energy (VRE) share is solely based on solar power generation. The energy systems of countries have been classified into four phases by International Energy Agency (IEA) based on the approximate share of VRE generation as follows:

- Less than 5% corresponds to phase 1;
- Between 5% and 10% corresponds to phase 2;
- Between 10% and 20% corresponds to phase 3 and
- More than 20% corresponds to phase 4

With a VRE share less than 5%, Cambodia belongs to phase 1. Hence, grid emission factor method can be applied for Cambodia.

However, ICAT RE methodology also indicates that the emission trajectory method can be used for a country with an energy system at any stage. Limitations of the emission trajectory method are its relative complexity and data intensity.

Timeframe of the intervention

Interventions with longer timeframes are likely to have a larger impact. The power purchase agreement of the solar power project is 25 years. Since the 100MW solar power project has a long-term contract (more than 15-20 years) it can contribute to a larger impact.

Furthermore, the assessment of GHG effects will be based on the capacity addition of grid connected solar power projects between 2020 and 2030. This will lead to a reduction of GHG emissions of Cambodian power sector against the business as usual scenario.

Hence, the emission trajectory method can be used to estimate the GHG impact of reverse auction policy.

Objective of the assessment

There are two objectives given by the ICAT RE methodology for selection of methodological approach. Both objectives need to be achieved in order to develop a functional MRV system for the selected reverse auction policy in Cambodia. These objectives are:

1. GHG emission level: To determine whether the reverse auction policy is on track to meet NDC and RE targets of the country. The emission trajectory method should be used for meeting this objective.

2. GHG emission reductions: To assess the effectiveness of reverse auction policy and improve the design and implementation while reporting on the progress of implementation. Either the emission trajectory method or grid emission factor method can be used to meet this objective.

The emission trajectory method will be suitable to assess the GHG impacts of the reverse auction policy, as it can meet both objectives of the ICAT Methodology.

The following calculation for ex-ante and ex-post scenarios has been assessed using emission trajectory method after analysing the outcomes of the I) impact on the energy system II) Timeframe of the intervention and III) Objective of the assessment.

ICAT RE methodology provides two options to assess GHG impacts of a policy according to the emission trajectory: using energy models where feasible; and otherwise using the method for limited data availability.

The method for limited data availability was used for the calculation as the data availability of this assessment is limited.

3.5.1 Baseline emission

Step 1: Projecting the future electricity demand in Cambodia

Where data availability is limited, first step should be to understand the fluctuation of electricity demand of the country over time. To project future electricity demand, three approaches are provided by the ICAT RE Methodology. These are as follow:

1. Use existing country-specific electricity demand forecasts
2. Where country-specific data and resources are not available, users may scale down data from regional scenarios
3. Estimate the future electricity demand

First approach was selected for the assessment as forecasted electricity demands from 2016 to 2030 have been published by the MME in the Revised Power Development Plan 2015.

Table 3-10 shows the estimated electricity demand of Cambodia for the period 2016-2030.

Table 3-10: Forecasted total electricity demand in Cambodia

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Forecasted Electricity Demand (GWh)	4,891	5,607	6,368	7,076	7,881	8,589	9,360	10,200	11,115	12,113	13,135	14,244	15,446	16,749	18,162

Source: (MME, 2015)(Base case)

Step 2: Projecting the future electricity generation in Cambodia

Future electricity generation is calculated using forecasted electricity demand, transmission and distribution (T&D) losses and own use of electricity by the power plants.

i. Total electricity generation[17]

Equation 2: Annual total electricity generation

$$\text{TEG} = \frac{TED}{1 - T\&D_{loss}[\%] - OwnUse[\%]}$$

TEG (GWh/year) = Annual total electricity generation

TED (GWh/year) = Annual total electricity demand

$T\ \&\ D_{loss}$ (%) = Annual transmission & distribution loss

Own Use (%) = Annual own use of electricity by power plants[18]

[17] Electricity supply in Cambodia consists of both domestic generation and imports.

[18] Normally, own use electricity may have negligible T&D losses, but this has not been considered in RE Methodology, which has been followed."

Table 3-11 shows the information on predicted T&D losses, predicted own electricity use and estimated lower and upper end electricity generation from 2016 to 2030.

	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
TED (GWh/year)	4,891	5,607	6,368	7,076	7,881	8,589	9,360	10,200	11,115	12,113	13,135	14,244	15,446	16,749	18,162
T & D loss (%)	11.10%	12%	13%	12.70%	11.70%	11.10%	10.70%	10.50%	10.20%	9.80%	9.40%	9.10%	8.70%	8.40%	8%
Own use electricity (%)	2%	2%	2%	2%	2.50%	2.50%	2.50%	2.20%	2.20%	2.20%	2.20%	2.20%	2.20%	2.20%	2.20%
Total electricity generation (GWh/year)	5,628	6,520	7,492	8,295	9,185	9,941	10,783	11,684	12,688	13,765	14,859	16,059	17,336	18,735	20,225
Import percentage (%): Assumed based on current data*	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Domestic electricity generation (GWh/year)	5,628	6,520	7,492	8,295	9,185	9,941	10,783	11,684	12,688	13,765	14,859	16,059	17,336	18,735	20,225

Table 3-11: Predicted electricity generation in Cambodia

Source: (MME, 2015)

*Note: Based on MME Revised PDP 2015, forecasted import has been assumed to be zero for base case after 2015. Therefore, country specific forecasted import percentage for the assessment was considered as zero. Furthermore, imported electricity has not been considered during the preparation of GHG inventory of second national communication. However, in real scenario, import percentage is around 25% in 2019 according to EAC (EAC, 2019).

As per this assessment, future domestic electricity generation in Cambodia from 2016 to 2030 would be between 5,628 GWh and 20,225 GWh.

Step 3: Forecasting electricity mix of Cambodia

The future electricity generation by technology has to be calculated based on the current electricity mix using one of the three approaches proposed under ICAT RE methodology: i) assume that the share of different technologies in the electricity mix remains as is; ii) continue historical trends for the shares of different technologies in the electricity mix; and iii) assume that certain technologies decrease more (or less) than others. Further, as per the same guidance approach 1 is the best approach when the future electricity mix development is unknown. Since the future electricity mix is not yet known in Cambodia due to unavailability of any official publication on the future electricity mix[19], approach 1 (assume that the share of different technologies in the electricity mix remains as is) was applied for estimating the future electricity mix of Cambodia.

Assumption: It was assumed that the share of different technologies in the selected electricity mix remains as it is until 2030. According to the ICAT RE methodology, current electricity mix or most recent electricity mix should be considered when forecasting the future electricity mix for the year 2030. However, the calculation was conducted based on the selected base year 2016. Therefore, electricity mix in 2016 was considered for this calculation.

Table 3-12: Electricity Generation by Source in 2016

Sources	Coal	Hydro Power	Fuel Oil	Solar PV	Wood, other biomass	Total Domestic Generation
GWh/year	2,394	2,568	478	0	42	5,482
%	43.7	46.8	8.7	0	0.8	100

Source: (EAC, 2016) - (EAC, 2018), Note: The numbers were rounded off.

Electricity mix for 2030 in the country was calculated based on the 2016 technology share indicated in Table 3-12. Hence, the shares of coal, hydro power, fuel oil and wood/other biomass in 2030 were considered to be 43.7%, 46.8%, 8.7% and 0.8% respectively. Table 3-12 shows that no solar PV existed in the electricity mix of the year 2016.

[19] Cambodia Basic Energy Plan (2019) published by Economic Research Institute for ASEAN and East Asia provides energy mixes for 2020, 2025 and 2030. However, this document was not recommended for use by the national team. (https://www.eria.org/publications/cambodia-basic-energy-plan/)

Table 3-13: Forecasted electricity mix in the Cambodia

Technology	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Coal (GWh/year)	2,459	2,849	3,274	3,625	4,014	4,344	4,712	5,106	5,545	6,015	6,493	7,018	7,576	8,187	8,838
Oil (GWh/year)	490	567	652	722	799	865	938	1,017	1,104	1,198	1,293	1,397	1,508	1,630	1,760
Hydro (GWh/year)	2,634	3,051	3,506	3,882	4,299	4,652	5,046	5,468	5,938	6,442	6,954	7,516	8,113	8,768	9,465
Solar PV (GWh/year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wood, other biomass (GWh/year)	45	52	60	66	73	80	86	93	102	110	119	128	139	150	162

Source: Author’s work based on current energy mix

Note: Values *were* rounded off.

Coal and hydro, which together account over 90% of forecasted electricity generation by 2030, have the highest share in the energy mix in the baseline forecast. Furthermore, solar power contribution for the electricity mix by 2030 is zero as there was no grid connected solar PV electricity generation in 2016.

Step 4: Calculation of emission levels based on technology specific emission factors

Emission levels should be estimated by applying the technology-specific emission factors to the electricity generation mix using one of the approaches given by the ICAT RE methodology.

Approach 1: Use future technology-specific emission factors available in national studies or other sources; and

Approach 2: Calculate technology-specific emission factors using historical emission factors.

Future technology-specific emission factors are not available in Cambodian national studies. Therefore, technology-specific emission factors were calculated using historical emission factors.

In order to identify the emission factors, following documents were referred.

(i) GHG inventory reporting, (ii) Mitigation action reporting in the National Communications (NC)

Emission factors under Tier 1 approach of IPCC, 2006 have been applied in the preparation of the GHG inventory in the Cambodia.

(iii) Project development plans for CDM projects

Technology specific emission factors for the CDM projects in Cambodia were estimated using the energy generation values and GHG emissions of power plants from "CDM Baseline Construction for the Phnom Penh Electricity Grid" (IGES & MoE, 2011).

(iv) International Energy Agency (IEA)

The IEA also has a readily available emission factor for Cambodia for the year 2016 as 29.2 tCO2/TJ. However, this value is for the entire energy industry without considering different technologies separately.

After the research it was observed that the most suitable and most recent country specific data are provided by the “CDM Baseline Construction for the Phnom Penh Electricity Grid" (IGES & MoE, 2011). Emission factors in this document have been used for the calculation of CDM projects submitted in and before 2013.

The most recent data on electricity generations and emissions of power plants are available in "Grid Emission Factors in Cambodia” published in the year 2016 (IGES & NCSD, 2016). Therefore, fuel consumptions and GHG emissions of power plants that consume diesel oil, heavy fuel oil and coal (Lignite) were obtained from the above document. Values given in this document under the calculation of operating margin are not technology specific. Therefore, values used for the calculation of build margin, which include technology of each power plant, were used.

Data given in the document related to power plants connected to three main grids, National Grid, Kampot-Sihanoukville Medium Voltage Grid and Kampong Cham Medium Voltage Grid were considered in calculating the technology specific emission factors for Cambodia.

Technology specific emission factors were estimated using the Equation 3 as per the ICAT RE methodology.

Equation 3: Calculating technology specific emission factors

$$EF_i^t \left[\frac{tCO_2}{MWh}\right] = \frac{TE\_EG_i^t\ [tCO_2]}{EG_i^t\ [MWh]}$$

Where:

EF = the emission factor of an electricity generation technology in a certain year,
TE_EG = the total emissions from electricity generation of a technology,
EG = the electricity generation,
i = the fossil fuel used for electricity generation (i.e. coal, lignite, gas, oil),
t = the year the electricity was generated.

Results from the application of above equation are shown in the following table.

Table 3-14: Estimation of emission factors for fossil fuel using national statistics

Name of power unit	Year	Fuel Type Energy Source	Net Electricity Generation (MWh/y) = EG	CO_2 Emissions (tCO_2) = TE_EG	Emission factor of an electricity generation technology (tCO_2/MWh) =EF
Sovanna Phum Investment Co., Ltd	2012	Residual Fuel Oil	37,420.50	23,386	
Colben Energy (Cambodia) PPSEZ Limited	2012	Residual Fuel Oil	2,256.70	1,333	
(Cambodia) Electricity Private Co, Ltd	2012	Residual Fuel Oil	209,459.30	146,207	

Colben Energy (CAMBODIA) Ltd Phnom Penh	2012	Residual Fuel Oil	31,074.10	24,784	
Colben Energy (CAMBODIA) Ltd Sihanoukville	2012	Residual Fuel Oil	51,152.60	39,754	
Total Residual Fuel Oil			331,363	235,464	0.7106
EDC-Kampot	2012	Gas / Diesel Oil	169.1	126	0.7451
Sovanna Phum Investment Co., Ltd	2008	Coal (Lignite)	37,421	23,386	
Total Coal			37,421	23,386	0.625

Source: (IGES & MoE, 2011; IGES & NCSD, 2016)

The calculated technology-wise emission factors for coal, residual fuel oil and diesel oil are 625 tCO_2/GWh, 711 tCO_2/GWh and 745 tCO_2/GWh respectively.

Residual fuel oil and diesel are included as fuel oil in existing energy mix (2016) though separate technology specific emission factors were calculated in Results from the application of above equation are shown in the following table.
Table 3-14. Therefore, consumption of residual fuel oil and diesel were disaggregated from fuel oil data using the information given in Table 3-15.

Table 3-15: Fuel consumption of residual fuel oil and diesel oil in 2012

Name of power unit	Fuel Type Energy Source		Fuel Consumption (ton) in 2012
EDC-C5	Primary Fuel Type Residual Fuel Oil	Residual Fuel Oil	2,874.00
EDC-C6			9,505.40
EDC-Siem Reap			250.5
Cambodia Utilities Pte. Limited			31,502.00
Khmer Electrical Power Co., Ltd			44,880.00
City Power Group Corporation			3,780.00
Colben Energy (CAMBODIA) Ltd Phnom Penh			8,245.00
Cambodia) Electricity Private Co, Ltd			48,353.00
EDCSihanoukville			3,270.00
Colben Energy (CAMBODIA) Ltd Sihanoukville			13,195.00

GTS Power Ltd			9,057.00
Total Residual Fuel Oil Consumption			174,912
EDC-C5	Secondary Fuel Type	Diesel Oil	421.8
EDC-C6			854.5
EDC-Siem Reap			70.1
Cambodia Utilities Pte. Limited			591
Khmer Electrical Power Co., Ltd			8
City Power Group Corporation			3
Colben Energy (CAMBODIA) Ltd Phnom Penh			2.7
Cambodia) Electricity Private Co, Ltd			303
EDCSihanoukville			5
Colben Energy (CAMBODIA) Ltd Sihanoukville			34.7
GTS Power Ltd			61
EDC-C3	Primary Fuel Type		87.6
EDC-Takeo and Angtasom			5
EDC-Banteay Meanchey & Mongkul Borei			13
EDCBattambang			3
EDC-C3			87.6
EDC-Kampot			42
Total Diesel Oil Consumption			2,593

Source: (IGES & NCSD, 2016)

Energy content of residual fuel oil (RFO) and diesel were calculated multiplying the consumptions of RFO and diesel in 2012 (total fuel consumption is shown in Table 3-16 based on the data from Table 3-15) by calorific values of the respective fuel type (Table 3-16). Then, the share of each fuel was calculated dividing the energy content of each fuel by total energy contents of RFO and diesel as shown in Table 3-16.

Table 3-16: Separation of generation from "fuel oil" into components

Technology	Total Consumption in 2012 (Ton)	Calorific Value (TJ/Gg) (IPCC, 2006)	Energy Content (TJ)	Share of total energy (%)
RFO	174,912	40.4	7,066.4	98%
Diesel	2,593	43	111.5	2%

Source: Author

Based on the outcome of Table 3-16, it shows 98% of fuel oil-based electricity generation is from residual fuel oil while remaining 2% is from diesel.

Using the above ratios, projected electricity mix of Cambodia can be re-calculated as shown in Table 3-17.

Table 3-17: Forecasted electricity mix in the country

Technology	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Coal (GWh/year)	2,459	2,849	3,274	3,625	4,014	4,344	4,712	5,106	5,545	6,015	6,493	7,018	7,576	8,187	8,838
Hydro (GWh/year)	2,634	3,051	3,506	3,882	4,299	4,652	5,046	5,468	5,938	6,442	6,954	7,516	8,113	8,768	9,465
Solar PV (GWh/year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wood, other biomass (GWh/year)	45	52	60	66	73	80	86	93	102	110	119	128	139	150	162
Residual oil - 98% (GWh/year)	480	556	639	708	783	848	919	997	1,082	1,174	1,267	1,369	1,478	1,597	1,725
Diesel oil - 2% (GWh/year)	10	11	13	14	16	17	19	20	22	24	26	28	30	33	35

Source: Author

Note: Values were rounded off.

Electricity generations of updated electricity mix (Table 3-17) were multiplied with the established technology-specific emission factors (Results from the application of above equation are shown in the following table.

Table 3-14) to calculate the baseline GHG emissions. Table 3-18 indicates the estimated annual baseline GHG emissions.

Table 3-18: Baseline GHG emissions using trajectory method for Cambodia

Technology	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Coal (tCO_2/year)	1,537,150	1,780,775	2,046,250	2,265,575	2,508,656	2,715,138	2,945,106	3,191,194	3,465,413	3,759,569	4,058,363	4,386,113	4,734,894	5,117,000	5,523,956
Residual oil (tCO_2/year)	341,173	395,245	454,158	502,848	556,798	602,622	653,665	708,284	769,146	834,437	900,752	973,494	1,050,908	1,135,716	1,226,041
Diesel oil (tCO_2/year)	7,294	8,448	9,715	10,750	11,905	12,889	13,976	15,146	16,450	17,843	19,258	20,815	22,469	24,287	26,217
Total (tCO_2/year)	**1,885,617**	**2,184,468**	**2,510,123**	**2,779,173**	**3,077,359**	**3,330,649**	**3,612,747**	**3,914,624**	**4,251,009**	**4,611,849**	**4,978,373**	**5,380,422**	**5,808,271**	**6,277,003**	**6,776,214**

Source: Author

Note: Values were rounded off.

Coal has the highest contribution for the baseline GHG emissions with 5,523,956 tCO_2e for the year 2030. Overall baseline GHG emissions for the year 2030 was estimated as 6,776,214 $MtCO_2e$.

Step 6: Estimate grid connected solar electricity generation due to reverse auction policy

To estimate electricity generation due to reverse auction policy, technical potential of grid connected solar power generation and specific yield of solar PV power generation are required. While technical potential of grid connected solar power generation has been estimated as 447 MW (lower end) and 492 MW (upper end) for the 2030 in the previous steps, specific yield of grid connected solar power generation is yet to be estimated in accordance with Equation 4.Equation 4: Calculating specific yield

Equation 4: Calculating specific yield

$$Specific\ yield_{solar\ PV} = annual\ capacity\ factor * annual\ average\ operation$$

Specific yield provides the amount of energy (MWh) produced for a 1 MW capacity over the year.

Table 3-19: Specific yield of solar PV

Parameter	Availability	Unit	Value	
Annual capacity factor	Available	%	19%[20]	X
Annual average operational days	Available	days	365	A
Number of hours	Available	hours	24	B
Annual average operational hours	A * B = Y	hours	8,760	Y
Specific yield $_{\text{Solar PV}}$	X * Y = Z	(MWh/ yr)/MW	1,664	Z

Source: Author

Note: Figures were rounded off

Specific yield (Solar PV) = 1,664 (MWh/year)/MW

The project GHG emissions need to be calculated each year as BTR will be due every two years. Therefore, emissions calculations should include all reporting years. RE additions were also considered for each year for this reason. The Given CAsp values of Table 3-5 are the RE addition for each year. Therefore, total solar capacity of each year can be shown in the following table.

[20] Annual capacity factor varies between 18% - 20% as per the national experts. As such, the annual capacity factor has been assumed as 19%.

Table 3-20: Annual RE addition

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Solar capacity addition or Given CAsp (MW)		264	414	0	0	0	0	0	0	59	85
Technical potential (MW)		264	678	678	678	678	678	678	678	737	822
Account for policy design characteristics (MW)- 20%		211	542	542	542	542	542	542	542	590	658
Account for financial feasibility (MW) - 20%		169	434	434	434	434	434	434	434	472	526
Account for other barriers (MW) - 15% (Lower)		144	369	369	369	369	369	369	369	401	447
Account for other barriers (MW) - 7% (Upper)		158	406	406	406	406	406	406	406	441	492

Source: Author

Note: Values were rounded off.

Electricity generation potential from grid connected solar PV systems, attributed to the implementation of reverse auction policy along with other existing incentive policies

The electricity generation potential (EG) from introducing auction policy for solar PV can be estimated by multiplying the assessed technical potential (MW) by the specific yield.

Equation 5 was applied to calculate annual electricity generation range ($EG_{min} – EG_{max}$).

Equation 5: Electricity generation potential

$$EG = Assessed\ technical\ potential * Specific\ yield$$

Table 3-21:Grid connected solar electricity generation due to reverse auction policy (EG_{min} & EG_{max})

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Electricity generation potential (GWh/year) _Lower Limit		240	614	614	614	614	614	614	614	667	744
Electricity generation potential (GWh/year) _Upper Limit		263	675	675	675	675	675	675	675	734	819

Source: Author

As per

Table 3-21, lower end grid connected solar electricity generation by 2030 ($EG_{min,2030}$) is 744 GWh while upper end grid connected solar electricity generation $EG_{max,2030}$ by 2030 is 819 GWh.

Step 7: Determine the future electricity mix after implementing reverse auction policy for grid connected solar power generation

Future electricity mix and grid connected solar electricity generation have been already estimated in previous steps. In this step, energy mix after implementing the reverse auction policy for grid connected solar power generation is estimated. In order to estimate energy mix in post-reverse auction policy scenario, it is important to determine which power generation technology/ies and how much electricity generation from those technologies will be replaced by the electricity generation by grid connected solar power plants implemented due to the reverse auction policy. This can be determined assessing the recent development of the power sector in Cambodia as shown in Table 3-22.

Table 3-22: Recent development in Cambodian power sector

Factors	Coal	Oil	Natural gas (NG)	Hydro	Solar	Biomass	Wind
Recent addition of power plants (2015 – 2019, MW)	200			80	95	29	80
Availability of natural resources	Potential coal mines in 5 provinces[21] ****. Mostly imported*****	Imported. Indications of local oil deposits	Imported. Demand is small	Technical potential is 8,600-10,000 MW ***	Estimated technical potential of over 8,000 MW*****	Theoretical potential of agricultural residues is about 15,000 gigawatt-hours (GWh) per year*****(2,978 MW)	Technical potential is 1,380 MW **
Fuel price*	132US$/ton	Not available	Not available	Not applicable	Not applicable	Not applicable	Not applicable
Existing subsidy schemes	.			Import of equipment and spare parts is tax exempted for one year. Tax exemptions granted on the imports of RE equipment are 15% of custom tax and 10% of VAT			
	Tax holidays are granted to investors for 9 years, in compliance with Cambodia Investment Law.						
Systemic changes to increase VRE share			LNG power plants to absorb more RE. *****	There is a high potential for hydro power. New hydro additions would facilitate further integration of VRE.	Pilot utility scale battery storage systems *		

Source: **(WWF, IES, 2016); ***(MoE, 2015); ****(Cambodia, 2011); *****(Asian Development Bank, 2018) & (MME, 2016)[22]

21 Stung Treng – 7 million tons

22 Some information was received from national experts in Cambodia*

As per the assessment from Table 3-22, the RGC intends to replace fuel oil-based power generation by coal-based power generation (as fuel oil-based power generation is expensive), and introduce new LNG power plants to absorb more variable renewable energy. Therefore, for simplicity it can be assumed that the grid connected solar power generation under the reverse auction policy may primarily replace fuel oil-based power generation. The electricity mix can be revised when firm plans are available.

Table 3-23 shows the expected annual lower and upper end electricity generation by technology in the business as usual scenario (BAU), the expected lower and upper end grid connected solar power generation as well as expected reduction of power generation due to the addition of new grid connected solar power plants after the implementation of the reverse auction policy (under the project scenario).

Table 3-23: Changes to electricity mix under lower and upper end forecasts

Technology	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lower end															
Oil: baseline (GWh/year)	490	567	652	722	799	865	938	1,017	1,104	1,198	1,293	1,397	1,508	1,630	1,760
Oil: Change in Electricity generation (GWh/year) _Lower						-240	-614	-614	-614	-614	-614	-614	-614	-667	-744
Oil: Project (GWh/year)	**490**	**567**	**652**	**722**	**799**	**625**	**324**	**403**	**490**	**584**	**679**	**783**	**894**	**963**	**1,016**
Solar PV: baseline (GWh/year)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar PV: Electricity generation potential (GWh/year) _Lower						+240	+614	+614	+614	+614	+614	+614	+614	+667	+744
Solar PV: Project (GWh/year)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**240**	**614**	**614**	**614**	**614**	**614**	**614**	**614**	**667**	**744**

Technology	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Upper end															
Oil: baseline (GWh/year)	490	567	652	722	799	865	938	1,017	1,104	1,198	1,293	1,397	1,508	1,630	1,760
Oil: Electricity generation potential (GWh/year) _Upper						-263	-675	-675	-675	-675	-675	-675	-675	-734	-819
Oil: Project (GWh/year)	**490**	**567**	**652**	**722**	**799**	**602**	**263**	**342**	**429**	**523**	**618**	**722**	**833**	**896**	**941**
Solar PV: baseline (GWh/year)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar PV: Electricity generation potential (GWh/year) _Upper						+263	+675	+675	+675	+675	+675	+675	+675	+734	+819
Solar PV: Project (GWh/year)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**263**	**675**	**675**	**675**	**675**	**675**	**675**	**675**	**734**	**819**

Source: Author

Note: Values were rounded off.

For both lower and upper end scenarios, grid connected solar power generation in 2030 (744 and 819 GWh respectively) will replace: 744 out of 1,760 GWh of expected fuel oil-based power generation at the lower end; and 819 of 1,760 GWh of expected fuel oil-based power generation at the upper end, which is in line with the government's expectation to reduce the use of oil-based power generation and to increase grid connected solar power generation.

Table 3-24 indicates the annual energy mix of Cambodia after considering the impact of grid connected solar power generation due to the implementation of reverse auction policy. Since solar power generation under the reverse auction policy is going to replace the fuel oil-based power generation, equivalent amount of energy to be generated by solar power generation was deducted from fuel-oil based power generation.

Table 3-24: Lower and upper end electricity mix after considering impact of reverse auction policy

Technology	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lower end															
Coal (GWh/year)	2,459	2,849	3,274	3,625	4,014	4,344	4,712	5,106	5,545	6,015	6,493	7,018	7,576	8,187	8,838
Oil (GWh/year)	490	567	652	722	799	625	324	403	490	584	679	783	894	963	1,016
Hydro (GWh/year)	2,634	3,051	3,506	3,882	4,299	4,652	5,046	5,468	5,938	6,442	6,954	7,516	8,113	8,768	9,465
Solar PV (GWh/year)	0	0	0	0	0	240	614	614	614	614	614	614	614	667	744
Wood, other biomass (GWh/year)	45	52	60	66	73	80	86	93	102	110	119	128	139	150	162
Upper end															
Coal (GWh/year)	2,459	2,849	3,274	3,625	4,014	4,344	4,712	5,106	5,545	6,015	6,493	7,018	7,576	8,187	8,838
Oil (GWh/year)	490	567	652	722	799	602	263	342	429	523	618	722	833	896	941
Hydro (GWh/year)	2,634	3,051	3,506	3,882	4,299	4,652	5,046	5,468	5,938	6,442	6,954	7,516	8,113	8,768	9,465
Solar PV (GWh/year)	0	0	0	0	0	263	675	675	675	675	675	675	675	734	819
Wood, other biomass (GWh/year)	45	52	60	66	73	80	86	93	102	110	119	128	139	150	162

Source: Author

Note: Values were rounded off.

Fuel oil consists of 98% of RFO and 2% of diesel in Cambodian energy mix as per the previous analysis under this assessment. Further, it is unlikely that grid connected solar power generation under the reverse auction policy will replace diesel-based power plants, which are mainly emergency power generation units. Therefore, it is likely that the grid connected solar power generation under the reverse auction policy will replace RFO-based power generation.

Based on the RFO and diesel shares in the previous paragraph, RFO and diesel-based power generation for each year are shown in the following table.

Table 3-25: Residual fuel oil and diesel share in energy mix

Technology	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lower end															
Residual fuel oil (GWh/year)	480	556	639	707	783	612	318	394	480	572	665	767	876	944	995
Diesel (GWh/year)	10	11	13	14	16	13	6	8	10	12	14	16	18	19	20
Upper end															
Residual fuel oil (GWh/year)	480	556	639	707	783	590	258	335	420	512	605	708	817	878	922
Diesel (GWh/year)	10	11	13	14	16	12	5	7	9	10	12	14	17	18	19

Source: Author

Note: Values were rounded off.

Step 8: Calculate GHG impact of the grid connected solar power generation due to the implementation of reverse auction policy

GHG emissions for the project scenario were calculated after determining the electricity mix under project scenario.

With regard to the estimation of future technology-specific emission factors for the project scenario, there are two approaches under ICAT RE methodology:

a. Assume that the specific emissions remain constant, indicating that there is no improvement in the energy efficiency of technologies and that the fuel composition stays the same;
b. Assume that the specific emissions improve over the years, indicating that there are energy efficiency improvements for the technology.

1st approach was selected in the absence of sufficient data to determine realistic future energy efficiency measures.

Table 3-26: Technology-specific emission factors for fossil fuel-based power plants

Technology	Coal	Residual fuel oil	Diesel
EF (tCO_2/GWh)	625	711	745

Source: Author's calculations based on (IGES & NCSD, 2016)

Electricity generation mix in the project scenario shown in Table 3-24 (except oil) and Table 3-25 were multiplied with the technology-specific emission factors in Table 3-26 to calculate the GHG emissions under the project scenario.

Table 3-27: GHG emissions under the project scenario using trajectory method for the country

Emissions from technology	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lower end															
Coal (tCO_2/year)	1,537,150	1,780,775	2,046,250	2,265,575	2,508,656	2,715,138	2,945,106	3,191,194	3,465,413	3,759,569	4,058,363	4,386,113	4,734,894	5,117,000	5,523,956
Residual oil (tCO_2/year)	341,173	395,245	454,158	502,848	556,798	435,395	225,842	280,461	341,323	406,614	472,929	545,671	623,085	670,964	707,637
Diesel oil (tCO_2/year)	7,294	8,448	9,715	10,750	11,905	9,313	4,828	5,997	7,301	8,694	10,110	11,667	13,321	14,349	15,131
Total	**1,885,617**	**2,184,468**	**2,510,123**	**2,779,173**	**3,077,360**	**3,159,845**	**3,175,776**	**3,477,652**	**3,814,036**	**4,174,877**	**4,541,401**	**4,943,450**	**5,371,299**	**5,802,312**	**6,246,724**
Upper end															
Coal (tCO_2/year)	1,537,150	1,780,775	2,046,250	2,265,575	2,508,656	2,715,138	2,945,106	3,191,194	3,465,413	3,759,569	4,058,363	4,386,113	4,734,894	5,117,000	5,523,956
Residual oil (tCO_2/year)	341,173	395,245	454,158	502,848	556,798	419,369	183,339	237,958	298,819	364,110	430,425	503,168	580,581	624,279	655,379
Diesel oil (tCO_2/year)	7,294	8,448	9,715	10,750	11,905	8,970	3,919	5,088	6,392	7,785	9,201	10,758	12,412	13,350	14,014
Total	**1,885,617**	**2,184,468**	**2,510,123**	**2,779,173**	**3,077,360**	**3,143,476**	**3,132,364**	**3,434,240**	**3,770,624**	**4,131,464**	**4,497,989**	**4,900,038**	**5,327,887**	**5,754,630**	**6,193,348**

Source: Author

Note: Values were rounded off.

The GHG emission by 2030 due to the implementation of reverse auction policy in Cambodia is 6,246,724 tCO_2e for lower end and 6,193,348 tCO_2e for upper end.

The emission reductions for lower end and upper end have presented in Table 3-28.

Table 3-28: GHG emission reduction in lower end and upper end from 2020 to 2030

Emissions	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lower end															
Ex-ante baseline scenario emission (tCO_2/year)	1,885,617	2,184,468	2,510,123	2,779,173	3,077,360	3,330,648	3,612,748	3,914,624	4,251,008	4,611,848	4,978,373	5,380,422	5,808,271	6,277,003	6,776,214
Ex-ante policy scenario emission (tCO_2/year)	1,885,617	2,184,468	2,510,123	2,779,173	3,077,360	3,159,845	3,175,776	3,477,652	3,814,036	4,174,877	4,541,401	4,943,450	5,371,299	5,802,312	6,246,724
Emission reduction (tCO_2/year)	0	0	0	0	0	170,803	436,972	436,972	436,971	436,972	436,972	436,971	436,972	474,691	529,490
Upper end															
Ex-ante baseline scenario emission (tCO_2/year)	1,885,617	2,184,468	2,510,123	2,779,173	3,077,360	3,330,648	3,612,748	3,914,624	4,251,008	4,611,848	4,978,373	5,380,422	5,808,271	6,277,003	6,776,214
Ex-ante policy scenario emission (tCO_2/year)	1,885,617	2,184,468	2,510,123	2,779,173	3,077,360	3,143,476	3,132,364	3,434,240	3,770,624	4,131,464	4,497,989	4,900,038	5,327,887	5,754,630	6,193,348
Emission reduction (tCO_2/year)	0	0	0	0	0	187,172	480,384	480,384	480,384	480,384	480,384	480,384	480,384	522,373	582,866

Source: Author

Note: Values were rounded off.

The GHG emission reductions by 2030 due to the implementation of reverse auction policy in Cambodia is within the range of 529,490 tCO_2e (lower end) and 582,886 tCO_2e (upper end)

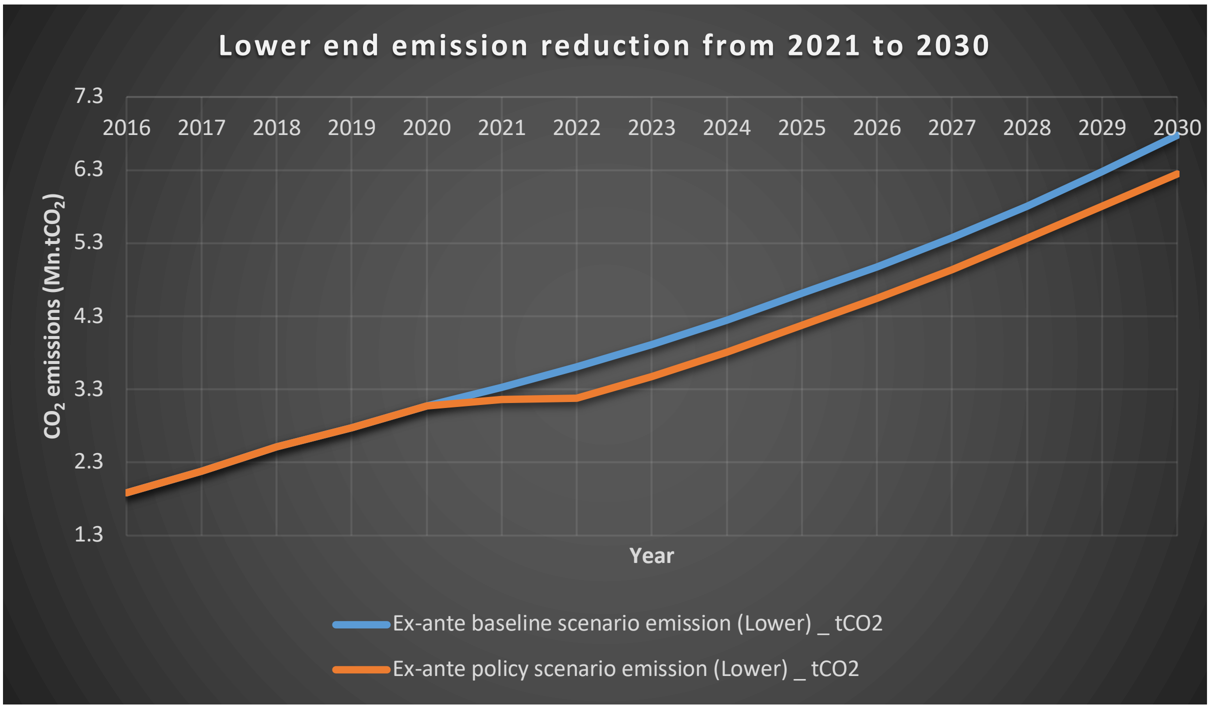


Figure 3.5: Graph illustrating the lower end CO_2 emission reduction

Source: Author

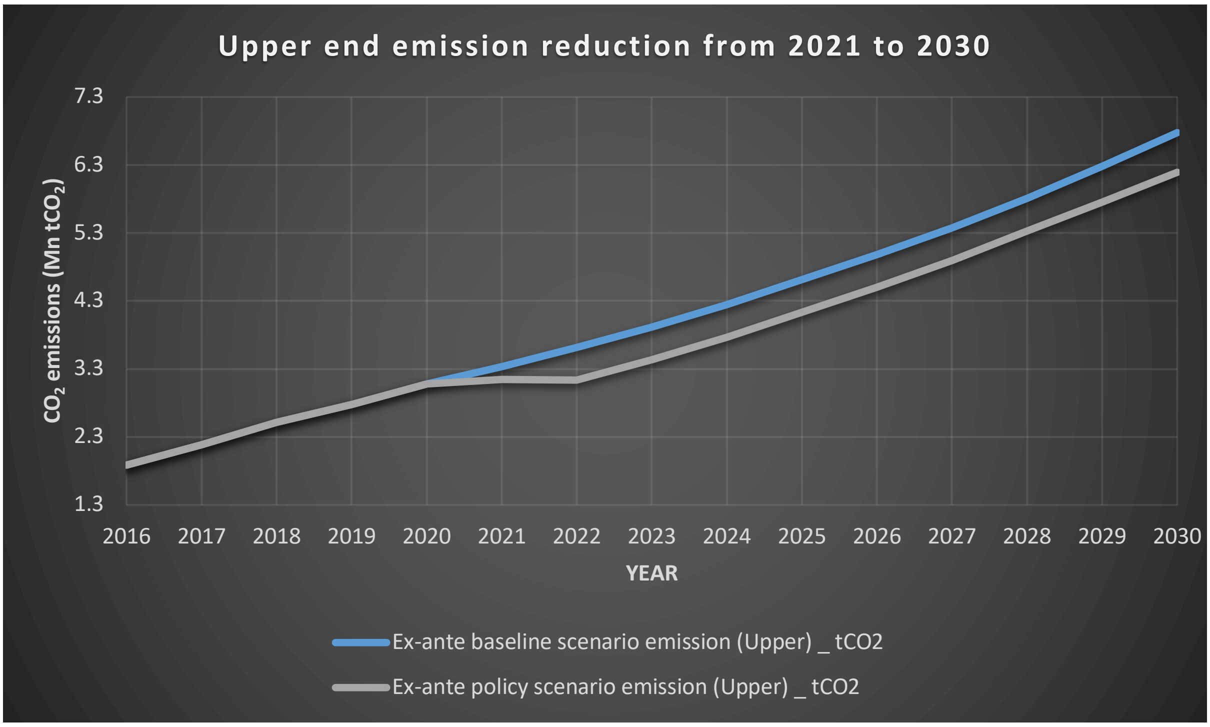


Figure 3.6: Graph illustrating the upper end CO_2 emission reduction

Source: Author

3.6 Option 1: Estimating GHG Impacts Ex-Post (Emission Trajectory Method)

Step 1: Introduction to estimating GHG impacts ex-post

Background

Ex-post calculation was carried out for the 10 MW solar power project, which was tendered in 2016 using reverse auction policy, and commissioned in 2017. This is the first grid connected solar power generation project introduced under the reverse auction policy as a pilot project of proposed National Solar Power Park Project. According to the success of this project, the Cambodian government with the support of ADB tendered the phase 1 of 100 MW National Solar Park Project (Phase 1: 60 MW solar power project) in 2019 (ADB, 2019).

Following table shows the electricity generation capacities in the grid for past years (2006 - 2018)

Table 3-29: Annual generation capacities in the grid

Technology	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Coal (MW/year)	-	-	13.0	13.0	13.0	13.0	13.0	133.0	268.0	403.0	429.2	564.2	551.2
Oil (MW/year)	282.7	296.9	353.1	340.0	328.0	342.5	321.0	325.3	291.3	304.6	304.2	295.1	266.8
Hydro (MW/year)	13.0	13.0	13.4	13.4	13.3	207.1	225.4	682.1	929.4	929.7	930.0	979.7	1,329.7
Solar PV(MW/year)	-	-	-	-	-	-	-	-	-	-	-	10.0	10.0

Source: (EAC, 2006) - (EAC, 2018)

Table 3-29 demonstrates that Cambodia added its first ever utility-scale solar plant in 2017, which, according to national experts, has been tendered by the government in 2016 using reverse auction policy.

Objectives of calculating ex-post GHG impacts

There are three objectives of the calculation of ex-post GHG impacts:

1. Objective 1: Compare achieved renewable energy addition with a policy cap or a renewable energy target, or achieved GHG emissions level with a sectoral emissions target
2. Objective 2: Compare achieved renewable energy addition or GHG emissions reductions with a baseline scenario
3. Objective 3: Compare achieved renewable energy addition or GHG emissions reductions with an ex-ante assessment

There was no planned policy cap or renewable/national target for the year 2017. Therefore, objective 1 above is not applicable for the 10 MW solar power project in that year. However, achieved renewable addition can be compared with policy cap established for the period 2021-2030, when performing the ex-post calculation for that period. Furthermore, the GHG emission level can be compared with the national target when conducting the calculation for the year 2030.

Procedure to achieve objectives 2 and 3 are explained in the following steps.

Step 2: Update baseline emission

Baseline emissions should be recalculated each time when an ex-post assessment is undertaken. This means ex-post baseline introduced by ICAT RE methodology is a dynamic baseline. This baseline will be developed through ex-post calculation labelled as "Ex-post baseline scenario", which is different from the "Ex-ante baseline scenario".

Users who develop a baseline scenario should calculate GHG emissions from the equivalent amount of electricity generated as in the policy scenario. However, solar generation in the policy scenario should be attributed to business-as usual sources (for our assessment using technology-specific emission factor for oil).

Following steps were followed during the update of the baseline scenario. Although these steps are similar to the steps followed when developing the baseline for ex-ante scenario, actual data were used for the ex-post calculation.

i. Developing the electricity mix

Actual energy mix in the year 2017 was used for the calculation.

Table 3-30: Actual annual electricity generation mix

Technology	2016	2017
Coal (GWh/year)	2,394.2	3,569.0
Oil (GWh/year)	478.3	289.7
Hydro (GWh/year)	2,568.0	2,711.1
Solar PV (GWh/year)		4.6
Wood, other biomass (GWh/year)	42.4	59.2
Total (GWh/year)	**5,482.9**	**6,633.6**

Source: (EAC, 2016)-(EAC, 2018)

Based on the assessment shown in Table 3-22, it was determined that the renewable electricity under policy scenario will displace the electricity that would have been generated by oil-based electricity under baseline scenario. This is valid for ex-post policy scenario and ex-post baseline scenario as well given the fact that oil based electricity generation has declined from 2016 (478.3 GWh) to 2017 (289.7GWh) while electricity generation from other sources (coal and hydro) have increased from 2016 to 2017 as per Table 3-29.

Therefore, generation mix of electricity for the ex-post baseline scenario was developed assuming that the solar electricity generation in ex-post policy scenario has displaced the electricity that would have been generated by oil-based power generation in ex-post baseline scenario.

Table 3-31: Revised generation mix of electricity for the ex-post baseline scenario

Technology	2016	2017
Coal (GWh/year)	2,394.2	3,569.0
Oil (GWh/year)	478.3	294.3
Hydro (GWh/year)	2,568.0	2,711.1
Solar PV (GWh/year)	0	0
Wood, other biomass (GWh/year)	42.4	59.2
Total (GWh/year)	**5,482.9**	**6,633.6**

Source: Author's work based on the existing data and trends

Solar electricity generation in the year 2017 (4.6 GWh/ year) under ex-post policy scenario was added to the oil electricity generation (289.7 GWh/year) to establish the ex-post baseline scenario.[23]

ii. GHG emissions for ex-post baseline scenario

GHG emissions for the ex-post baseline scenario was calculated multiplying technology-specific emission factors with the energy generation from relevant technologies in the energy mix. Latest available emission factors, which are valid and applicable at the given year for which ex-post calculation is conducted, should be applied. The emission factors were valid and applicable for the base year 2016. However, ex-post assessment is conducted for year 2017. Therefore, it is assumed that the emission factors applied for 2016 can also be applied for year 2017 too.

[23] It is advisable to check which fossil technology has been reasonably displaced by the solar electricity generation and apply the respective fossil fuel technology to determine the baseline emissions. In case, it is difficult to determine the baseline fossil fuel technology, the grid emission factor should be applied to calculate the GHG impacts of grid connected solar power generation under reverse auction policy.

Table 3-32: Technology-specific emission factors for fossil fuel-based power plants

Technology	Coal	Residual fuel oil	Diesel oil
EF (tCO_2/GWh)	625	711	745

Source: Author

The total oil electricity generation is further separated into RFO and diesel as in ex-ante calculation. (98% for the residual fuel oil and 2 % for diesel oil).

Table 3-33: Ex-post baseline emission (Emission trajectory method)

Technology	2016	2017
Coal (tCO_2/year)	1,496,375.0	2,230,625.0
Residual oil (tCO_2/year)	333,267.0	205,059.5
Diesel oil (tCO_2/year)	7,129.7	4,388.1
Total (tCO_2/year)	**1,836,771.7**	**2,440,072.6**

Source: Author

The ex-post baseline emission in 2017 is 2,440,072.6 tCO_2/year, which is higher than the ex-ante baseline emission in 2017, 2,184,468.2 tCO_2/year. Reason for this difference is that the electricity generation calculated from forecasted electricity demand (5,607 GWh/year) in 2017 is 6,520 GWh/year lesser than the actual generation in the year 2017, which is 6,633.6 GWh/year.

Step 3: Actual achieved RE addition

RE addition of the project is 10 MW, which was developed under ADB National Solar Power Project and commissioned in October 2017 (Table 3-29). The electricity generation from solar PV in the year 2017 (within 3 months period) is 4.6 GWh/year. As explained before, 10 MW solar power project is the only solar power project connected to the grid in 2017. Therefore, total electricity generation from solar power projects is 4.6 GWh for year 2017.

Therefore, actual achieved RE addition is 10 MW solar power, which resulted for 4.6 GWh electricity generation in year 2017.

Step 4: Estimate GHG impacts

Actual electricity generation reported in 2017 is used for the calculation. Ex-post policy scenario was developed by following the steps in Chapter 8 of ICAT RE Methodology (ex-ante calculation steps in this assessment).

i. GHG emissions in the ex-post policy scenario

Actual electricity generation and the same technology-specific emission factors used in the baseline scenario were used for the calculation. Electricity generation values in Table 3-30 were multiplied by emission factors in Table 3-32 to calculate ex-post policy emissions.

Table 3-34: GHG emissions in the ex-post policy scenario (Emission trajectory method)

Technology	2016	2017
Coal (tCO_2/year)	1,496,375	2,230,625
Residual oil (tCO_2/year)	333,267	201,860
Diesel oil (tCO_2/year)	7,130	4,314
Total (tCO_2/year)	**1,836,772**	**2,436,799**

Source: Author

The GHG emissions of ex-post policy scenario for the year 2017 is 2,436,799 tCO_2/year, which is higher than the GHG emissions of ex-ante policy scenario for the year 2017, 2,184,468 tCO_2/year. This is due to the fact that forecasted electricity demand for the year 2017 was 6,520 GWh/years, which is lower than the actual electricity generation in the year 2017, 6,633.6 GWh/year.

Table 3-35: Emission reduction for the ex-post scenario (Emission trajectory method)

Technology	2016	2017
Baseline emission (tCO_2/year)	1,836,772	2,440,073
Ex-post emission (tCO_2/year)	1,836,772	2,436,799
Emission reduction (tCO_2/year)	**0**	**3,274**

Source: Author

GHG impact of commissioning the10 MW solar power plant in October 2017 is 3,274 tCO_2e.

GHG impact of the10MW power plant is illustrated in the following figures.

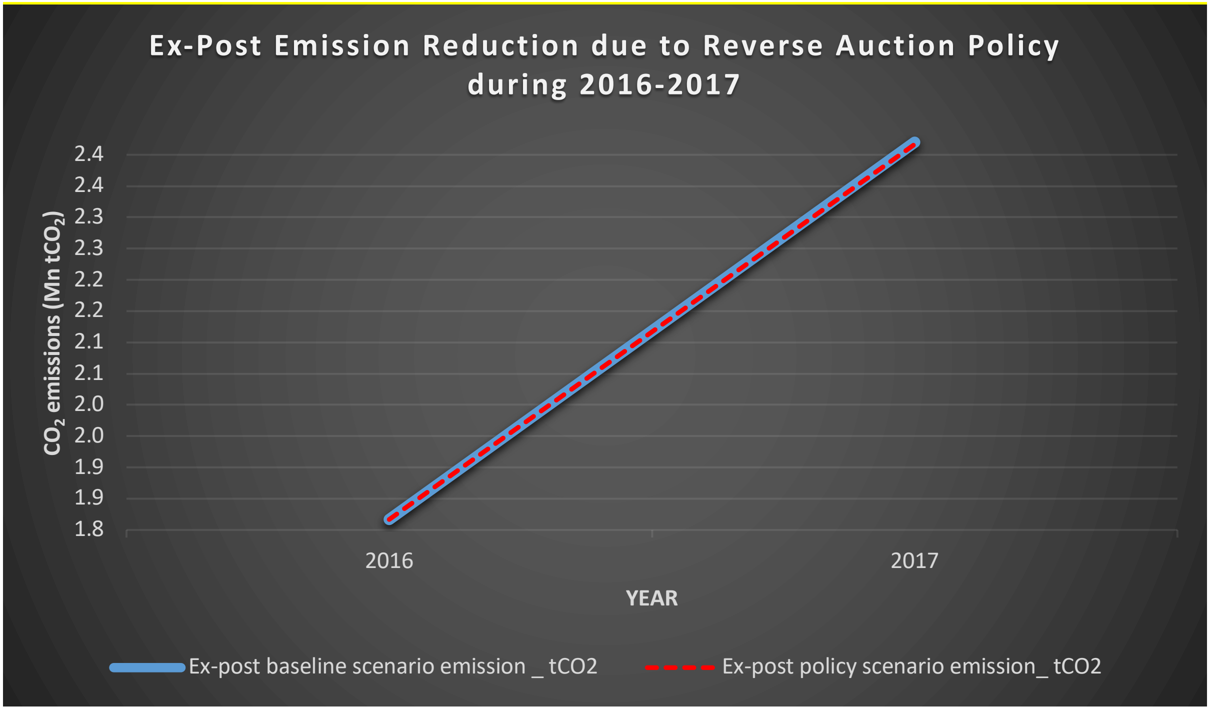


Figure 3.7: Graph illustrating the ex-post CO_2 emission reduction (Emission trajectory method)
Source: Author (Note: The emission reduction is too small to be displayed on the graph)

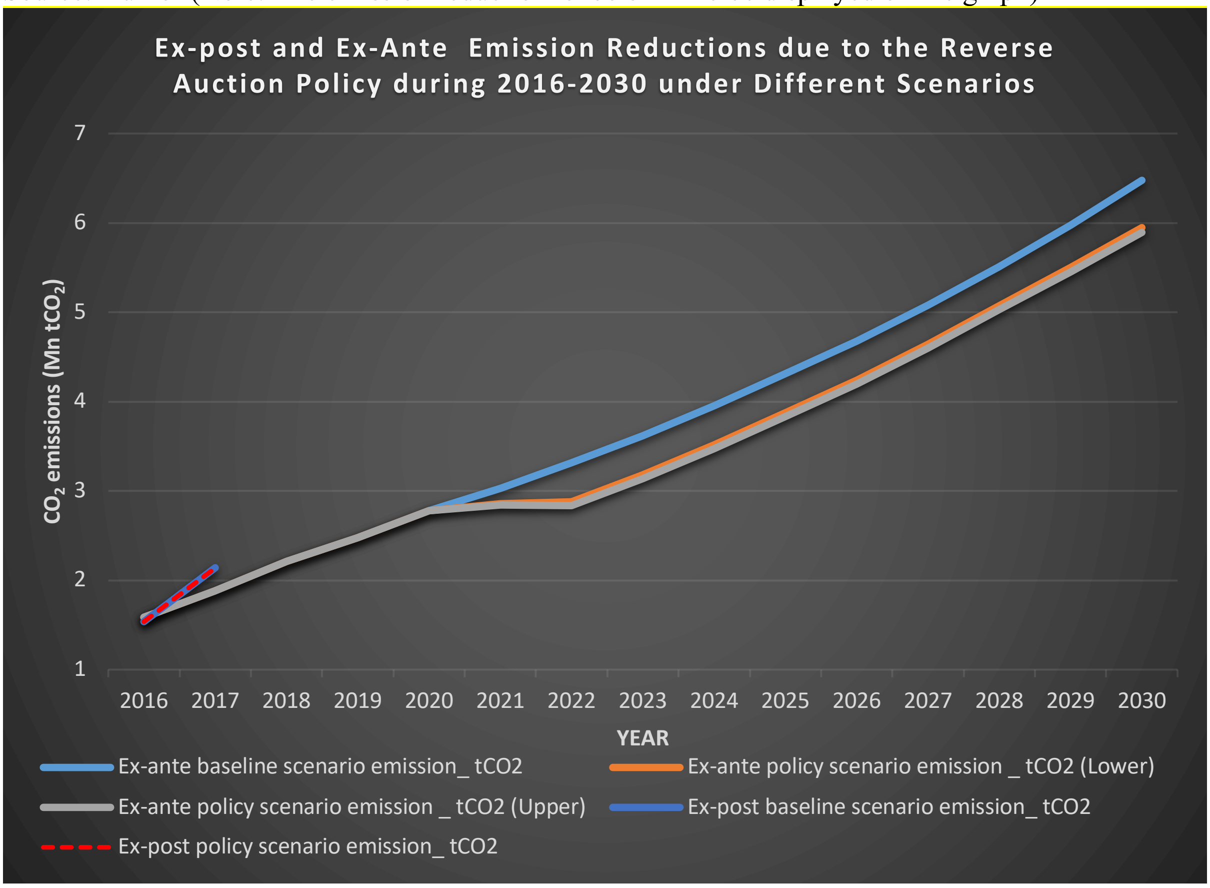


Figure 3.8: Graph illustrating the comparison between ex- ante and ex-post scenarios (Emission trajectory method)
Source: Author

It is recommended to use emission trajectory method to determine the ex-post emission scenario provided that the baseline technology, which would have generated the electricity in the absence of the grid connected solar power project under reverse auction policy, can be easily identified. If the determination of baseline technology is difficult, the grid emission factor method should be applied to calculate the ex-post GHG impacts for grid connected solar power generation under the reverse auction policy. The method to estimate the GHG impacts in ex-post using the grid emission factor method is shown below.

3.7 Option 2: Estimating GHG Impacts Ex-Post (Grid Emission Factor Method)

Steps 1-3 used in the emission trajectory method are not applicable for this option as the emission reduction can be calculated directly.

Step 4: Estimate GHG impacts

In this option, grid emission factor is multiplied with electricity generation addition from the solar power project under the policy to calculate GHG emissions reduction

Latest available grid emission factor should be applied for the calculation. Latest available grid emission factor has been published in 2016 (IGES & NCSD, 2016).

Table 3-36: Grid emission factor for fossil fuel-based power plants

Simplified Combined Margin from "Grid Emission Factors in Cambodia", 2016	
Emission factor (tCO_2/GWh)	724[24]

Source: (IGES & NCSD, 2016).

By multiplying the grid emission factor by the RE addition, the impact of the policy was calculated and the result is shown in Table 3-37

Table 3-37: Emission reduction for the ex-post scenario (Grid emission factor method)

	RE addition (GWh/year)	Emission factor (tCO_2/GWh)	2017
Emission reduction (tCO_2/year)	4.6	724	**3,330**

Source: Author

GHG impact of commissioning the 10 MW solar power plant in October 2017, under the reverse auction policy is 3,330 tCO_2e. Following graphs illustrate the GHG impact of the

[24] This grid emission factor is applicable only if solar power project connected to one of the following grids. National Grid, Kampot-Sihanoukville Medium Voltage Grid and Kampong Cham Medium Voltage Grid. However, emission factor should be recalculated if the solar power project is not connected to any of the three grids listed above.

10MW solar power project added under the reverse auction policy. For comparison, the baseline GHG emission calculated ex-post under option 1 is also indicated.

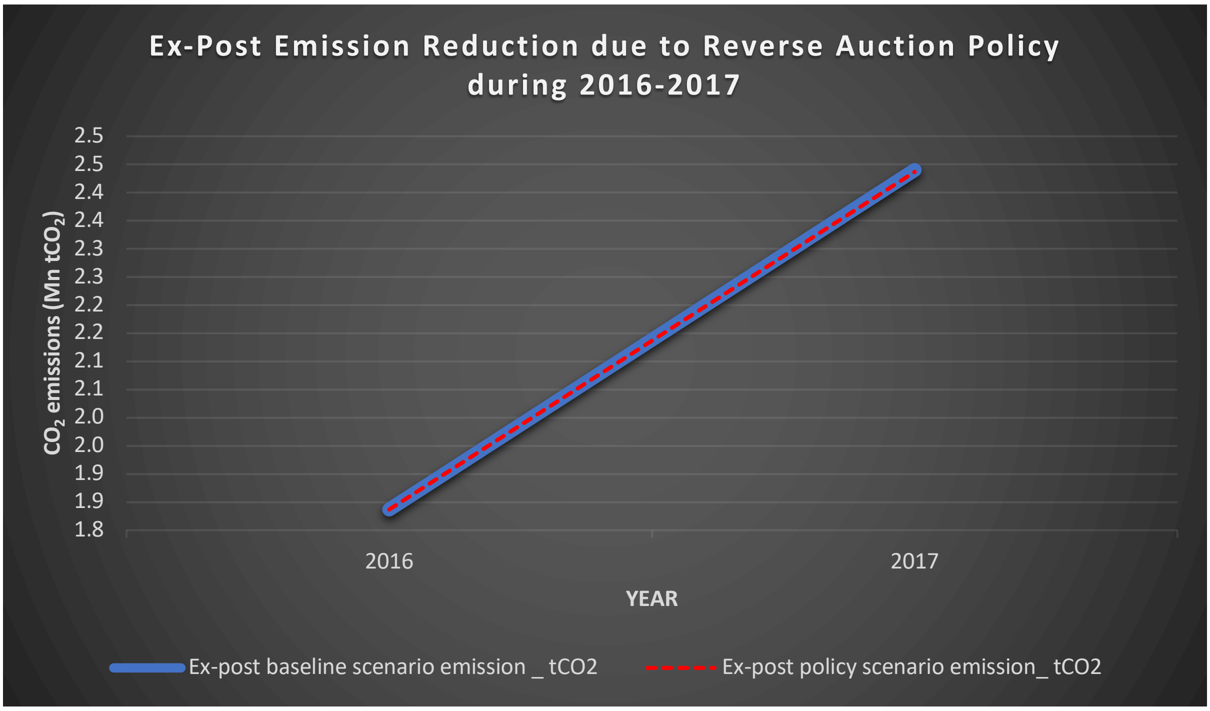


Figure 3.9: Graph illustrating the ex-post CO_2 emission reduction (Grid emission factor method)
Source: Author (Note: The emission reduction is too small to be displayed on the graph)

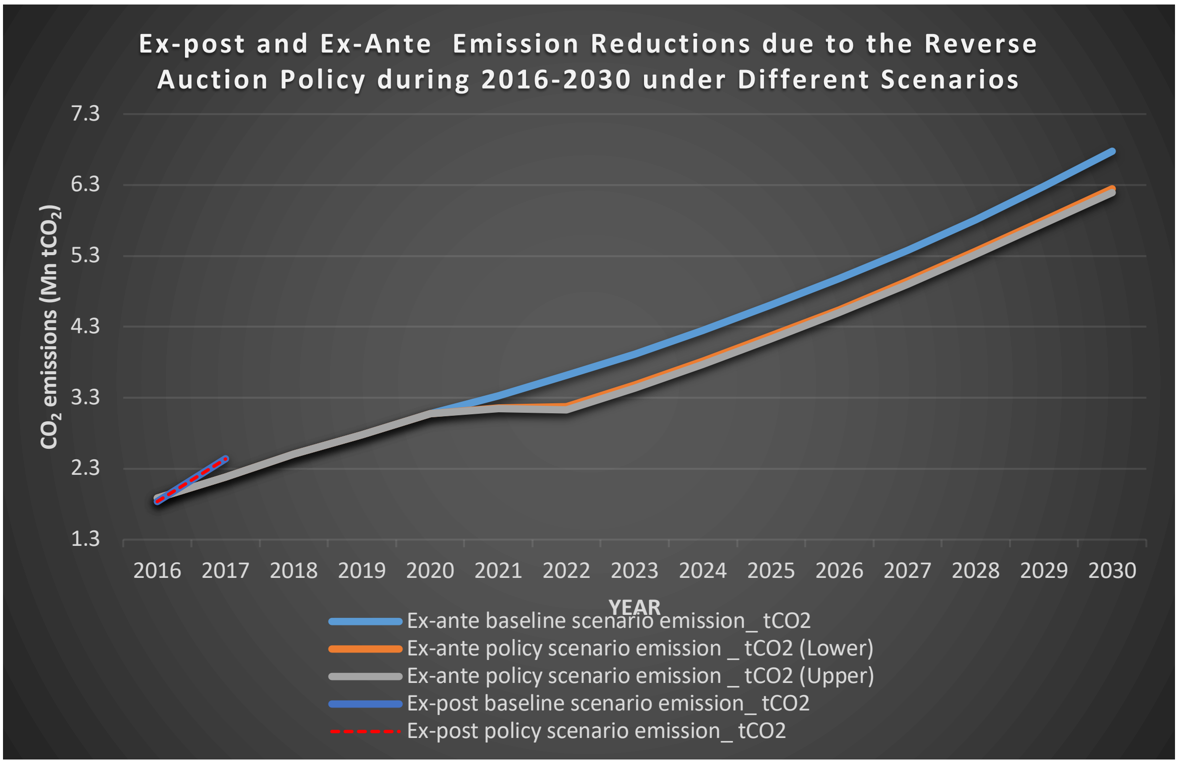


Figure 3.10: Graph illustrating the comparison between ex- ante and ex-post scenarios (Grid emission factor method)

Source: Author

4 Reporting

This chapter describes the information to be provided on the progress of the policy implementation including the emission reductions achieved. In addition, reporting chapter also includes the information on GHG assessment methodology, roles and responsibilities of each party who will provide, collect, and communicate required data.

First subsection describes the data management system, which explains what, when, how and whom to be reported for assessing and communicating GHG impact of the grid connected solar power generation under the reverse auction policy.

4.1 Data Management System

Table 4.1 provides a list of parameters to be monitored and reported by the institutions in order to assess GHG impact of the grid connected solar power generation under the reverse auction policy in accordance with the methodology described in Chapter 3.

Table 4-1 Data needed to assess the GHG impact of the grid connected solar power generation under the reverse auction policy, and the responsible entities.

Parameter	Responsible organization	Publicly available	Only documented internally	Data requirement
Total electricity demand (Projected)	MME	Yes	No	Ex-ante
T & D loss (Projected)		Yes	No	Ex-ante
Investment in electricity generation technologies		Yes	No	Ex-post
Status of abundance of natural resources in the country		Yes	No	Ex-post
Subsidy schemes for certain technologies		Yes	No	Ex-post
Type of systems and system changes to accommodate higher shares of VRE		Yes	No	Ex-post
Fuel price (historical/projected)		Yes	No	Ex-post
Maximum quantity of installed capacity supported by the policy (policy cap)		Yes	No	Ex-post

Effect of sectoral trends		Yes	No	Ex-post
Effect of the other policies		Yes	No	Ex-post
Account for other barriers		Yes	No	Ex-ante
Total emissions from electricity generation of a technology	EAC	Yes	No	Ex-post
Annual capacity factor		No	Yes	Ex-ante
Electricity use of the plant (Own use of electricity)		No	Yes	Ex-ante
Electricity generation & Electricity generation mix		Yes	No	Ex-post
Levelized Cost of Electricity		Yes	No	Ex-ante
Consumer tariff of electricity		Yes	No	Ex-ante
Auction demand and auction design	EDC	Yes	No	Ex-ante
Longevity of the power purchase agreement		Yes	No	Ex-ante
Qualification requirements		Yes	No	Ex-ante
Winner selection process		Yes	No	Ex-ante
Sellers' contractual liability requirement		Yes	No	Ex-ante
Electricity tariff for solar power		No	Yes	Ex-ante
Net electricity supplied to the grid from solar power plant		No	Yes	Ex-post
Installed solar capacity under the reverse auction policy		Yes	No	Ex-post
Annual average operation days of solar plant	IPP	No	Yes	Ex-ante

Source: Author

Note: *Data required to assess the ex-ante GHG impact are only needed once within the assessment period. For this study, ex-ante assessment is conducted for the assessment period of 2021-2030. Unless policy or the assessment period is changed, ex-ante data* ***need not*** *be monitored. Data required to assess the ex-post GHG impact* ***need to*** *be monitored annually (mandatory).*

As per Table 4.1, there are 26 parameters to be monitored in order to assess the GHG impacts of grid connected solar power plants under the reverse auction policy in accordance with ICAT RE methodology. The information will be gathered from four individual entities. Most of the information will be gathered from MME and EDC. Data collection templates will be included as part of the next deliverable under the procedures.

Table 4.2 provides a summary of the roles and responsibilities of each institution in measuring and reporting the data required to assess GHG impact of the grid connected solar power generation under the reverse auction policy.

Table 4-2 Roles and responsibilities of the respective organizations in monitoring and reporting mitigation action

Organization	Roles and responsibilities
MME	Provide data required to assess the effect of all power sector policies valid and applicable at the time of implementing the reverse auction policy (e.g. import tax incentives for RE equipment). Provide the data required to analyze the barriers for the implementation of the reverse auction policy Analyze and report the projected electricity demand and T&D loss to the existing working group at the MME Analyze and report the trends of the RE sector, such as, variation in the natural resource potential, investment in electricity generation technologies, etc., to the existing working group at the MME Analyze and report the maximum quantity of installed capacity supported by the selected policy (policy cap)
EDC	Provide data related to the auction process such as auction demand and auction design Decide and report data on selection process of project developer such as qualification requirement, winner selection process Provide data on Sellers' contractual liability requirement, Longevity of the PPA Provide solar capacity installed under reverse auction policy Calculate and report net electricity supplied to the grid from each solar power plant installed under reverse auction policy
EAC	Report electricity generation and generation mix of the country (these data are also published in annual reports) Analyze and report total emissions from electricity generation of a technology Report data related to electricity use of the power plants (these data are also published in the annual energy balance) Analyze and report the annual capacity factor of solar technology

	Calculate and report the LCOE of solar technology Provide tariff related data
Project developers	Report financial, operational, technical data related to the power plant

Source: Author

Table 4.2 provides only a summary while detailed information on the roles and responsibilities will be provided in the MRV protocol to be developed as part of the next deliverable. Most of the data required to analyze the GHG impact of the reverse auction policy are already collected by the respective institutions for various other reasons. Figure 4.1 provides the proposed data management system to collect the relevant data from the respective institutions. (Please refer to Annex VII for an enlarged version of the diagram)

As illustrated in Figure 4-1, EDC will provide the data regarding the design characteristics of the power sector policies and the electricity tariff data of solar technology to assess the financial feasibility of the project. Installed solar power capacity under the reverse auction policy and net electricity supplied to the grid from each solar power plant shall be reported annually to assess the ex-post GHG impact.

Annual report and energy balance of the country are published by the EAC annually. Electricity generation, electricity generation mix and own electricity use of the power plants can be extracted from those reports. Total emissions from electricity generation using different technologies, LCOE, consumer tariff of the electricity and the annual capacity factor of solar technology will also be calculated and reported by the EAC. If projected electricity demand and T&D loss is not available, EAC will provide the current electricity demand and the T&D loss for the calculation. If data required to decide the fossil fuel technology that will be replaced by the solar power is not available, grid emission factor of the country will be provided by the EAC for the ex-post calculation.

MME publishes a Power Development Plan of the country for 5 to 10 years period. This document contains information on electricity demand, expected T&D loss and maximum quantity of installed capacity supported by the policy (policy cap). For estimating the financial feasibility of the power sector projects, MME needs to provide the data required to estimate the trends of the sector, effect of power sector policies (excluding reverse auction policy) in the power sector, and how to account for other barriers. Further, information on investment in electricity generation technologies, subsidy schemes for certain technologies, abundance of the natural resources in the country, and changes done in the electricity sector to accommodate a higher share of VRE will also be provided by the ministry. In the absence of a designed policy cap, MME will provide data on national renewable energy potential and renewable resource availability, to estimate the technical potential. If actual values are not available, planned capacity factor of the solar technology will be provided to calculate the specific field yield.

Independent Power Producers (IPPs) will provide the operational data such as annual average operational days to calculate the specific field yield. If calculated LCOE is not available for the solar technology in order to analyze the financial feasibility, data required to calculate the LCOE such as investment expenditures, O&M costs, electricity generation, economic lifetime of the system, power generation capacity of the system, capacity factor and discount rate will also be provided by the IPPs. If discount rate is not available, calculated weighted average cost of capital (WACC) or the data required to calculate the value such as cost of equity, percentage of financing that is equity, cost of debt, percentage of financing that is debt and corporate tax rate will be provided.

If country data for projected electricity demand is not available, current electricity demand and the T&D loss will be provided by EAC. Projected population needs to be extracted from UN DESA database and the actual population of the country can be collected from the NIS or the MoP.

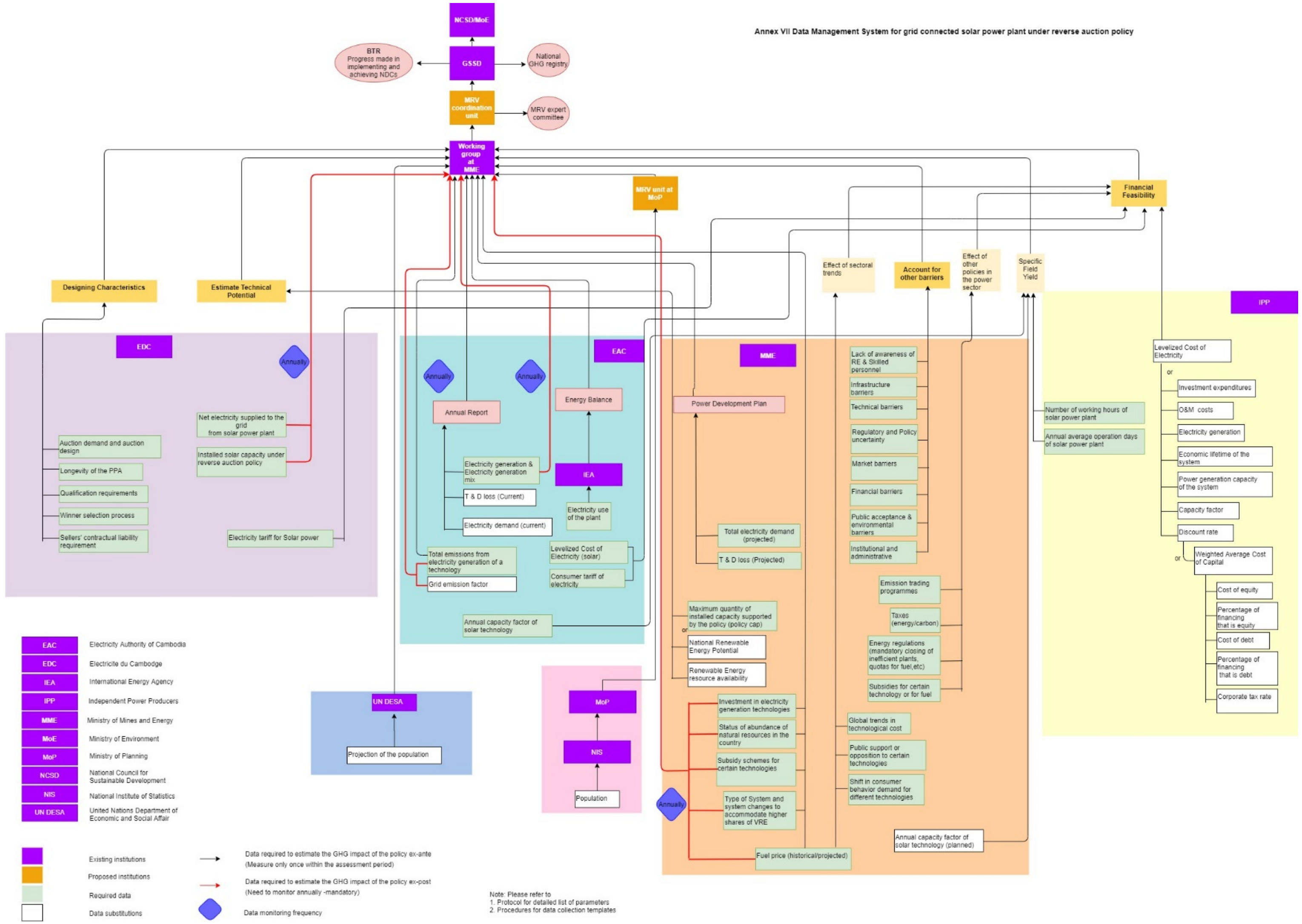


Figure 4.1 Proposed Data Management System,

Source: Author

4.2 Institutional Arrangement

Most of the policies affect multiple economic sectors and multiple stakeholder groups across different levels of governance. Therefore, it is important to establish a proper coordination mechanism in order to implement a policy in an effective and efficient manner. Institutional arrangement does so by setting clear roles and responsibilities for all relevant actors and laying procedures that guide these stakeholders.

When developing an institutional structure for the MRV of an RE policy (reverse auction policy) in Cambodia, it is important to understand the existing governance structure and the reporting lines in the sector. The proposed institutional arrangement is based on the existing set up with necessary adjustments.

4.2.1 Existing Institutional Arrangement of the Energy Sector

Following are the key players in policy making and operations of the energy sector (Asian Development Bank, 2018).

The Ministry of Mines and Energy (MME) is the main decision maker regarding the energy sector activities. The MME has the authority for the formulation of policies, strategies, plans and technical standards for the energy sector.

Electricity Authority of Cambodia (EAC) functions as the regulator, safeguarding the rights of the consumers in the energy industry. The EAC has authority to issue rules, regulations, and procedures on power market operations while it is responsible for awarding licenses and setting tariffs.

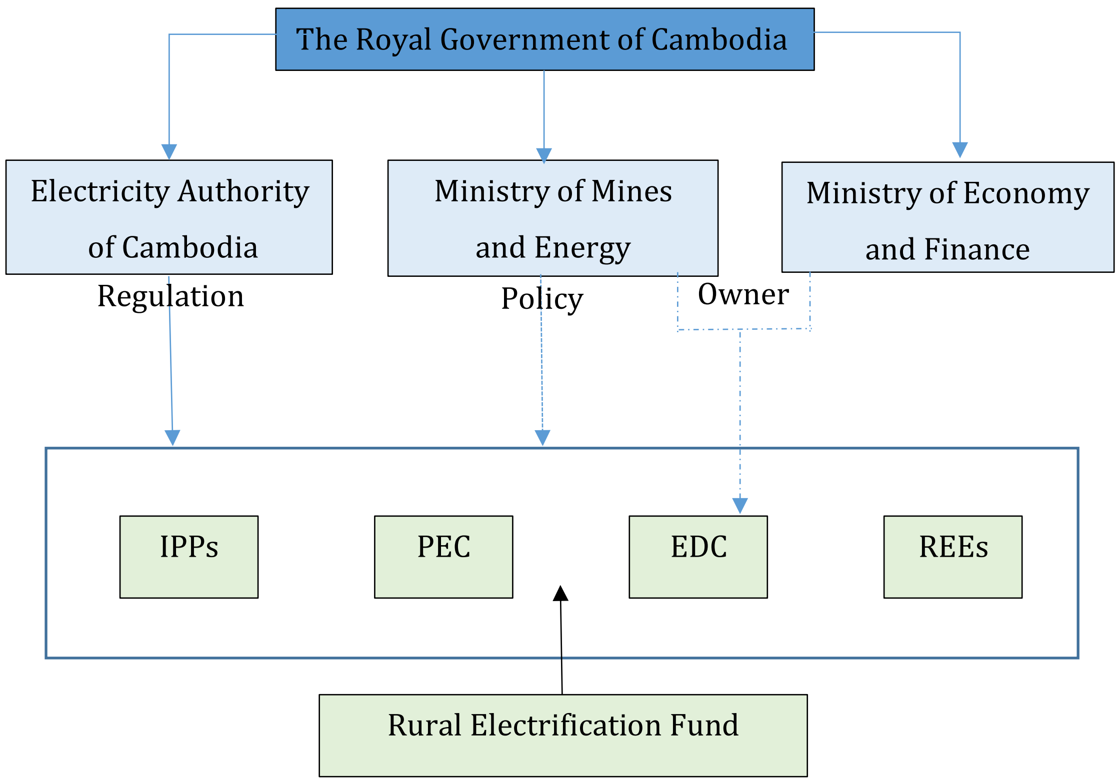
Electricite Du Cambodge (EDC) is a state-owned utility carrying out the functions of generation, transmission and distribution of electricity. The EDC purchases electricity from Independent Power Producers (IPPs) and sells electricity to Rural Electricity Enterprises (REEs) as well.

IPPs and REEs are privately owned while all other organizations in the industry are government entities.

Rural Electrification Fund (REF) is responsible for subsidizing rural electrification. As per the mandate, REF is responsible for promoting equitable rural electrification coverage by facilitating the population's access to electricity for economic, social, and household uses at affordable prices. Further REF also encourages private sector to participate in providing sustainable rural electrification services through the economic, technical, and commercial exploitation of well-proven, new, and renewable energy technologies.

Ministry of Economy and Finance (MEF) is the focal point for structural reform; international economic and financial cooperation and integration; lobbying for foreign aid and preparing plans for borrowing and repayment of foreign loans; and facilitating long-term and concessional finance. The MEF acts as a key stakeholder in preparing the energy policy.

Ministry of Environment (MoE) is authorized to review and approve the environmental assessments and environmental management plans of all energy projects.



Ownership control of EDC

Policy, planning and technical standard

Tariff, licenses, financial performance, enforcement of regulations, rules and standards

Subsidies and technical assistance for diesel REEs, mini and micro hydro projects and solar home systems

Figure 4.2 Existing Institutional arrangement

Source: MME, 2019

4.2.2 Institutional arrangement for addressing climate change

The administrative structure of the climate change related matters in Cambodia consists of different ministries, and departments operated within the NCSD.

Figure 4.3 provides the institutional arrangement established to address the climate change in Cambodia.

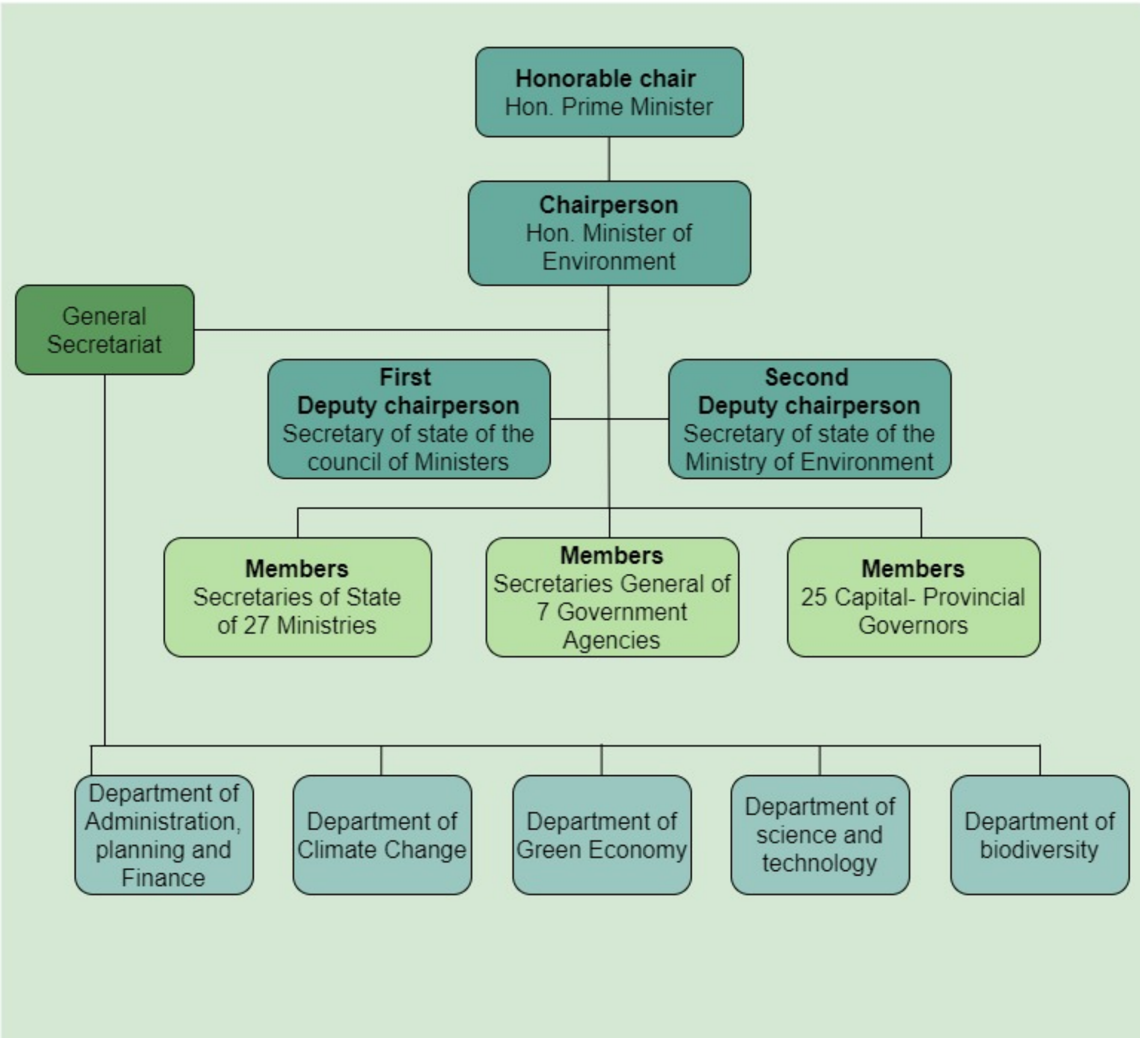


Figure 4.3 Institutional arrangement of NCSD

Source: Department of climate Change, 2014

Ministry of Environment (MoE)

The MoE, which is the national focal point to the UNFCCC with functions as the institutional head on environment and climate change related matters.

National Council for Sustainable Development (NCSD)

NCSD is mandated to prepare, coordinate and monitor the implementation of policies, strategies, legal instruments, plans and programmes related to all areas of sustainable development and to monitor and report on Cambodia's implementation of its international commitments to the respective international bodies. The council comprises of high-level representatives (Secretaries and Under-Secretaries of State) of concerned government ministries and agencies, with the Hon. Prime Minister as its Honorary Chair and the Hon.Minister of Environment as its Chair. List of the members is given in Annex V (Department of Climate Change, 2014).

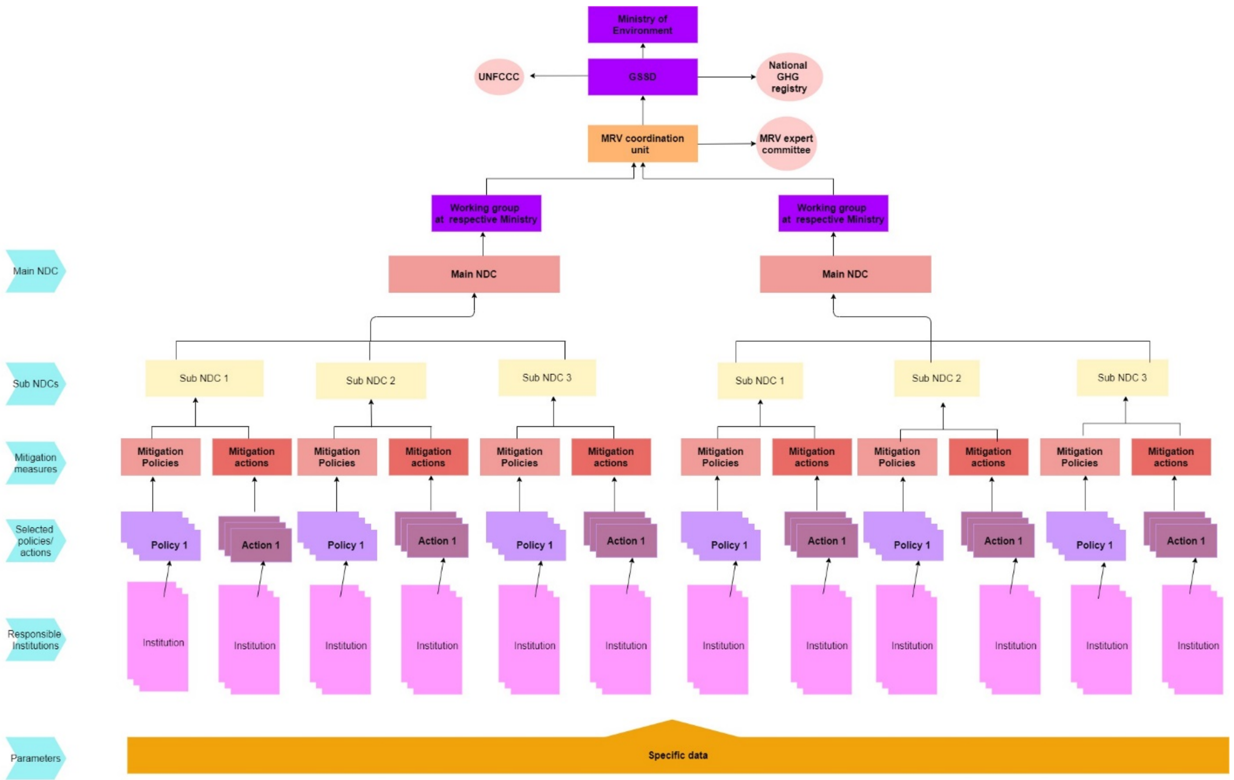
General Secretariat of Sustainable Development (GSSD)

GSSD, which is the general secretariat to the NCSD, acts as the functional focal point to the UNFCCC. It is responsible for the preparation and implementation of legal instruments, policies, strategic plans, action plans, programmes, and projects related to sustainable development. GSSD also coordinates the stakeholders at national, regional and international levels. More details on the roles and responsibilities of the GSSD is given in Annex VI (Department of Climate Change, 2014).

Department of Climate Change

DCC is the technical national focal point of the Cambodia. It plays an important role as the coordinating body for climate change activities including information sharing and networking. It is also responsible for data collection, compilation and preparation of GHG inventory, BURs and NDCs of the country. More details on the roles and responsibilities of the DCC are given in Annex VI (Department of Climate Change, 2014).

4.2.3 Proposed national institutional arrangement for implementing the MRV system in Cambodia



Existing institutions

Proposed institutions

Existing institutions

Proposed institutions

Figure 4.4 Proposed National Institutional Arrangement for implementing the MRV system

Source: Author

Figure 4.4 illustrates the proposed institutional arrangement for implementing an MRV system in Cambodia, which covers the MRV of proposed mitigation efforts (mitigation policies[25] and actions[26]) under the NDCs. The proposed national institutional arrangement will help to track the achievement of NDCs in energy industries, manufacturing industries, transport and other industries, and track the NDC achievements of the country. As proposed institutional arrangement represents the national level data collectors, coordinators, and national and international reporters, this will improve the efficiency and accuracy of the national and international reporting process. Proposed institutional arrangement is capable of linking future national MRV systems for all the NDCs.

4.2.4 Proposed overall national institutional arrangement for implementing MRV system of RE policy in Cambodian power sector.

As per the NDCs submitted to the UNFCCC, Cambodia expects to reduce the GHG emissions by 16% from energy industries in 2030 compared to the baseline emissions. The RGC has proposed 8 sub NDCs (mitigation measures) to achieve this target.

1. Connect decentralized renewable generation to the grid
2. Promote grid connected hydro power generation
3. Promote grid connected biomass energy generation
4. Promote grid connected solar power generation
5. Promote grid connected biogas energy generation
6. Promote off-grid solar home systems
7. Promote energy efficiency by end users
8. Promote off-grid hydro power generation (pico, mini and micro)

Respective authorities of the country follow different strategies to achieve these sub NDCs such as introducing mitigation policies (e.g. reverse auction policy to promote solar energy) and implementing different mitigation actions (e.g. introducing solar home systems to rural households). However, in order to increase the transparency of these achievements, NDCs need to be tracked and reported to the UNFCCC with the BTR of the country.

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[25] Policies which change management practices and/or consumer behaviours which ultimately reduces the GHG emissions

[26] Specific **actions**, projects, activities, or processes undertaken to reduce or prevent emission of greenhouse gases

NDC tracking can be done by analyzing the GHG impacts of the proposed policies or actions. Various data from different institutions will be needed for the analysis. A properly designed institutional arrangement will make this process efficient and systematic.

Figure 4.5 proposes an institutional arrangement to implement the proposed RE MRV system in Cambodia. For data and parameters, it specifically indicates the data and parameters required to assess the GHG impacts of reverse auction policy to promote grid connected solar power generation. (Please see Annex VIII for a larger version of the diagram)

System consists of data providers, existing working group at the MME, MRV coordination unit at GSSD, MoE and NCSD. Roles and responsibilities of each institutions are described below.

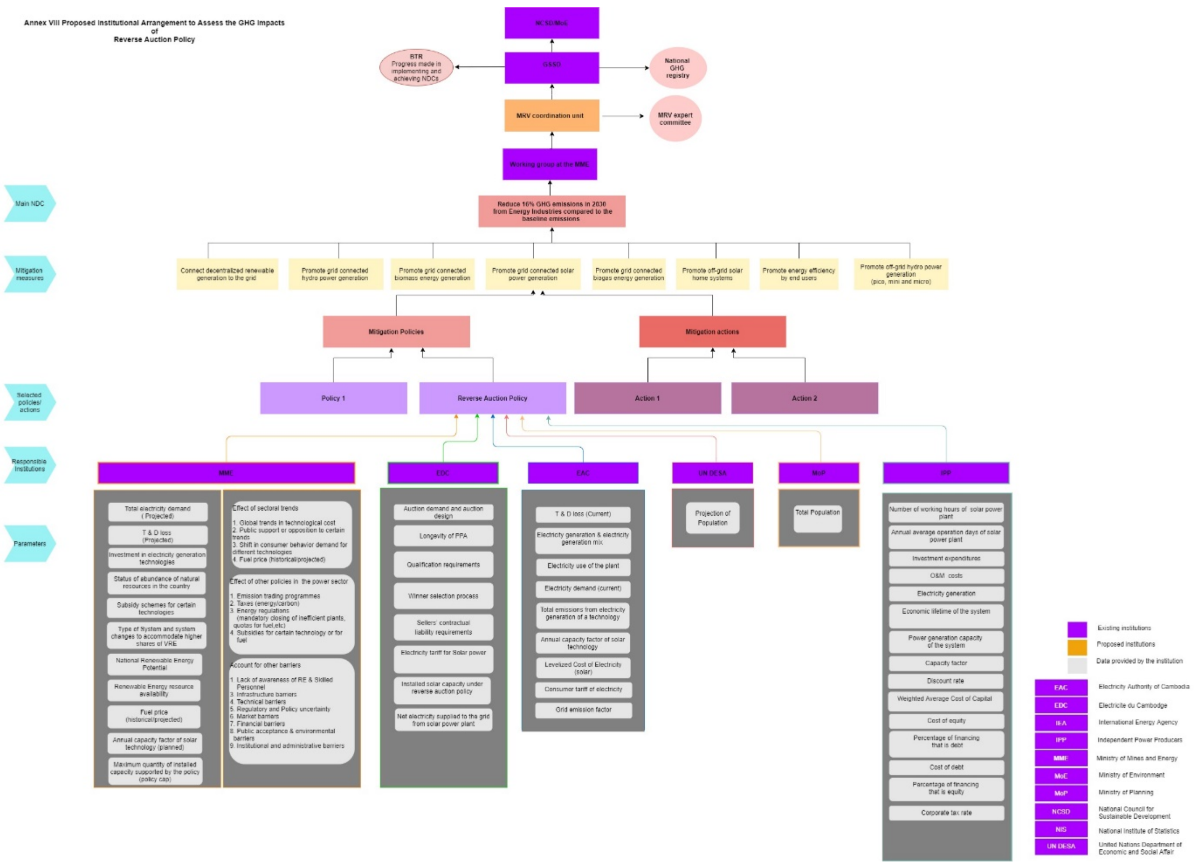

Figure 4.5 Proposed Institutional Arrangement for RE MRV system

Source: Author

Ministry of Environment/NCSD

Ministry of Environment and NCSD are responsible for the overall functioning of the MRV system

MRV Coordination Unit at GSSD

Contribution from different stakeholders, who will act at different capacites, is required to establish a successful MRV system. Since the MRV system is a relatively new concept for many stakeholders, it is important to establish guidelines for data collection, reporting, calculation, etc. AS GSSD already has experience in facilitating the preparation of legal instruments, policies, strategic plans, action plans, programmes and projects related to sustainable development, it is suggested to establish an MRV coordination unit at the GSSD. The unit may include an MRV expert representing each sector (MRV expert of energy industry, transport sector, manufacturing industry, forestry, agriculture, etc.). Roles and responsibilities of the proposed MRV coordination unit are listed in Table 4.3.

Apart from these responsibilities, GSSD will be responsible for reporting the required data to the UNFCCC.

Table 4-3 Responsibilities of the MRV coordination unit

Responsibilities of the MRV coordination unit
Provide guidance and training to stakeholders for: i) collecting, recording, reporting, and analysing data accurately; and ii) Assessment of GHG impacts of mitigation policies and actions
Channel technical and financial support for MRV of RE policy
Establish extensive and effective communication channels with the stakeholders
Plan and conduct all coordination and consultation activities with governmental and if appropriate non-governmental stakeholders in relation to MRV of policies, strategies and mitigation actions
Build capacities of the stakeholders and keep track of capacity-building efforts, domestic (unilateral) as well as international
Conduct an evaluation exercise to identify key lessons learnt and areas for improvement.

Compile and integrate all the sectoral MRV reports and transform them into a cohesive document to be submitted to UNFCCC
Incorporate reporting from all line ministries and their regulatory bodies and keep an updated registry of relevant actions (e.g. policies and projects);
Collect and aggregate information on new RE policies, and direct those to the MRV process
Maintain and update the registry of all the RE projects in the country
Reflect on the progress of policy implementation and adjust to new circumstances
Keep the MRV expert committee informed of progress and emerging issues
Establish guidelines for quality control and quality assurance of collected data; and develop and oversee the implementation of a quality assurance/quality control strategy for the entire MRV process
Mediate between parties when concerns surface, for example, over a disagreement in terms of responsibilities or a potential conflict of interest

Source: Adapted from National MRV framework for transport sector in Sri Lanka, 2019

Existing working group

As illustrated in Figure 4.1, data will be required from different entities regulated by the same ministry. Therefore, establishment of a coordination unit will be essential to ensure the efficiency and comprehensiveness of data collection and processing. Existing working group at the ministries will coordinate and process the sector specific data. As most of the data providers are regulated by the respective ministry, existing working group at the ministry level will improve the tendency of data submission. Further, it will also make the coordination process easier.

Data collection, quality assurance and quality control of the collected data, and calculation of GHG emission reductions will be the main responsibilities of the existing working group at the ministry. Existing working group at the ministry will be assigned for the responsibilities given in Table 4.5. To achieve these responsibilities, the existing working group which already function under the ministry will form three main teams; namely data collection team, QA/QC team and the technical team.

Figure 4.6 illustrates the proposed teams within the existing working group. Data collection, QA/QC, and technical teams will have separate team leaders. All three teams will be guided by the leader of the existing working group. The existing working group will report the calculated GHG emissions annually to MRV expert committee for verification.

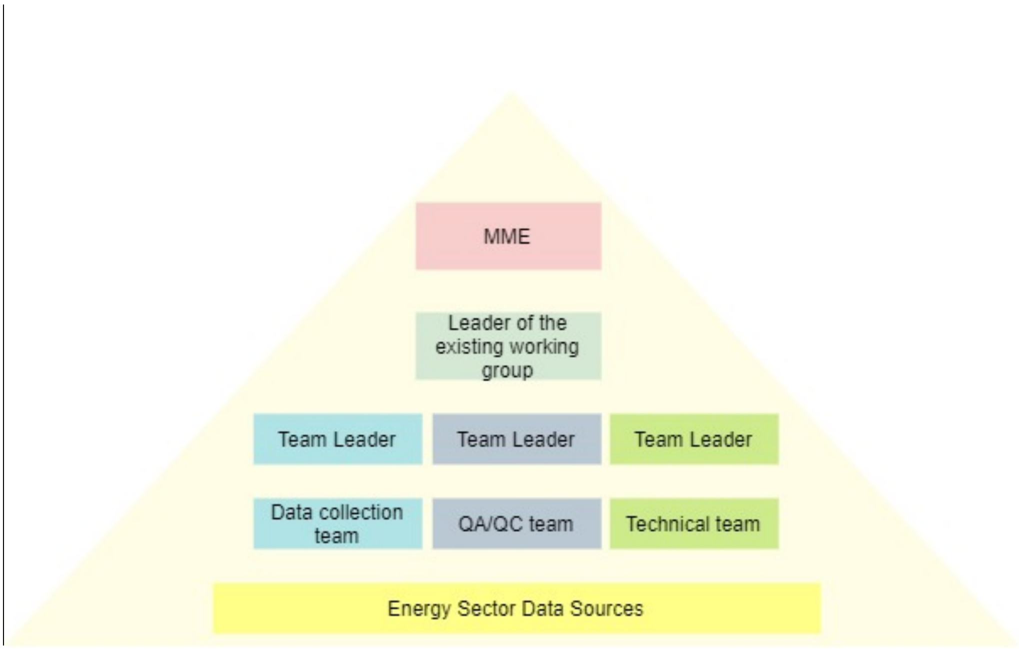

Figure 4.6 Teams to be established under the existing working group

Source: Author

Table 4-4 Responsibilities of the energy sector Existing working group

Responsibilities of Energy sector working group
Coordination of the flow of information from individual institutions and ministries for a collective assessment of impacts and multiple benefits of policies, strategies and actions
Calculation of GHG impacts of RE sector policies, strategies and actions
Quality assurance and quality control of data
Identifying all institutions that will be involved in data collection
Allocating responsibilities for all institutions ensuring that there is a clear lead for each institution, and establish an institutional level formal approval process
Developing a time frame and a schedule for the preparation and submission of necessary data including specific dates for deliverables, and monitoring the execution

Documenting systematically, as appropriate, all the assumptions, data and methods used
Storing and safe keeping of data and calculations.

Source: Adapted from National MRV framework for transport sector in Sri Lanka, 2019

MRV Expert Committee

Completed calculations need to be verified by a third party to ensure that calculations meet the international standards. Therefore, existing working groups at the ministries will submit the GHG emissions reductions calculations annually to the MRV expert committee through the MRV coordination unit. The Committee may include an MRV expert representing each sector (MRV expert of energy industry, transport, manufacturing industry, forestry, agriculture, etc.).

The committee will be appointed by the Minister in charge of MoE. Responsibilities listed in Table 4.4 need to be taken into account when appointing the committee.

Committee will be chaired by the Director General of the GSSD. The experts may be selected from the National GHG inventory team. Chairman of the committee may decide the composition based on the requirement.

Table 4-5 Roles and responsibilities of MRV expert committee

Roles and responsibilities of MRV expert committee
Verify the emission reduction calculations carried out by existing working groups at the ministries.
Provide necessary guidance and feedback to existing working groups at the ministries on calculations and selected methodologies.
Make recommendations for improving the data collection processes
Study and update the emission factors for relevant sectors
Provide recommendations on suitable methodologies to calculate the impact of the mitigation actions
Establish systems and procedures for the verification of reported impacts of policies

Source: Adapted from National MRV framework for transport sector in Sri Lanka, 2019

4.3 Quality assurance and Quality Control

IPCC guidelines for National Greenhouse Gas Inventories, 2006 defines the quality control as "a system of routine technical activities to assess and maintain the quality of the inventory as it is being compiled."

Quality Assurance (QA) is "a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process" (IPCC, 2006).

Table 4-6 Responsibilities of QA/QC teams

Roles and Responsibilities of QA and QC teams
QC team • Check the accuracy of data acquisition and calculations • Review the use of approved standardized procedures for emission and removal calculations, measurements, estimating uncertainties, archiving information and reporting • Conduct a technical review of categories, activity data, emission factors, other estimation parameters, and methods
QA team • Verify that measurable objectives were met • Ensure that the inventory represents the best possible estimates of emissions and removals given the current state of scientific knowledge and data availability

Source: IPCC, 2006

As per the IPCC guideline, establishment of a QA/QC system will be required to perform the above-mentioned roles and responsibilities. Figure 4.7 illustrates the major elements of a QA/QC and verification system.

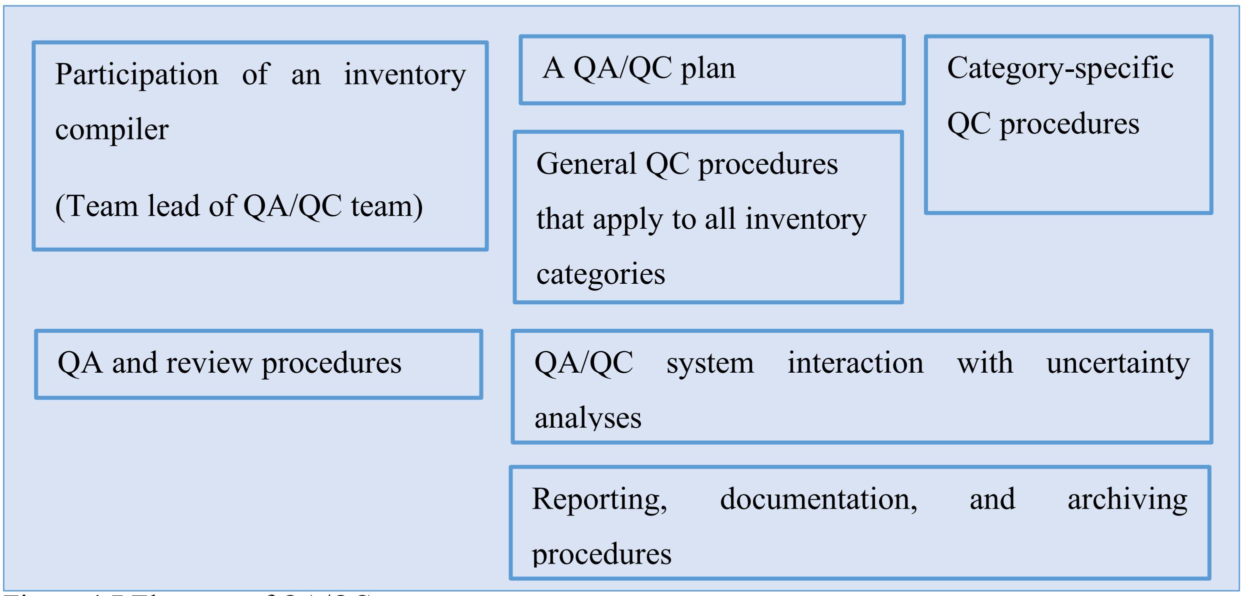

Figure 4.7 Elements of QA/QC system

Source: IPCC Guidelines for National Greenhouse Gas Inventories, 2006

QA/QC plan

A QA/QC plan is used to define the criteria and processes to ensure and verify that data meet specific data-quality objectives throughout the Data Lifecycle. Such data quality objectives may be based upon and refined from the principles such as timeliness, completeness, consistency, comparability, accuracy, transparency and improvement.

General QC procedure

General QC procedures include generic quality checks related to calculations, data processing, completeness, and documentation that are applicable to all inventory source and sink categories. Annex IV, provides a check list that can used for the quality check throughout the process.

Category – specific QC procedures

Category-specific QC complements general inventory QC procedures, and is directed at specific types of data used in the methods for individual source or sink categories. Category-specific QC activities include both emissions (or removals) data QC and activity data QC. The relevant QC procedures will depend on the method used to estimate the emissions or removals for a given category.

Emission factors used for the calculations can be either IPCC default values, country specific or direct emission measurements. The QC process which may be selected varies depending on the selected emission factor. More details on this aspect are given in Chapter VI of the IPCC guidelines for National Greenhouse Gas Inventories, 2006.

Activity data can also be categorized as national level and site-specific activity data. If national level activity data are selected for the assessment, following fundamental QC checks should be considered:

I) QC checks on reference sources for national activity data;

II) Comparisons with independently compiled data sets;

III) Comparisons with samples;

IV) Trend checks of activity data. If site specific data were selected, QC will be checked by: I) QC checks of measurement protocol; II) Comparisons between sites and with national data; and III) Production and consumption balances

QC related to the calculation will include checking the algorithm of the calculation, safeguards against duplication of inputs, unit conversion errors, and or similar calculation errors.

QA procedure

As per the IPCC guidelines, QA procedures include reviews and audits to assess the quality of the inventory, to determine the conformity of the procedures followed, and to identify areas where improvements could be made.

QA/QC uncertainty estimates

The QA/QC process and uncertainty analyses provide valuable feedback to one another. They can identify critical components of the inventory estimates and data sources that contribute to both the uncertainty level and inventory quality. Primary focus for improving the monitoring and reporting process would fall on such critical components.

5 Verification

Relevant institutions will report the required data annually to the existing working group of the respective ministry. The authenticity and accuracy of the data will be verified by the QA and QC unit of the ministry. After that, the GHG impact of concerned policy calculated by the existing working group will be verified by the MRV expert committee. Finally, the verified calculations will be approved by MRV coordination unit at the GSSD.

6 Recommendations

Institutional arrangement

Currently Cambodia does not have a formalized institutional arrangement to regulate the MRV activities. Existing MRV activities are conducted through the technical working group, which includes the line ministries and national entities. Adopting the proposed institutional arrangement will help authorities to assign roles and responsibilities to the stakeholders; to manage the data collection process, calculations and reporting; and to improve the verification process; efficiently and systematically.

Regulatory framework revision

Currently Cambodia does not have a mandatory GHG reporting system or regulations. This causes difficulties in obtaining activity data due to the unavailability of data, confidential nature of some data, unavailability of designated officers to collect and disseminate data, etc. As part of the implementation of the MRV system for RE policies, the required regulations and mandates for reporting should be developed to empower the "Existing working group at the ministry" in order to collect data. This ensures the regulated access to confidential data and provides additional assurances for data providers. Introduction of mandatory reporting regulations also ensures that the identified data gaps are addressed for effective reporting to the system and that the MRV system is periodically compiled in a sustainable manner. Any changes in regulations has to be properly communicated to all the relevant stakeholders. At the same time, the existing regulatory framework should be revisited if all the NDCs are translated to policies.

Ensure good institutional coordination - Most of the time, the relevant ministry is unaware of their roles and responsibilities in relation to MRV activities. Proper communication among the respective ministries regarding the MRV activities are vital to maintain an effective MRV system. Proposed MRV coordination unit will play an important role in ensuring the proper coordination among the diverse set of stakeholders.

Capacity and awareness building- Stakeholders should be properly trained to enhance technical skills. They should be educated on the roles and responsibilities of persons in each institution and MRV process and procedure. A well-structured training programme should be conducted for the “Existing working group at the ministry”. After training the stakeholders, user-friendly manuals can be given for reference. Performance review meetings on the MRV system should be held annually to reflect on the performance and identify challenges in implementing the RE policy MRV system.

Human capacity - Human capacity is required to ensure that the necessary data are collected and reported periodically and systematically. Since there are new institutions such as MRV coordination unit at GSSD, sufficient number of staff with relevant skills should be recruited.

High level support - Support from the high-level officials is essential “Because the benefits of monitoring reporting systems do not necessarily secure directly to the entities that provide data to such systems. These entities may see few incentives in providing data. for this reason and specially in the context of centralized monitoring and reporting systems clear mandate and high level support are often needed” (Bakhtiari, Hinostroza, & Puig, 2018). Therefore, it is necessary to ensure the support from the officials of the MME as well as from other related ministries in order to effectively implement the MRV system. This can be achieved by raising awareness among all government agencies about the needs and benefits of an MRV system.

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Annex I Summary of Cambodia's NDCs

Information Contained in Cambodian NDC	Mitigation	Target	Unconditional	Reduce GHG emissions by 27% from BAU levels in 2030 in energy, manufacturing, and transportation sectors.
			Conditional	Additional LULUCF contribution of 4.7tCO_2e/ha/year (equivalent to 10.6 MtCO_2eq of additional sequestration compared to BAU).
		Basis of Target	Analytical Basis	• Mitigation potential evaluated based on sectoral reductions and "previous needs analyses, experience from successful projects, pilot projects, feasibility studies, literature reviews, and expert opinion." • BAU projections developed using the LEAP model for energy sector and COMAP for LULUCF sector.
			Existing Policies	• Cambodia Climate Change Strategic Plan 2014-2023 • Green Growth Policy and Roadmap • National Forest Program (2010-2029)
			Mitigation Actions	• Mitigation actions include: ✓ 16% reduction in energy emissions (1.8 MtCO_2e). Includes renewable generation and promoting energy efficiency. ✓ 7% reduction in manufacturing emissions (0.727 MtCO_2e). Includes renewable energy and energy efficiency for factories and brick kilns. ✓ 1% reduction from other sources (0.155 MtCO_2e). Includes energy efficient buildings, cook stoves, and biodigesters.

			✓ Increase forest cover to 60% of total land cover through the implementation of the National Forest Program (2010-2029) and the Forest Law Enforcement, Governance and Trade program. ✓ 3% reduction in transport emissions (0.39 $MtCO_2eq.$). Includes mass transit and motor vehicle inspections.
	Adaptation	Included in NDC	Yes
	Adaptation	Implementation Strategies	Yes; climate change adaptation is mainstreamed in national and subnational planning, included through the National Adaption Plan.
	Adaptation	Priority Sectors	Agriculture; Infrastructure; Forestry; Health; Coastal Zones.
	Adaptation	Data Quality & Transparency	The NDC includes qualitative actions to incorporate adaptation into Cambodia's priority sectors.
	Participation		The NDC developed under the National Council for Sustainable Development, which has representatives from relevant ministries.
	Financial Assistance		US$1.27 billion is required for the implementation of the NDC activities (upto 2018).
	Technical Needs Identified in the INDCs		• Technical support to develop the MRV and M&E systems. • Technical support for a detailed technology needs assessment.
Information from other sources	GHG Inventories and Reports		• Submitted First National Communication in 2002. • Second National Communication is under development. • Latest inventory submitted to the UNFCCC was for 1994 (prepared using Tier 1 methodology following IPCC 1996 Guidelines). • No BUR submitted to date.

Source: Kingdom of Cambodia,2017

Annex II Information to be provided in the BTR on mitigation policies

Information to report in the BTR	BTR requirement	NDC requirement	NC requirement	BUR requirement
Information on actions, policies and measures (tabular for- mat in BTR)	• Name		• Information on pro- grammes containing measures to mitigate climate change (may)	• Name
	• Description		• Information on pro- grammes and measures implemented or planned which contribute to mitigation, including, as appropriate, relevant information by key sectors, on methodologies, scenarios, results, measures and institutional arrangements (encouraged)	• Information on programmes and measures implemented or planned which contribute to mitigation, including, as appropriate, relevant information by key sectors, on methodologies, scenarios, results, measures and institutional arrangements (encouraged)
	• Objectives			• Quantitative goals
	• Type of instrument (regulatory, economic instrument or other)			• Objectives of the action and steps taken or envisaged to achieve that action

	• Status (planned, adopted or implemented)			• Progress of implementation of the mitigation actions, steps taken or envisaged
	• Sector(s) affected			• Sector
	• Gases affected			• Gases
	• Start year of implementation			• Progress indicators
	• Implementing entity or entities			• Information on international market mechanisms
	• Estimates of expected and achieved GHG emissions reductions (encouraged, if flexibility is needed)			• Results achieved, such as estimated outcomes and estimated emission reductions
	• Costs (may report)			
	• Non-GHG mitigation benefits (may report)			
	• How the mitigation actions			

	interact with each other (may report)			

Information to report in the BTR	BTR requirement	NDC requirement	NC requirement	BUR requirement
Information on actions, policies and measures (in narrative format or as an annex to the BTR)	• Methodologies and assumptions used to estimate the GHG emissions reductions or removals by each action, policy and measure	• Assumptions and methodological approaches used for accounting for the implementation of policies and measures or strategies in the NDC	• Use whatever methods available and appropriate to formulate and prioritize programmes containing measures to mitigate climate change; this should be done within the framework of sustainable development (encouraged)	•Information on methodologies and assumptions
	• Those actions, policies and measures that are no longer in place compared with the most recent BTR, and why they are no longer in place (should report)		Use appropriate technical resources to assess mitigation programmes (may report)	
	• Actions, policies and measures that influence GHG emissions from international			

	transport (should report)			
	• How the actions, policies and measures are modifying longer-term trends in GHG emissions and removals (should report)			
	• Assessment of economic and social impacts of response measures (encouraged to provide detailed information)		• Information on any steps taken to integrate climate change into relevant social, economic and environmental policies and actions (encouraged)	
Adaptation actions and/ or economic diversification plans resulting in mitigation co-benefits	• Sectors and activities associated with response measures	• Specific projects, measures and activities to be implemented to contribute to mitigation co-benefits		
	• Social and economic consequences	• How the economic and social		

	from the response measures' actions	consequences of response measures have been considered in developing the NDC		
	• Challenges and barriers to address the consequences			
	• Actions to address the con-sequences			

Source: Unfolding the reporting requirements for Developing Countries under the Paris Agreement's: Enhanced Transparency Framework, 2020

Annex III Energy Sector policies and strategies

Following table summarizes various policies, strategies and other relevant activities in the energy sector.

Law/ Policy /Plan	Title	Year	Current status	Purpose
Policy	Energy Sector Development Policy	1994	Some targets have been achieved.	• To provide an adequate supply of energy at a reasonable and affordable price throughout Cambodia; • To ensure a reliable, secure electricity supply at prices which facilitate investment in Cambodia and development of the national economy; • To encourage environmentally and socially acceptable development and exploration of energy resources for all sectors of Cambodian economy; • To encourage the efficient use of energy; and • To minimize detrimental environmental effects resulting from energy supply and use.
Law	The Law on Electricity - 2001	2001	Amended in 2015	• To govern and prepare a framework for the electric power supply and services throughout the Kingdom of Cambodia
Plan	Renewable Electricity Action Plan (REAP) 2002-2012	2002	Expired	• Introduce and encourage the implementation of the rural electrification policy, targeting the rural areas by emphasizing the adoption of the new and existing RE technologies.

	Rural Electrification Fund	2004	Achieved the installation of 929.47 MW hydro power capacity through the fund. (Enforced)	• To facilitate the poor households in rural areas to have access to electricity for their houses from grid supply by providing interest free loan to be repaid in instalments, • To facilitate the remote rural household, which is not likely to have access to the electricity network for a long period, to have access to electricity through Solar Home System, • To facilitate the private electricity supplier in rural areas to access funding for investment on expansion of electricity supply network in order to allow all rural households in its license areas to have access to electricity, • To facilitate the poor households in rural areas to have access to electricity with low price under the Framework of Strategic Planning for Reduction the Rate and Gap of the tariff for Sale of the Electricity in the Kingdom of Cambodia for the year 2015 to 2020 in Provinces and Cities, and To provide electricity for pumping for agricultural irrigation uses.
Plan	National Strategic Development Plan (NSDP)	2019	Recently updated to NSDP (2019-2023) & Enforced	• Operational and guiding tools to achieve the objectives, goals and targets. • Practical document to achieve realistic, specific high priority national targets. (Chapter 6 of this plan has an M&E section that cover energy sector too)
Policy	Rural Electrification	2006	A Master Plan Study on Rural Electrification by	• To increase opportunity for renewable energy technologies through adopting an actionable framework.

	by Renewable Energy Policy (REREP) 2006-2020		Renewable Energy (RE) in the Kingdom of Cambodia was prepared in 2006 with ICA support. RE targets have also been set up until 2020.	• To increase access to electricity in rural areas nationwide.
Road Map	National Policies and Strategies on Green Growth	2009	The National Green Growth Roadmap (NGGR) was adopted in 2009 (MoE, 2009)	• To green the development sector through creating an enabling environment for green investment to grow in Cambodia
Policy & Strategies	National Policies and Strategies on Green Growth	2013	The National Policy of Green Growth and the National Strategic Plan on Green Growth 2013 – 2030 adopted in 2013 (NCGG, 2013)	• To promote national economy with - growth stability, - reduction and prevention of environmental pollution, - safe ecosystem, - poverty reduction, and • To promote: - public health service, - educational quality, - natural resource management, - sustainable land use, and water resource management Furthermore, policy encourages energy efficiency improvements, ensuring food safety and promoting or glorifying the national culture in Cambodia

Policy	National Energy Efficiency Policy (2018 – 2035)	2017	Draft	• Reduce energy demand by 20% in 2035 relative to the business as usual scenario (BAUs) • Reduce CO_2 emissions by 3 million tons in 2035, or 28.5 million tons cumulatively between 2017 and 2035, relative to the BAU scenario • To save energy consumption of 1 million tons of oil equivalent (toe) by 2035 relative to the BAU scenario • To reduce energy intensity by 65% in 2035, relative to 2014

ANNEX IV General Inventory QC procedure

GENERAL INVENTORY QC PROCEDURES	
QC Activity	**Procedures**
Check that assumptions and criteria for the selection of activity data, emission factors, and other estimation parameters are documented.	• Cross-check descriptions of activity data, emission factors and other estimation parameters with information on categories and ensure that these are properly recorded and archived.
Check for transcription errors in data input and references.	• Confirm that bibliographical data references are properly cited in the internal documentations. • Cross-check a sample of input data from each category (either measurements or parameters used in calculations) for transcription errors.
Check that emissions and removals are calculated correctly.	• Reproduce a set of emissions and removals calculations. • Use a simple approximation method that gives similar results to the original and more complex calculations to ensure that there is no data input error or calculation error.
Check that parameters and units are correctly recorded and that appropriate conversion factors are used.	• Check that units are properly labelled in calculation sheets. • Check that units are correctly carried through from beginning to end of calculations. • Check that conversion factors are correct. • Check that temporal and spatial adjustment factors are used correctly.

Check the integrity of database files.	• Examine the included intrinsic documentation - confirm that the appropriate data processing steps are correctly represented in the database. - confirm that data relationships are correctly represented in the database. - ensure that data fields are properly labelled and have the correct design specifications. - ensure that adequate documentation of database and model structures and operations are archived.
Check for consistency in data between categories.	• Identify parameters (e.g. activity data, constants) that are common to multiple categories and confirm that there is consistency in the values used for these parameters in the emission/removal calculations.
Check that the movement of inventory data among processing steps is correct.	• Check that emissions and removals data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries. • Check that emissions and removals data are correctly transcribed between different intermediate products.
Check that uncertainties in emissions and removals are estimated and calculated correctly.	• Check that qualifications of individuals providing expert judgement for uncertainty estimates are appropriate. • Check that qualifications, assumptions and expert judgements are recorded. • Check that calculated uncertainties are complete and calculated correctly. • If necessary, duplicate uncertainty calculations on a small sample of the probability distributions used by Monte Carlo analyses (for example, using uncertainty calculations according to Approach 1).

Check time series consistency.	• Check for temporal consistency in time series input data for each category. • Check for consistency in the algorithm/method used for calculations throughout the time series. • Check methodological and data changes resulting in recalculations. • Check that the effects of mitigation activities have been appropriately reflected in time series calculations.
Check completeness.	• Confirm that estimates are reported for all categories and for all years from the appropriate base year to the period of the current inventory. • For subcategories, confirm that entire category is being covered.
Trend checks.	• For each category, current inventory estimates should be compared to previous estimates, if available. If there are significant changes or departures from expected trends, re-check estimates and explain any differences. Significant changes in emissions or removals from previous years may indicate possible input or calculation errors. • Check value of implied emission factors (aggregate emissions divided by activity data) across time series. - Do any years show outliers that are not explained?

Review of internal documentation and archiving.	• Check that there is detailed internal documentation to support the estimates and enable reproduction of the emission, removal and uncertainty estimates. • Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review. • Check that the archive is closed and retained in a secure place following the completion of the inventory. • Check integrity of any data archiving arrangements of outside organizations involved in inventory preparation.

Source: IPCC Guidelines for National Greenhouse Gas Inventories,2006

Annex V - Members of the NCSD

Hon. Minister of Environment – Chair

A Secretary of State of the Council of Ministers – First Deputy

A Secretary of State for Environment – Second Deputy

A Secretary of State for Agriculture, Forestry and Fisheries

A Secretary of State for Mines and Energy

A Secretary of State for Water Resources and Meteorology

A Secretary of State for the Interior

A Secretary of State for National Defense

A Secretary of State for Foreign Affairs and International Cooperation

A Secretary of State for Economy and Finance

A Secretary of State for Rural Development

A Secretary of State for Commerce

A Secretary of State for Industry and Handicrafts

A Secretary of State for Planning

A Secretary of State for Education, Youth and Sports

A Secretary of State for Social Affairs, Veterans and Youth Rehabilitation

A Secretary of State for Land Management, Urban Planning and Construction

A Secretary of State for Information

A Secretary of State for Justice

A Secretary of State for National Assembly–Senate Relations and Inspection

A Secretary of State for Post and Telecommunications

A Secretary of State for Health

A Secretary of State for Public Works and Transport

A Secretary of State for Culture and Fine Arts

A Secretary of State for Tourism

A Secretary of State for Cults and Religion

A Secretary of State for Women's Affairs

A Secretary of State for Labour and Vocational Training

A Secretary of State for Public Functions

Secretary General of the Supreme National Economic Council

Secretary General of the Council for the Development of Cambodia

Secretary General of the National Committee for Subnational Democratic Development

Secretary General of the Agricultural and Rural Development Council

Secretary General of the National Committee for Disaster Management

Governors of the Capital Provincial Governing Boards

Secretary General of the Cambodian National Mekong Committee

Secretary General of the NCSD

Source: Department of Climate Change,2004

Annex VI - Roles and responsibilities of existing institutions

Roles and responsibilities of GSSD

- Coordinate and perform day-to-day work in accordance with instructions and decisions of the NCSD;
- Develop NCSD's programmes and work plans to submit to the NCSD for review and approval;
- Lead and coordinate implementation of the programmes and work plans approved by NCSD;
- Facilitate preparation of legal instruments, policy, strategic plans, action plans, programmes and projects related to sustainable development;
- Coordinate and support the implementation of legal instruments, policy, strategic plans, action plans, programmes and projects related to sustainable development and conduct review, monitoring and evaluation (M&E) and reporting regularly;
- Mobilize and manage resources for implementation of the legal instruments, policy, strategic plans, action plans, programmes and projects related to sustainable development;
- Propose establishment of mechanisms required for sectoral issues related to NCSD's roles and duties and provide support to relevant activities and regular operations of the mechanisms;
- Coordinate and support the strengthening of cooperation related to sustainable development with development partners, civil society, private sector, academia, and relevant stakeholders at national, regional and global levels;
- Lead and coordinate research and study, education, training and exchange of technologies related to sustainable development;
- Manage data and disseminate information related to sustainable development and NCSD's activities to the public;
- Review and study the possibility to participate in international agreements related to sustainable development for NCSD;
- Develop draft position papers and strategy for participation in international negotiations relevant to sustainable development;

- Facilitate preparation of national reports in accordance with international agreements relevant to sustainable development to which Cambodia is a party;
- Participate in national, regional and international meetings on issues related to sustainable development;
- Manage NCSD's finance and budget;
- Organize meetings, take minutes and produce reports of the NCSD;
- Develop monthly, quarterly, semi-annual, nine-monthly, and annual reports for NCSD; and
- Perform any other duties as assigned by the NCSD and chairperson of the NCSD's Executive Committee.

Source: Department of Climate Change,2004

Roles and responsibilities of Department of Climate Change

- Develop draft legal instruments, policy, strategic plans, action plans and budget, promote collaboration with relevant stakeholders, build staff capacity of the department, manage finances, conduct internal monitoring, and manage administration relevant to the roles and duties of the department;
- Coordinate and implement legal instruments, policy, strategic plans, action plans, programmes and projects to mitigate greenhouse gases (GHGs) and adapt to climate change as well as conduct monitoring and evaluation, and reporting regularly;
- Coordinate the development and management of GHGs inventories, national reports, and deliver government commitments under United Nations Framework Convention on Climate Change (UNFCCC);
- Coordinate to provide technical support in GHG inventory by sources;
- Coordinate assessment of climate change vulnerability and opportunity;
- Strengthen partnership and international cooperation to mobilize resources to respond to climate change;
- Propose fund development and management to support implementation of policy to respond to climate change;
- Design, develop and manage climate change information and knowledge management system;
- Disseminate government response to climate change to the public, development partners and international community;
- Perform duty as national focal point for international conventions, protocols, and agreements related to climate change;
- Coordinate with climate change focal point persons in relevant ministries and agencies;
- Develop monthly, quarterly, semi-annual, nine-monthly and annual reports of the department and the Secretariat; and
- Perform other tasks as assigned by NCSD's Secretary General.

Source: Department of Climate Change,2004