ICAT | INITIATIVE FOR Climate Action Transparency

RENEWABLE ENERGY METHODOLOGY

Assessing the greenhouse gas impacts of renewable energy policies

ICAT SERIES OF
ASSESSMENT GUIDES

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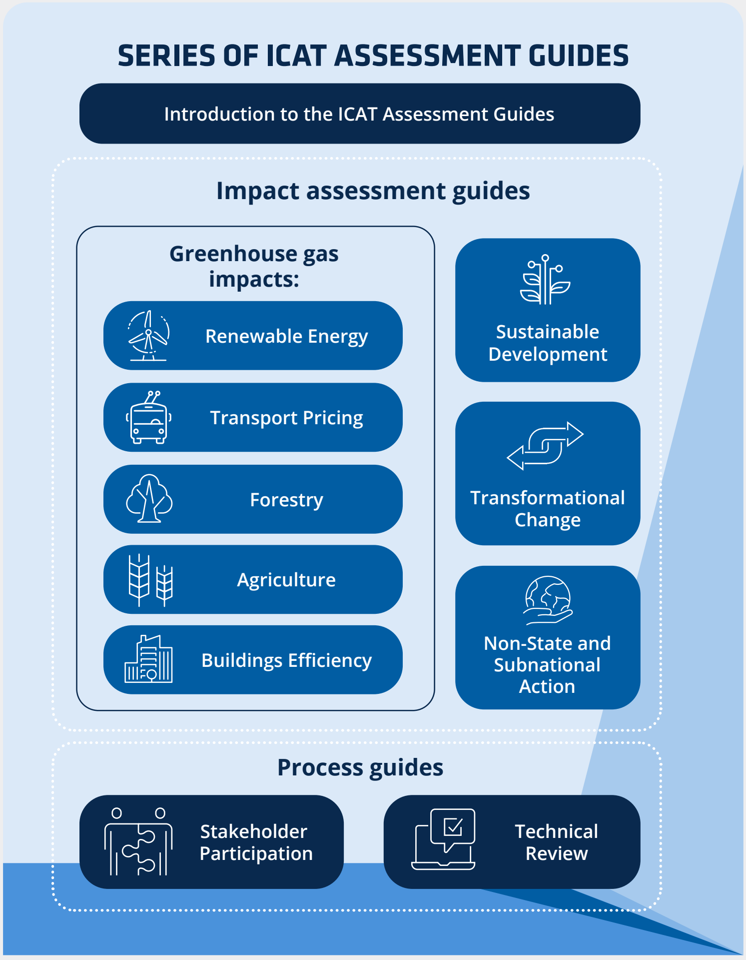
How to use the Assessment Guides

This guide is part of a series developed by the Initiative for Climate Action Transparency (ICAT) to help countries assess the impacts of policies and actions. It is intended to be used in combination with other ICAT assessment guides and can be used in conjunction with other guidance.



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PART I

Introduction, objectives, steps and overview of renewable energy policies

1 Introduction

Energy use is responsible for almost 75% of global greenhouse gas (GHG) emissions. More than 40% of these emissions come from electricity and heat production.[1] *A fundamental transformation of the energy system is required to achieve net zero global emissions in the second half of the 21st century.*

Renewable energy (RE) policies will play a significant role in this transition. Governments around the world are implementing increasingly ambitious policies to accelerate the move away from fossil fuel sources of energy to renewable sources. The declining cost of RE technologies and their potential to support sustainable development objectives are helping to accelerate the change.

In this context, there is an increasing need to assess and communicate the impacts of RE policies to ensure that they are effective in mitigating GHG emissions, advancing development objectives, and helping countries meet their sectoral targets and national commitments. The Initiative for Climate Action Transparency (ICAT) Renewable Energy Methodology *helps policymakers assess the impacts of RE policies and improve the effectiveness of policies. It can play a critical role in providing the information needed for preparing reports under the Paris Agreement's enhanced transparency framework and for the United Nations Sustainable Development Goals (SDGs).*

1.1 Purpose of the methodology

This document provides methodological guidance for assessing the GHG impacts of RE policies. The methodology provides a stepwise approach for estimating the effects of policy design characteristics, economic and financial factors, and other barriers on the potential for RE policies to achieve their technical potential for the assessment period. Methods are provided to convert this impact (expressed in terms of newly installed RE capacity or generated electricity) into GHG emissions reductions.

[1] WRI (2017).

This methodology is part of the series of ICAT guides for assessing the impacts of policies and actions. It is intended to be used in combination with any other ICAT documents that users choose to apply. The series of assessment guides is intended to enable users who choose to assess GHG, sustainable development and transformational impacts of a policy to do so in an integrated and consistent way within a single impact assessment process. Refer to the *Introduction to the ICAT Assessment Guides*[2] for more information about the ICAT assessment guides and how to apply them in combination.[3]

1.2 Relationship to other guidance and resources

This methodology uses and builds on existing resources mentioned throughout the document. These include the Clean Development Mechanism (CDM) large-scale consolidated methodology *ACM0002: Grid-Connected Electricity Generation from Renewable Sources*,[4] and the CDM Tool to Calculate the Emission Factor for an Electricity System.[5]

The methodology builds on the Greenhouse Gas Protocol *Policy and Action Standard* (© WRI 2014; all rights reserved)[6] and the draft *Policy and Action Standard – Energy Supply Sector Guidance*[7] (both of which provide guidance on estimating the GHG impacts of policies and actions, and discussion on many of the accounting concepts in this document, such as baseline and policy scenarios), to provide a detailed method for specific RE policies. The

[2] https://climateactiontransparency.org/wp-content/uploads/2020/01/Introduction-to-the-ICAT-Assessment-Guides.pdf

[3] https://climateactiontransparency.org/wp-content/uploads/2020/01/Renewable-Energy-Methodology-Executive-summary.pdf

[4] Available at: https://cdm.unfccc.int/methodologies/DB/8W400U6E7LFHHYH2C4JR1RJWWO4PVN.

[5] Available at: https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v2.pdf/history_view.

[6] Available at: www.ghgprotocol.org/policy-and-action-standard.

[7] Available at: www.ghgprotocol.org/sites/default/files/ghgp/standards_supporting/Energy%20Supply%20-%20Additional%20Guidance.pdf.

methodology adapts the structure, and some of the tables, figures and text from the *Policy and Action Standard*, where relevant. Chapters 1, 2, 4, 5, 6, 10 and 11, and the glossary include elements drawn from the *Policy and Action Standard*. Figures and tables adapted from the *Policy and Action Standard* are cited, but for readability not all text taken directly or adapted from the standard is cited.

A full list of references is provided at the end of this document.

1.3 Intended users

This methodology is intended for use by policymakers and practitioners seeking to estimate GHG mitigation impacts of domestic policies and actions in the context of development and implementation of nationally determined contributions (NDCs), national low emission development strategies, nationally appropriate mitigation actions (NAMAs) and other mechanisms. The primary intended users are developing country governments at any level (national, subnational or municipal), and relevant stakeholders who are implementing and assessing RE policies. Throughout the document, the term "user" refers to the entity implementing the methodology.

The main emphasis of the methodology is the assessment of GHG impacts. Impact assessment can also inform and improve the design and implementation of policies. Thus, intended users also include any stakeholders involved in the design and implementation of national RE policies, RE targets, NDCs, low emission development strategies and NAMAs, including research institutions, businesses and non-governmental organizations.

1.4 Scope and applicability of the methodology

This document provides general principles and concepts, and a stepwise method for estimating the GHG impacts of three types of RE policies:[8]

- **feed-in tariff policies (including feed-in premiums)** – policies that aim to promote RE deployment by offering long-term purchase agreements with power producers at a specified price per kilowatt-hour (kWh)
- **auction policies (including tender policies)** – competitive bidding procurement processes for renewable electricity in the form of either capacity (megawatt – MW) or electricity generated (megawatt-hour – MWh)
- **tax incentive policies** – policies under which authorities at the national, subnational or municipal level offer tax incentives for the installation and operation of RE installations.

These types of RE policies form the core of many policy packages that countries are using to promote RE and are further discussed in Chapter 3. RE can also be promoted via economic instruments (such as emissions trading programmes or carbon taxes), actions to change the regulatory environment (such as grid access), priority dispatch and wheeling, and capacity-building programmes (such as development initiatives by energy service companies). However, the focus of this methodology is on policies that specifically target RE deployment for grid-connected electricity generation, and these other types of instruments and actions are only discussed peripherally in this methodology. There is also scope for important RE policies to incentivize off-grid RE, and renewables-based heating and cooling (in particular, solar water heaters and geothermal technologies). Appendix F lists the full criteria used to choose the scope of the methodology.

This document is organized into four parts (see Figure 1.1). It details a process for users to follow when conducting a GHG assessment of RE policies. It provides guidance on defining the assessment, an approach to GHG assessment that includes ex-ante (forward-looking) assessments and ex-post (backward-looking) assessments, and monitoring and reporting. Throughout the document, examples are provided to illustrate how to apply the methodology.

The methodology is applicable to policies:

- at any level of government (national, subnational, municipal) in all countries and regions
- that are planned, adopted or implemented
- that are new policies or actions; or extensions, modifications or eliminations of existing policies or actions.

The methodology does not provide exhaustive accounting methods for all RE technologies. For

[8] Throughout this document, where the word "policy" is used without "action", it is used as shorthand to refer to both policies and actions. See Glossary for definition of "policy or action".

FIGURE **1.1**

Overview of the methodology

Part I: Introduction, objectives, steps and overview of renewable energy policies

Understand the purpose and applicability of the methodology (Chapter 1)
Determine the objectives of the assessment (Chapter 2)
Understand renewable energy policies (Chapter 3)
Understand assessment steps and principles (Chapter 4)

↓

Part II: Defining the assessment

Clearly describe the policy to be assessed (Chapter 5)
Indentify GHG impacts, and define the GHG assessment boundary and assessment period (Chapter 6)

↓

Part III: Assessing impacts

Estimate RE addition of the policy ex-ante (Chapter 7)
Estimate GHG impacts of the policy ex-ante (Chapter 8)
Estimate GHG impacts of the policy ex-post (Chapter 9)

↓

Part IV: Monitoring and reporting

Identify key performance indicators and parameters to monitor, and develop a monitoring plan (Chapter 10)
Report the results and methodology used (Chapter 11)

example, the GHG impact of electricity generation from biomass depends on the emissions associated with growing the biomass and any land-use change. In such cases, the methodology highlights technology-specific considerations and provides references to other resources, where possible, but does not provide detailed accounting methods.

1.5 When to use the methodology

The methodology can be used at multiple points throughout the policy design and implementation process, including:

- **before policy implementation** – to assess the expected future impacts of a policy (through ex-ante assessment)
- **during policy implementation** – to assess the impacts achieved to date, ongoing performance of key performance indicators, and expected future impacts of a policy
- **after policy implementation** – to assess what impacts have occurred as a result of a policy (through ex-post assessment).

Depending on individual objectives and when the methodology is applied, users can implement the steps for ex-ante assessment, ex-post assessment or both. The most comprehensive approach is to apply the methodology before implementation, regularly during policy implementation and again after implementation. Users carrying out an ex-post assessment only can skip Chapters 7 and 8. Users carrying out an ex-ante assessment only can skip Chapter 9.

1.6 Key recommendations

The methodology includes key recommendations that are recommended steps to follow when assessing and reporting impacts. These recommendations are intended to help users to produce credible and high-quality impact assessments that are based on the principles of relevance, completeness, consistency, transparency and accuracy.

Key recommendations are indicated in subsequent chapters by the phrase “It is a *key recommendation* to …”. All key recommendations are also compiled in a check list at the beginning of each chapter.

Users who want to follow a more flexible approach can use the methodology without adhering to the key recommendations. The *Introduction to the ICAT Assessment Guides* provides more information on how and why key recommendations are used within the ICAT assessment guides, and on following either the “flexible approach” or the “key recommendations approach” when using the documents. Refer to the *Introduction to the ICAT Assessment Guides* before deciding which approach to follow.

1.7 Alignment with the enhanced transparency framework of the Paris Agreement

This methodology can help countries to fulfil their accounting and reporting requirements under the enhanced transparency framework of the Paris Agreement. Specifically, the methodology can help countries understand the impacts of RE policies, estimate baseline emissions and GHG impacts, conduct projections, and monitor progress over time using indicators and parameters. This enables countries to account for their contributions and track progress towards implementation and achievement of their NDCs. Alignment of indicators and parameters (i.e. using the same indicators and parameters to assess the impacts of an RE policy and to meet reporting requirements of the transparency framework) is recommended for the following:

- Estimating baseline emissions and GHG impacts. Align input parameters used to estimate baseline emissions and GHG impacts of RE policies with the input parameters used for GHG accounting of NDCs (Chapter 8).

- Projections and assessment period. Align the parameters and assessment period used to develop projections for RE policies with the parameters and time frame used to meet reporting requirements of the transparency framework (Chapters 6 and 8).

- Monitoring and tracking progress towards NDCs. Indicators and parameters used in this methodology to monitor RE policy implementation can also be used to track progress towards implementation and achievement of an NDC (Chapter 10). Some indicators suggested in this methodology can be used to track sustainable development and transformational impacts (Chapter 6).

1.8 Process for developing the methodology

This methodology has been developed through an inclusive, multi-stakeholder process convened by ICAT. The development is led by the NewClimate Institute (technical lead) and Verra (co-lead), who serve as the secretariat and guide the development process. The first draft was developed by drafting teams, consisting of a subset of a broader Technical Working Group (TWG) and the secretariat. The TWG consists of experts and stakeholders from a range of countries identified through a public call for expressions of interest. The TWG contributed to the development of the technical content of the methodology through participation in regular meetings and written comments. The energy sector TWG contributed to both the ICAT *Renewable Energy Methodology* and the *Buildings Efficiency Methodology*. A Review Group provided written feedback on the first draft of the methodology. ICAT’s Advisory Committee, which provides strategic advice to ICAT, reviewed the second draft.

The second draft was applied by ICAT participating countries and other non-state actors to ensure that it can be practically implemented. The current version of the methodology was informed by the feedback gathered from that experience.

More information about the methodology development process, including governance of the initiative and the participating countries, is available on the ICAT website.[9]

All contributors are listed in the Contributors section.

[9] https://climateactiontransparency.org

2 Objectives of assessing the GHG impacts of renewable energy policies

This chapter provides an overview of objectives users may have in assessing the GHG impacts of RE policies. Determining the assessment objectives is an important first step, since decisions made in later chapters are often guided by the stated objectives.

Checklist of key recommendations

- Determine the objectives of the assessment at the beginning of the impact assessment process

Assessing the GHG impacts of RE policies is a key step towards identifying opportunities and gaps in effective GHG mitigation strategies. Impact assessment supports evidence-based decision-making by enabling policymakers and stakeholders to understand the relationship between policies and expected GHG impacts. It is a *key recommendation* to determine the objectives of the assessment at the beginning of the impact assessment process.

Examples of objectives for assessing the GHG impacts of a policy are listed below. The ICAT *Sustainable Development Methodology* and *Transformational Change Methodology* can be used to assess the broader sustainable development and tranformational impacts of RE policies, and users should refer to that methodology for objectives for assessing such impacts.

2.1 General objectives

- **Estimate the GHG impacts of policies to determine whether they are on track to help meet goals** such as NDCs or other emissions targets.
- **Maximize positive impacts** of policies, such as increased GHG emissions reductions, RE capacity addition and RE electricity generation.
- **Ensure that policies are cost-effective** and that limited resources are invested efficiently.

2.2 Objectives of assessing impacts before policy implementation

- **Improve policy design and implementation** by understanding the impacts of different design and implementation choices.
- **Inform goal setting** by assessing the potential contribution of policies to national goals and targets, such as NDCs.
- **Access financing** for policies by estimating potential GHG emissions reductions, or by estimating the RE capacity addition and RE electricity generation, together with a well-designed policy framework that fosters the development of bankable projects and businesses.

2.3 Objectives of assessing impacts during or after policy implementation

- **Assess policy effectiveness** by determining whether RE policies are delivering the intended results.
- **Improve policy implementation** by determining whether RE policies are being implemented as planned.
- **Learn from experience and share best practices** about policy impacts.
- **Track progress toward national goals and targets** such as NDCs, the SDGs of the 2030 Agenda for Sustainable Development and national RE targets/action plans, and understand the contribution of RE policies towards achieving them.
- **Inform future policy design**, including reformulation of NDCs towards enhanced ambition, and decide whether to continue current actions, enhance current actions or implement additional actions.

- **Report**, domestically or internationally, including under the Paris Agreement's enhanced transparency framework, on the impacts of policies achieved to date.

- **Meet funder requirements** to report on GHG emissions reductions, RE capacity addition or RE electricity generation.

Users should identify the intended audience(s) of the assessment report. Possible audiences include policymakers, the general public, non-governmental organizations, companies, funders, financial institutions, analysts, research institutions, or other stakeholders affected by (or who can influence) the policy or action. For more information on identifying stakeholders, refer to the ICAT *Stakeholder Participation Guide* (Chapter 5).

Subsequent chapters provide flexibility to enable users to choose how best to assess the impacts of policies and actions in the context of their objectives, including which impacts to include in the GHG assessment boundary, and which methods and data sources to use. The appropriate level of accuracy and completeness is likely to vary by objective. Users should assess the impacts of their policies with a sufficient level of accuracy and completeness to meet the stated objectives of the assessment.

3 Overview of renewable energy policies

Historically, energy markets alone have not been able to deliver the desired level of renewable deployment in many countries. National-, subnational- and municipal-level support policies have been implemented to help to overcome market failures and to spur increased investment in RE. These policies help to reduce the cost of production, increase the price at which RE is sold or increase the volume of RE purchased. This chapter provides an overview of the three types of RE policy covered by the methodology.

3.1 Types of renewable energy policy

RE policies may be designed to overcome barriers to RE technological development and implementation, or to actively incentivize technological innovation, and speed and ease of implementation. Types of RE policies are shown in Table 3.1.[10]

TABLE **3.1**

Overview of policy instruments in the energy supply sector

Type of policy instrument *(Policies in bold are those covered by the methodology)*	Number of countries	Share of countries (%)
Reduction in sales, energy, value-added or other taxes	98	52
Public investment, loans or grants	82	43
Feed-in tariff and feed-in premium policies	81	43
Biofuels obligations and mandates	66	35
Auctions and tenders	64	34
Capital subsidy, grant or rebate	58	31
Net metering	52	27
Investment or production tax credits	45	24
Electric utility quota obligation and renewable portfolio standards	29	15
Tradable RE credits	29	15
Energy production payment[a]	25	13
Heat obligations and mandates	21	11

Source: REN21 (2016).

[a] The REN21 glossary defines an energy production payment as a "direct payment of the government per unit of renewable energy produced", whereas a feed-in tariff is defined as a "policy that sets a price that is guaranteed over a certain period of time at which power producers can sell renewably generated electricity into the grid" (REN21, 2016). A feed-in tariff in that sense is a particular type of the energy production payment. Feed-in tariff policies can therefore be seen as the most prevalent policy type.

[10] For a comprehensive overview of RE policies, see: https://irena.org/publications/2018/Apr/Renewable-energy-policies-in-a-time-of-transition.

Depending on the country circumstances, regulatory agencies and public utilities may be responsible for designing and implementing RE policies, but civil society and private actors may also have a large role to play.

Some key elements of RE policies include:[11]

- contributing to a rate of return that allows recovery of costs at a rate appropriate to the risk of investment
- guaranteeing access to networks and markets
- implementing long-term contracts to reduce risk
- using contract provisions that account for a diversity of technologies and applications
- using incentives that decline over time as technologies and/or markets mature, ensuring predictability
- ensuring broad inclusiveness with potential for participation.

3.2 Types of renewable energy policies covered by the methodology

Incentive mechanisms are a core driver for the expansion of RE capacity in many countries. Feed-in tariff policies are price-based instruments that provide a fixed, guaranteed electricity price, or a fixed or fluctuating price premium. Auctions and tender policies are quantity-based instruments that set the fixed amount of electricity generation from renewable sources to be achieved, where the market determines the price. Tax incentive policies use the tax system to improve the financial feasibility of RE investments.

These policies can be technology neutral or technology specific. For example, an auction policy can include all RE technologies, or can use eligibility criteria to include only specific technologies such as onshore and offshore wind, solar or biomass.

This methodology primarily considers these incentive policies. However, in addition to the incentive mechanisms provided through these policies, investors will consider issues relating to consent, permits and land; broader electricity market set-up (for on-grid renewables); offtake arrangements; and networks and related costs. This methodology therefore also considers how such factors can be taken into account when quantifying the GHG impact of RE policies.

3.2.1 Feed-in tariff policies (including feed-in premiums)

Feed-in tariff policies aim to promote RE deployment by offering long-term purchase agreements with power producers at a specified price per kilowatt hour.

In this methodology, feed-in tariff policies also include feed-in premiums, which provide power producers with a premium on top of the market price of their electricity production. Premiums can either be fixed at a constant level (independent of market prices) or sliding (with variable levels that depend on market prices). They provide market certainty for power producers by guaranteeing payments that are usually awarded as long-term contracts for 15–20 years.

Feed-in tariffs and feed-in premiums have been globally successful in promoting most RE technologies, including wind, solar photovoltaic (PV), solar thermal, geothermal, biogas and biomass. Successful feed-in tariffs and feed-in premiums tend to encourage a diverse array of technologies and have been used for projects of varying sizes. They have been widely successful as a result of inclusion of many of the following elements:[12]

- tariffs for all potential power producers, including utilities
- tariffs guaranteed for long enough to ensure an adequate rate of return
- tariff payment levels with carefully calculated starting values based on cost of generation, and differentiated by technology type and project size
- property access and dispatch
- utility purchase obligation
- regular long-term design evaluations and short-term payment level adjustments.

[11] Adapted from IPCC (2012).

[12] IPCC (2011).

3.2.2 Auction policies (including tender policies)

Auction policies for RE generation contracts create a competitive environment to procure renewable electricity through a defined selection process. In this methodology, "auction policies" refers to both auction and tender policies.[13]

Under these policies (as applicable in this methodology), governments issue a request for bids for the total investment cost of a project or for the cost per unit of electricity. An auction process will generally involve an open bidding process, whereas with tenders the bidding is done in confidence. They are usually designed with a total capacity of projects that will be funded. The government then selects multiple winning bids until the total capacity reaches the auction capacity goals.

Specific design elements of auction and tender policies are associated with several trade-offs:

- **Demand** – trade-off between ambition for an increasing share of renewables and cost-effectiveness. This may be manifested through a decision to introduce a technology-specific auction to develop a specific technology, or a technology-neutral auction to allow competition, which favours more cost-competitive technologies.
- **Qualification requirement** – trade-off between reducing entry barriers to encourage competition and discouraging underbidding.
- **Winner selection process** – trade-off between keeping the process simple and transparent, and ensuring that the objectives are achieved by the auction.
- **Sellers' liabilities** – weighing the allocation of risks between the power producer and the auctioneer, and exercising caution on the overallocation of risks to producers.

Price competition in auctions and tenders may favour larger and more established players, such as utilities or public companies, to the detriment of smaller players. High administrative or financial qualification requirements may result in too few bidders, which may impede the realization of the true low-cost potential.

Policymakers might consider using technology-specific tenders to enable a diverse supply. They might also consider adding local content rules, which require the use of a certain percentage of local equipment or local ownership of the project. In return, there may be an offer of lower interest rates, local tax benefits or even bonus payments for local power producers, which can benefit communities and prevent excess imports of the cheapest technologies.

3.2.3 Tax incentive policies

Various types of tax incentive policies are available for the development and deployment of RE technologies. Many governments use tax policies to promote RE sources for electricity generation. Tax incentives types include:

- value added tax exemptions
- income tax exemptions
- import or export fiscal benefits
- sales tax exemptions
- accelerated depreciation
- property tax incentives
- tax credits
- exemptions from local taxes
- RE-specific taxes, such as a geothermal vapour tax or geothermal surface tax
- other fiscal benefits.

Tax incentives usually apply to services and equipment. Pre-investment expenses are related to RE projects, as well as income from the sale of electricity or other ancillary income. Policymakers can further opt for fiscal stability incentives, whereby eligible RE technologies are shielded from potential future changes in the fiscal regime or any additional fees. Tax incentive policies can be effective when linked to the generation of electricity and not just the installation of capacity.

Different levels of government (national, subnational or municipal) may implement various tax incentive policies simultaneously.

[13] For a comprehensive guide to auction policy design, see: https://irena.org/publications/2015/Jun/Renewable-Energy-Auctions-A-Guide-to-Design.

3.3 Policy caps

Some RE policies may be subject to a cap, as in the following examples:

- A cap may be set as part of a feed-in tariff policy, either at a maximum per year or over the lifetime of the policy – this practice is increasingly common to limit the overall cost of the policy.
- Policy caps are implicit in the design of auctions and tender policies. Under these policies, a certain quantity is auctioned or tendered, serving as the cap on either the number of installations, megawatts installed or electricity generated.
- The country has an RE target that the RE policy aims to contribute towards.

Table 3.2 explains how the methodology is applicable to these different RE policies.

TABLE **3.2**

Overview of caps for renewable energy policies

RE policy	Applicability of the methodology	RE policies to which the methodology is applicable
The cap is part of the policy design (e.g. capped feed-in tariff or auction)	Methodology helps users assess whether there are any factors preventing the policy from reaching its cap (e.g. whether the scope is too limited or barriers exist that hinder the policy's impact).	• Auction policies • Feed-in tariff policies with a cap
A separate target exists in the country that the policy aims to contribute towards (e.g. an RE target such as 25% RE by 2025)	Methodology helps users assess whether the policy is sufficiently ambitious to achieve the target, or whether there are factors that may reduce the effectiveness of the policy.	• Feed-in tariff policies with national RE target in place • Tax incentive policies with national RE target in place
No target exists, nor does the policy provide an indication of the impact that should be achieved	Methodology helps users assess the impact of the policy, based on its design and other factors.	• Stand-alone feed-in tariff policies • Stand-alone tax incentive policies

4 Using the methodology

This chapter provides an overview of the steps involved in assessing the GHG impacts of RE policies, and outlines assessment principles to help guide the assessment.

Checklist of key recommendations

- Base the assessment on the principles of relevance, completeness, consistency, transparency and accuracy

4.1 Overview of steps

This document is organized according to the steps a user follows to assess the GHG impacts of an RE policy (see Figure 1.1). Depending on when the methodology is applied, users can skip certain chapters. For example, for ex-post assessments, users can skip Chapters 7 and 8.

4.2 Planning the assessment

Users should review this methodology, the *Introduction to the ICAT Assessment Guides* and other relevant assessment guides, and plan the steps, responsibilities and resources needed to meet their objectives for the assessment in advance. This includes identifying in advance the expertise and data needed for each step, planning the roles and responsibilities of different actors, and securing the budget and other resources needed. Any interdependencies between steps should be identified – for example, where outputs from one step feed into another – and timing should be planned accordingly.

The time and human resources required to implement the methodology and carry out an impact assessment depend on a variety of factors, such as the complexity of the policy being assessed, the extent of data collection needed and whether relevant data have already been collected, and the level of accuracy and completeness needed to meet the stated objectives of the assessment.

4.2.1 Choosing a desired level of accuracy based on objectives

A range of options exist for assessing GHG impacts that allow users to manage trade-offs between the accuracy of the results, and the resources, time and data needed to complete the assessment, based on objectives. Some objectives require more detailed assessments that yield more accurate results (to demonstrate that a specific reduction in GHG emissions is attributable to a specific policy, with a higher level of certainty), whereas other objectives may be achieved with simplified assessments that yield less accurate results (to show that a policy contributes to reducing GHG impacts, but with less certainty around the magnitude of the impact).

Users should choose approaches and methods that are sufficient to accurately meet the stated objectives of the assessment and ensure that the resulting claims are appropriate – for example, whether a policy contributes to achieving GHG emissions reductions or whether emissions reductions can be attributed to the policy. Users should also consider the resources required to obtain the data needed to meet the stated objectives of the assessment.

4.2.2 Approaches to GHG impact assessment

The methodology can be used to estimate either a GHG emissions level or GHG emissions reductions (either can be done ex-ante or ex-post). The choice is guided by the user's objectives in undertaking the impact assessment.

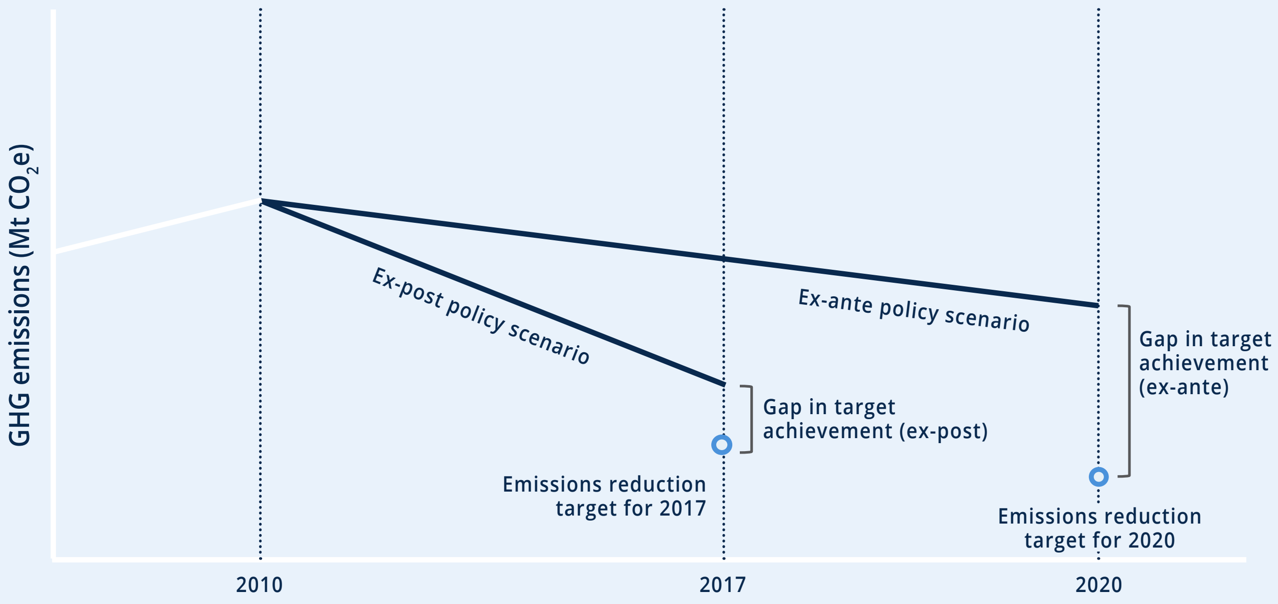
Estimating a GHG emissions level

The objective of estimating an emissions level is to evaluate policy performance in achieving NDCs. NDCs may have established emissions targets relative to a specific base year, or RE deployment or sectoral emissions levels. In such cases, users do not need to develop a baseline scenario or estimate baseline emissions.

Estimating an emissions level, either ex-ante or ex-post, allows comparison with a target, as shown in Figure 4.1. Here, an ex-ante estimate of emissions

FIGURE **4.1**

Use of GHG emissions level in ex-ante and ex-post impact assessment



Source: Adapted from WRI (2014).

levels out to 2020 shows that there is a gap, and expected emissions reductions in the sector are not on track to be met. The figure also shows an ex-post estimate of emissions levels, estimated in 2017. Here, the emissions level is higher than the target – in other words, the anticipated emissions reductions have not been achieved.

Estimating GHG emissions reductions

Estimating emissions reductions is relevant where the objective is to evaluate the GHG impact of a specific policy. This requires comparing policy scenario emissions with baseline scenario emissions. Figure 4.2 illustrates the estimation of GHG emissions reductions ex-ante and ex-post. The reductions are calculated by subtracting the ex-ante (or ex-post) policy scenario emissions from the ex-ante (or ex-post) baseline emissions. To estimate the ex-ante emissions reductions, both the policy scenario emissions and baseline emissions are forecasted. To estimate the ex-post emissions reductions, baseline emissions are estimated according to the most likely baseline scenario. The policy scenario emissions are estimated based on observed data.

Note that an RE policy may lead to GHG emissions reductions in situations where the *absolute* level of GHG emissions is rising – that is, the methodology estimates reductions based on the difference between baseline and policy scenario emissions, both of which may be rising, but at different rates.

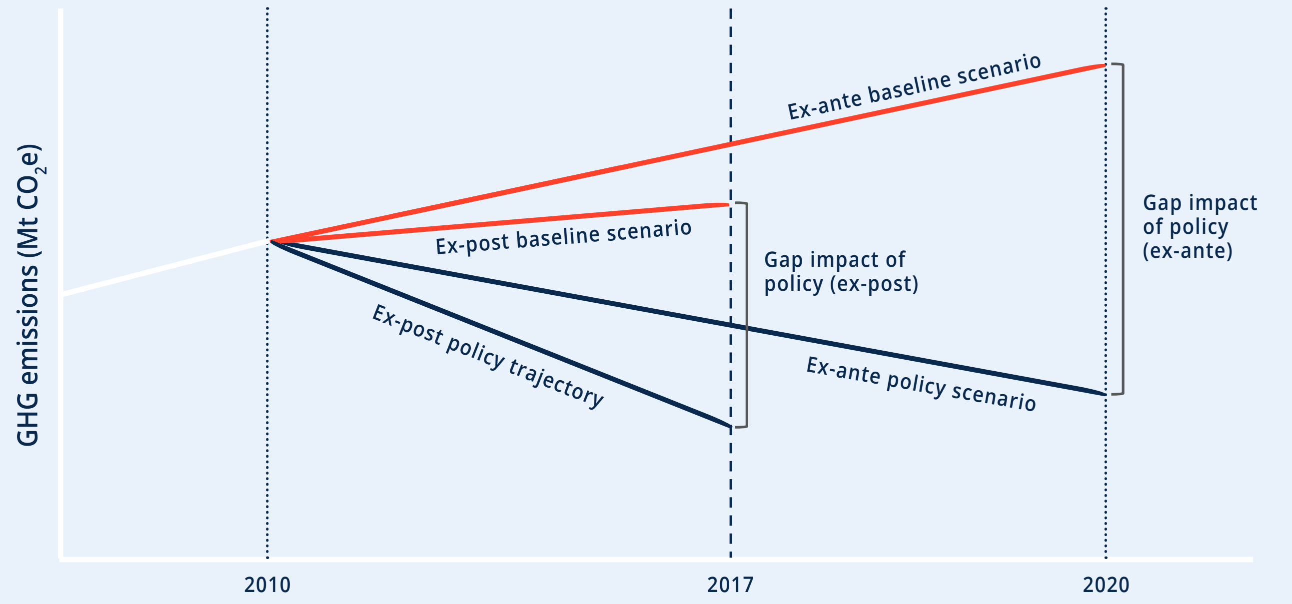
Ex-ante and ex-post assessment steps

Estimating GHG impacts ex-ante is divided into two parts. First, the RE addition of the policy is estimated (Chapter 7). RE addition is the additional installation of RE capacity or electricity generation from renewable sources realized via the policy, expressed in megawatts or megawatt-hours, respectively. Second, the GHG impacts from this RE addition are estimated (Chapter 8).

RE addition is estimated by first estimating the technical potential for the assessment period of the policy (the maximum RE resource potential for the technology or the policy cap) and then following stepwise guidance to evaluate the policy design characteristics and other factors that affect the likelihood that the policy will achieve this technical potential (illustrated in Figure 4.3). The result is the actual RE addition that the policy is expected to

FIGURE **4.2**

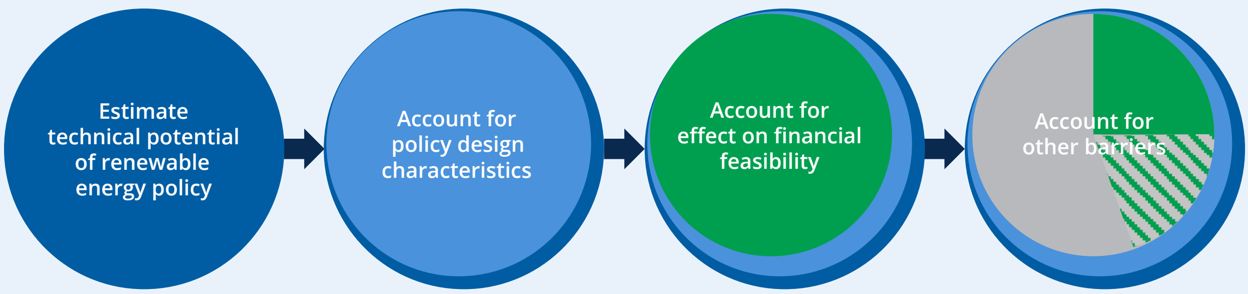
Estimating GHG emissions reductions with a baseline scenario



Source: WRI (2014).

FIGURE **4.3**

Steps for estimating renewable energy addition of the policy ex-ante



achieve. Once the RE addition has been estimated, it can then be translated into a GHG emissions level or GHG emissions reductions.

Estimating GHG impacts ex-post is also divided into two parts. First, data are collected from relevant agencies to determine the RE addition. Second, the GHG impacts (emissions level or emissions reductions) are estimated.

4.2.3 Methods for obtaining or estimating data

It is recommended that users use country-specific data. Potential data sources include the ministry of energy, national energy research institutes, and international agencies such as the International Energy Agency (IEA) or the International Renewable Energy Agency (IRENA). Where country-specific data are not available, users may use regional data or make estimates with input from experts. Section 8.2.2 provides further guidance for cases where data availability is limited.

4.2.4 Expert judgment

Expert judgment and assumptions will probably be needed to complete an assessment where information is not available or requires interpretation. Expert judgment is defined by the Intergovernmental Panel on Climate Change (IPCC) as a "carefully considered, well-documented qualitative or quantitative judgment made in the absence of unequivocal observational evidence by a person or persons who have a demonstrable expertise in the given field".[14] The goal is to be as representative as possible to reduce bias and increase accuracy. The user can apply their own expert judgment or consult experts.

Expert judgment can include applying proxy data, interpolating information, estimating a cap or technical potential for the assessment period, evaluating a barrier to RE deployment, or other types of assumptions or judgment.

When relying on expert judgment, information can be obtained using methods that help to avoid bias – known as expert elicitation. The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* provides a procedure for expert elicitation, including a process for helping experts understand the elicitation process, avoiding biases, and producing independent and reliable judgments.[15]

Expert judgment can be associated with a high level of uncertainty. As such, experts can be consulted to provide a range of possible values and the related uncertainty range, or to help select suitable values from a range of values. Expert judgment can be informed or supported by broader consultations with stakeholders.

It is important to document the reason that no data sources are available and the rationale for the value chosen.

4.2.5 Planning stakeholder participation

Stakeholder participation is recommended at many steps throughout the methodology. It can strengthen the impact assessment and the contribution of policies to GHG emissions reduction goals in many ways, including by:

- establishing a mechanism through which people who may be affected by, or can influence, a policy have an opportunity to raise issues and have these issues considered before, during and after policy implementation
- raising awareness and enabling better understanding of complex issues for all parties involved, thereby building their capacity to contribute effectively
- building trust, collaboration, shared ownership and support for policies among stakeholder groups, leading to less conflict and easier implementation
- addressing stakeholder perceptions of risks and impacts, and helping to develop measures to reduce negative impacts and increase benefits for all stakeholder groups, including the most vulnerable
- increasing the credibility, accuracy and comprehensiveness of the assessment by drawing on diverse expert, local and traditional knowledge and practices – for example, to provide inputs on data sources, methods and assumptions
- increasing transparency, accountability, legitimacy and respect for stakeholders' rights
- enabling enhanced ambition and financing by strengthening the effectiveness of policies and the credibility of reporting.

Various sections throughout this methodology explain where stakeholder participation is recommended – for example, in identifying a complete list of GHG impacts

[14] IPCC (2000).

[15] IPCC (2006). Note that the enhanced transparency framework states that "Each Party shall use the 2006 IPCC Guidelines and any subsequent version or refinement of the IPCC Guidelines agreed upon by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA)".

(Chapter 6), identifying barriers to RE deployment (Chapter 7), monitoring performance over time (Chapter 10) and reporting (Chapter 11).

Before beginning the assessment process, users should consider how stakeholder participation can support the objectives, and include relevant activities and associated resources in their assessment plans. It may be helpful to combine stakeholder participation for impact assessment with other participatory processes involving similar stakeholders for the same or related policies, such as those being conducted for assessment of sustainable development and transformational impacts, and for technical review.

It is important to conform with national legal requirements and norms for stakeholder participation in public policies. Requirements of specific donors, and of international treaties, conventions and other instruments that the country is party to should also be met. These are likely to include requirements for disclosure, impact assessments and consultations. They may include specific requirements for certain stakeholder groups (e.g. United Nations Declaration on the Rights of Indigenous Peoples, International Labour Organization Convention 169).

During the planning phase, it is recommended that users identify stakeholder groups that may be affected by, or may influence, the policy. Appropriate approaches should be identified to engage with stakeholder groups, including through their legitimate representatives. Effective stakeholder participation could be facilitated by establishing a multi-stakeholder working group or advisory body consisting of stakeholders and experts with relevant and diverse knowledge and experience. Such a group may provide advice and potentially contribute to decision-making; this will ensure that stakeholder interests are reflected in design, implementation and assessment of policies.

Refer to the ICAT *Stakeholder Participation Guide* for more information, such as how to plan effective stakeholder participation (Chapter 4), identify and analyse different stakeholder groups (Chapter 5), establish multi-stakeholder bodies (Chapter 6), provide information (Chapter 7), design and conduct consultations (Chapter 8), and establish grievance redress mechanisms (Chapter 9). Appendix E of this document summarizes the steps in this methodology where stakeholder participation is recommended and provides specific references to relevant guidance in the ICAT *Stakeholder Participation Guide*.

4.2.6 Planning technical review (if relevant)

Before beginning the assessment process, users should consider whether the assessment report will be subject to technical review. The technical review process emphasizes learning and continual improvement, and can help users identify areas for improving future impact assessments. Technical review can also provide confidence that the impacts of policies have been estimated and reported according to ICAT key recommendations. Refer to the ICAT *Technical Review Guide* for more information on the technical review process.

4.3 Assessment principles

Assessment principles underpin and guide the impact assessment process, especially where the methodology provides flexibility. It is a *key recommendation* to base the assessment on the principles of relevance, completeness, consistency, transparency and accuracy, as follows:[16]

- **Relevance.** Ensure that the GHG assessment appropriately reflects the GHG impacts of the policy and serves the decision-making needs of users and stakeholders – both internal and external to the reporting entity. Users should apply the principle of relevance when selecting the desired level of accuracy and completeness from a range of methodological options. Applying the principle of relevance depends on the objectives of the assessment. Because of the varied nature of users' objectives, it may be more relevant to estimate and report an intermediate impact, such as the RE addition expressed as installed capacity (MW) or generated electricity (MWh) achieved by the policy, rather than the GHG emissions reductions.

- **Completeness.** Include all significant GHG impacts and sources in the GHG assessment boundary. Disclose and justify any specific exclusions.

- **Consistency.** Use consistent accounting approaches, data-collection methods and calculation methods to allow meaningful performance tracking over time. Document any changes to the data, GHG assessment

[16] Adapted from WRI (2014).

boundary, methods or any other relevant factors in the time series.

- **Transparency.** Provide clear and complete information for stakeholders to assess the credibility and reliability of the results. Disclose all relevant methods, data sources, calculations, assumptions and uncertainties. Disclose the processes, procedures and limitations of the GHG assessment in a clear, factual, neutral and understandable manner through an audit trail with clear documentation. The information should be sufficient to enable a party external to the GHG assessment process to derive the same results if provided with the same source data. Chapter 11 provides a list of recommended information to report to ensure transparency.

- **Accuracy.** Ensure that the estimated change in GHG emissions and removals is systematically neither over nor under actual values, as far as can be judged, and that uncertainties are reduced as far as practicable. Achieve sufficient accuracy to enable users and stakeholders to make appropriate and informed decisions with reasonable confidence about the integrity of the reported information. Accuracy should be pursued as far as possible, but, once uncertainty can no longer be practically reduced, conservative estimates should be used. Box 4.1 provides guidance on conservativeness.

In addition to the principles above, users should follow the principle of comparability if it is relevant to the assessment objectives – for example, if the objective is to compare multiple policies based on their GHG impacts, or to aggregate the results of multiple impact assessments and compare the collective impacts with national goals (discussed further in Box 4.2).

- **Comparability.** Ensure common methods, data sources, assumptions and reporting formats, such that the estimated GHG impacts of multiple policies can be compared.

In practice, users may encounter trade-offs between principles when developing an assessment. For example, a user may find that achieving the most complete assessment requires using less accurate data for a portion of the assessment, which could compromise overall accuracy. Users should balance trade-offs between principles depending on their objectives. Over time, as the accuracy and completeness of data increase, the trade-off between these principles will likely diminish.

BOX **4.1**

Conservativeness

Conservative values and assumptions are more likely to overestimate negative impacts or underestimate positive impacts resulting from a policy. Users should consider conservativeness in addition to accuracy when uncertainty can no longer be practically reduced, when a range of possible values or probabilities exists (e.g. when developing baseline scenarios), or when uncertainty is high.

Whether to use conservative estimates and how conservative to be depends on the objectives and the intended use of the results. For some objectives, accuracy should be prioritized over conservativeness, to obtain unbiased results. The principle of relevance can help guide what approach to use and how conservative to be.

BOX **4.2**

Applying the principle of comparability when comparing or aggregating results

Users may want to compare the estimated impacts of multiple policies – for example, to determine which policy has the greatest positive impacts. Valid comparisons require that assessments have followed a consistent methodology – for example, regarding the assessment period; the types of impact categories, impacts and indicators included in the GHG assessment boundary; baseline assumptions; calculation methods; and data sources. Users should exercise caution when comparing the results of multiple assessments, since differences in reported impacts may be a result of differences in methodology rather than real-world differences. To understand whether comparisons are valid, all methods, assumptions and data sources used should be transparently reported. Comparability can be more easily achieved if a single person or organization assesses and compares multiple policies using the same methodology.

Users may also want to aggregate the impacts of multiple policies – for example, to compare the collective impact of several policies in relation to a national goal. Users should likewise exercise caution when aggregating the results if different methods have been used and if there are potential overlaps or interactions between the policies being aggregated. In such a case, the sum would either overestimate or underestimate the impacts resulting from the combination of policies. For example, the combined impact of a local energy efficiency policy and a national energy efficiency policy in the same country will probably be less than the sum of the impacts had they been implemented separately, since they affect the same activities. Chapter 5 provides more information on policy interactions.

PART II

Defining the assessment

5 Describing the policy

This chapter provides guidance on describing the policy. To assess the GHG impacts of a policy, users need to describe the policy that will be assessed, decide whether to assess the individual policy or a package of related policies, and choose whether to carry out an ex-ante or ex-post assessment.

Checklist of key recommendations

- Clearly describe the policy (or package of policies) that is being assessed

5.1 Describe the policy to be assessed

To effectively carry out an impact assessment (described in subsequent chapters), a detailed understanding of the policy being assessed is needed. It is a *key recommendation* to clearly describe the policy (or package of policies) that is being assessed. Table 5.1 provides a checklist of recommended information that should be included in a description to enable an effective assessment.

Table 5.2 outlines additional information that may be relevant, depending on the context.

If assessing a package of policies, these tables can be used to document either the package as a whole or each policy in the package separately. The first two steps in the chapter (Sections 5.1 and 5.2) can be done together or iteratively.

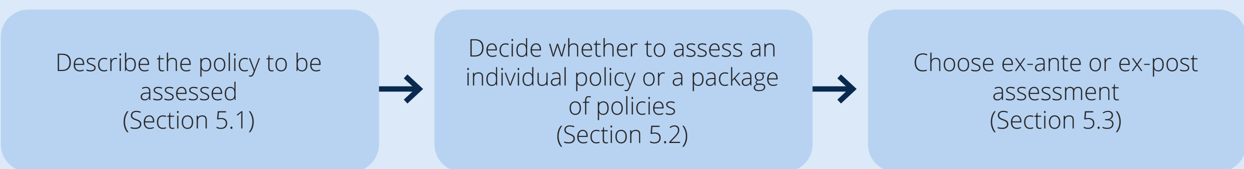
Users who are assessing the sustainable development and/or transformational change impacts of the policy (using the ICAT *Sustainable Development Methodology* and/or *Transformational Change Methodology*) should describe the policy in the same way to ensure a consistent and integrated assessment.

5.2 Decide whether to assess an individual policy or a package of policies

If multiple policies are being developed or implemented in the same time frame, users can assess them either individually or as a package. When making this decision, users should consider the assessment objectives, the feasibility of assessing impacts individually or as a package, the scope and level of incentive, and the degree of interaction between the policies. Where interactions exist, there can be advantages and disadvantages to assessing policies individually or as a package.

FIGURE **5.1**

Overview of steps in the chapter



Source: Adapted from WRI (2014).

TABLE **5.1**

Checklist of recommended information to describe the policy being assessed

Information	Description	Example
Title of the policy or action	Policy name	Feed-in tariff without cap
Type of policy or action	The type of policy, such as those presented in Table 3.1	Feed-in tariff policy
Description of specific interventions	The specific intervention(s) carried out as part of the policy, such as the technologies, processes or practices implemented	Policy characteristics: • Tariff differentiation – higher tariffs for small projects and lower tariffs for large-scale projects (set to give rates of return of 5–8%) • Eligibility – the only technology eligible under the feed-in tariff is solar PV • Utility role – government-owned single buyer with guaranteed purchase up to the annual production quota • Payment structure – premium-price policies • Contract and payment duration – premium is offered over a project's entire lifetime • Forecasting – no forecasting requirements • Grid access – grid priority for renewable energies • Policy adjustments – only inflation adjustments over lifetime of feed-in tariff
Status of policy	Whether the policy is planned, adopted or implemented	Implemented
Date of implementation	The date the policy comes into effect (not the date that any supporting legislation is enacted)	1 July 2016
Date of completion (if relevant)	If relevant, the date the policy ceases, such as the date a tax is no longer levied or the end date of an incentive policy with a limited duration (not the date that the policy no longer has an impact)	No end date has currently been set
Implementing entity or entities	The entity or entities that implement(s) the policy, including the role of various local, subnational, national, international or any other entities	Ministry of Energy/Energy Regulatory Commission
Objectives and intended impacts or benefits of the policy	The intended impact(s) or benefit(s) of the policy (e.g. the purpose stated in the legislation or regulation)	To increase deployment of solar PV and increase energy security
Level of the policy	The level of implementation, such as national level, subnational level, city level, sector level or project level	National

TABLE **5.1**, continued

Checklist of recommended information to describe the policy being assessed

Information	Description	Example
Geographic coverage	The jurisdiction or geographic area where the policy is implemented or enforced, which may be more limited than all the jurisdictions where the policy has an impact	Small, least developed country
Sectors targeted	The sectors or subsectors that are targeted	Energy supply, grid-connected solar PV
Greenhouse gases targeted	The GHGs the policy aims to control, which may be more limited than the set of GHGs that the policy affects	Carbon dioxide
Other related policies or actions	Other policies or actions that may interact with the policy assessed	Fossil fuel subsidies, tender policies, tax incentive policies

Source: Adapted from WRI (2014).

TABLE **5.2**

Checklist of additional information that may be relevant to describe the policy being assessed

Information	Description	Example
Intended level of mitigation to be achieved and/or target level of other indicators	Target level of key indicators, if relevant	National target: • 15% share of PV or RE in electricity mix • 20% sectoral emissions reduction below base year Y Policy: • The policy does not have a separate target but instead is designed in an open manner.
Title of establishing legislation, regulations or other founding documents	The name(s) of legislation or regulations authorizing or establishing the policy (or other founding documents, if there is no legislative basis)	Energy Feed-in Law
Monitoring, reporting and verification procedures	References to any monitoring, reporting and verification procedures associated with implementing the policy	A coordinating body will be formed to ensure continuous monitoring and create a monitoring plan. The power producer establishes QA and QC measures to control and manage reading, recording, auditing and archiving all relevant data and documents. Monitoring data for net electricity generation at the plant level can be obtained from the periodic electricity meter records kept by the power producer and/or the electricity board or grid company. These may be cross-checked with invoices sent by power producers to the grid company.

TABLE **5.2,** continued

Checklist of additional information that may be relevant to describe the policy being assessed

Information	Description	Example
Enforcement mechanisms	Any enforcement or compliance procedures, such as penalties for non-compliance	The feed-in tariff has enforcement mechanisms in place to ensure that the reported data (electricity generation) are correct.
Reference to relevant documents	Information to allow practitioners and other interested parties to access any guidance documents related to the policy (e.g. through websites)	Renewable Energy Sources Act
Broader context or significance of the policy	The broader context for understanding the policy	The policy will contribute to the national target of a 15% share of PV or RE in the electricity mix, and the 20% sectoral emissions reduction below base year 2005. The policy will reduce consumption of fossil fuels and contribute to energy security.
Outline of sustainable development impacts of the policy or action	Any anticipated sustainable development benefits other than GHG mitigation	Will lead to more construction jobs and greater energy security. Solar energy will also provide quick alternative power during severe climate changes that may occur (El Niño). Will lead to increased solar electricity generation in the country, contributing to energy security by displacing fossil fuel energy source that require fuel imports.
Key stakeholders	Key stakeholder groups affected by the policy	• Departments or ministries of energy • Energy regulatory commissions • Energy planning offices • Power producers • Investors • Utilities • Consumers • Constituents affected at installation sites
Other relevant information	Any other relevant information (e.g. costs, sustainable development and transformational change benefits)	

Source: Adapted from WRI (2014).
Abbreviations: QA, quality assurance; QC, quality control

5.2.1 Types of policy interactions

Policies interact if their total impact, when implemented together, differs from the sum of their individual impacts had they been implemented separately. Table 5.3 provides an overview of the four possible relationships. Further information is available in the *Policy and Action Standard*.

Policy interactions should be considered in the context of other RE policies, as well as broader energy policy. Some RE policies may be implemented as part of a suite of measures to meet broad energy policy objectives in integrated policy planning, which is periodically reviewed (e.g. decommissioning of fossil fuel plants coupled with phasing out nuclear and deployment of RE, as an integrated policy). Where this is the case, the RE component may be implemented using, for example, a tender process with many periodic windows that set the cap based on how well the other elements of the integrated energy policy are performing (i.e. whether the decommissioning of fossil fuel plants is on schedule, or whether a nuclear phase-out programme is delayed or has altered its ambition). These considerations affect the potential for RE deployment over time.

5.2.2 Identification of interaction between policies

Where related policies exist, users should first consider their specific objectives and circumstances when deciding whether to assess an individual policy or a package of interacting policies. An approach is set out below to help with this decision.

Step 1: Characterize the type and degree of interactions between policies
Assess the relationship between the policies and the degree of interaction (minor, moderate or major), based on published studies of similar combinations of policies or on expert judgment. The assessment will be qualitative, since a quantitative assessment would require many of the steps needed for a full assessment.

Consider whether the same types of RE installations or technologies are eligible under the policy being assessed and other policies identified. Table 5.4

TABLE **5.3**

Types of relationships between renewable energy policies

Type	Description
Independent	Multiple policies do not interact with each other. The combined impact of implementing the policies together is equal to the sum of the individual impacts of implementing them separately.
Overlapping	Multiple policies interact, and their combined impact is less than the sum of their individual impacts. This category includes policies that have identical or complementary goals, as well as policies that have different or opposing goals.
Reinforcing	Multiple policies interact, and their combined impact is greater than the sum of the individual impacts of implementing them separately.
Overlapping and reinforcing	Multiple policies interact, and have both overlapping and reinforcing interactions. The combined impacts may be greater or less than the sum of the individual impacts of implementing them separately.

Source: WRI (2014).

TABLE **5.4**

Example of mapping policies that target the same emissions sources

Policy being assessed	Other policies targeting the same sources	Type of interaction (independent, overlapping, reinforcing, overlapping and reinforcing)	Degree of interaction (minor, moderate, major)
Feed-in tariff policy, biomass installations eligible	Tender policy, offshore wind energy installations eligible	Independent	Minor
	Tax incentive policies for solar and biomass installations	Overlapping (and potentially reinforcing)	Moderate

Source: Adapted from WRI (2015).

provides an example of a relationship between policies that target the same GHG emissions sources – in this example, a feed-in tariff for biomass installations interacts with two other policies that target the same emissions source.

Step 2: Undertake a preliminary analysis to understand the nature of interactions and decide whether to assess an individual policy or a package of policies
This analysis is high level and qualitative; detailed analysis of interactions is addressed in subsequent chapters. The criteria and questions in Table 5.5 can help users decide whether to assess an individual policy or a package of policies.

5.3 Choose ex-ante or ex-post assessment

Choose whether to carry out an ex-ante assessment, an ex-post assessment, or a combined ex-ante and ex-post assessment. Choosing between ex-ante and ex-post assessment depends on the status of the policy. Where the policy is planned or adopted, but not yet implemented, the assessment will be ex-ante by definition. Alternatively, where the policy has been implemented, the assessment can be ex-ante, ex-post, or a combination of ex-ante and ex-post. The assessment is an ex-post assessment if the objective is to estimate the impacts of the policy to date, an ex-ante assessment if the objective is to estimate the expected impacts in the future, and a combined ex-ante and ex-post assessment if the objective is to estimate both the past and future impacts. An ex-ante assessment can include historical data if the policy is already implemented, but it is still ex-ante (rather than ex-post) if the objective is to estimate future effects of the policy.

TABLE **5.5**

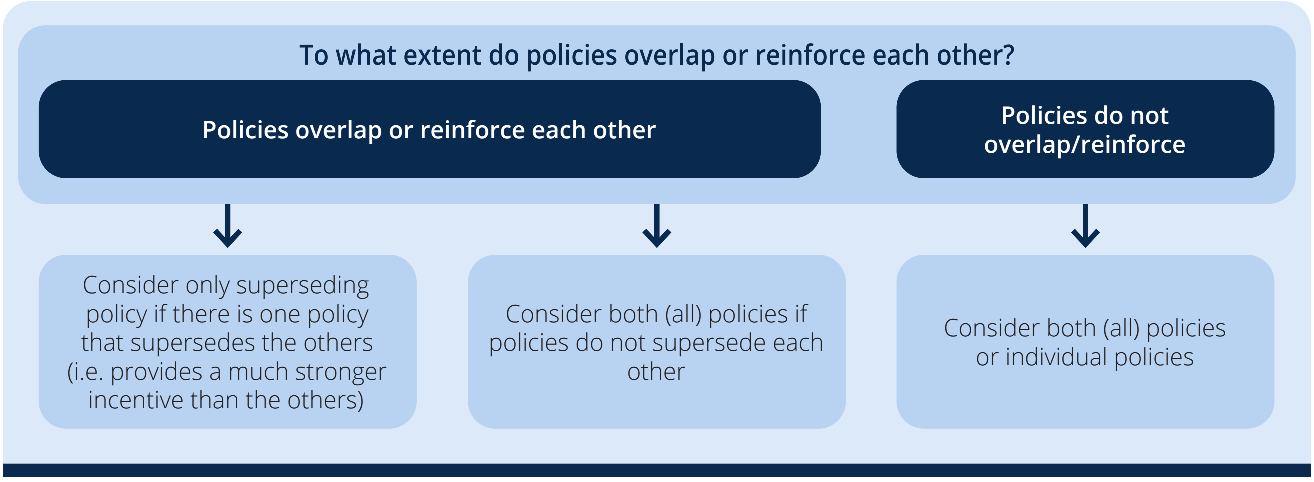
Criteria for determining whether to assess an individual policy or a package of policies

Criterion	Questions	Recommendation
Objectives and use of results	Do the end users of the assessment results want to know the impact of individual policies?	If "Yes", undertake an individual assessment.
Significant interactions	Are there significant (major or moderate) interactions between the identified policies, either overlapping or reinforcing, which will be missed if policies are assessed individually?	If "Yes", consider assessing a package of policies.
Scope and level of incentive	Does one policy clearly provide a stronger incentive than the others? Do the other policies spur additional emissions reductions not already covered by the policies with stronger incentives? See the decision tree in Figure 5.2 to assess overlap in incentives provided by different policies.	If "Yes", consider focusing on the policy superseding the others in an individual assessment.
Feasibility	Will the assessment be manageable if a package of policies is assessed? Are data available for assessing the package of policies? Are the policies implemented by a single entity?	If "No", consider undertaking an individual assessment.
	For ex-post assessments, is it possible to disaggregate the observed GHG impacts of interacting policies?	If "No", consider assessing a package of policies.

Source: WRI (2014).

FIGURE **5.2**

Overlap and reinforcement in incentives provided by different policies



6 Identifying impacts: how renewable energy policies reduce GHG emissions

This chapter provides a method for identifying the most common GHG impacts of RE policies, and guidance for users to identify any additional impacts their policies may have. A subset of impacts that are considered significant is then taken from this list and included in the GHG assessment boundary. The chapter also provides a method for defining the assessment period. The steps in this chapter are closely interrelated. Users can carry out the steps in sequence or in parallel, and the process may be iterative.

Checklist of key recommendations

- Identify all potential GHG impacts of the policy and associated GHG source categories
- Develop a causal chain
- Include all significant GHG impacts in the GHG assessment boundary
- Define the assessment period

6.1 Identify GHG impacts

GHG impacts are the changes in GHG emissions that result from the policy. For most RE policies being assessed using this methodology, the sole relevant GHG impacts are likely to be reduced emissions from existing fossil fuel power plants and/or avoided emissions from new fossil fuel power plants that would have been built. For these policies, users may want to skip this section. For policies that may have other GHG impacts, such as emissions of methane (CH_4) and carbon dioxide (CO_2) from water reservoirs, users should follow the method in this section to ascertain the policy's GHG impacts.

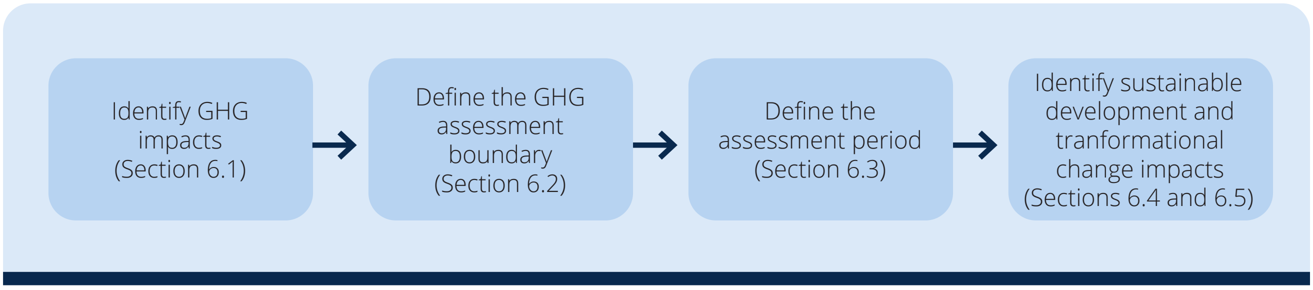
6.1.1 Identify intermediate effects

To identify the GHG impacts of a policy, it is useful to first consider how the policy is implemented by identifying the relevant inputs and activities associated with implementing the policy. Inputs are resources that go into implementing the policy, and activities are administrative activities involved in implementing the policy. These inputs and activities lead to intermediate effects, which are changes in behaviour, technology, processes or practices that result from the policy. These intermediate effects then lead to the policy's GHG impacts (the reduction in emissions).

Identification of intermediate effects enables a complete and accurate assessment, and is necessary to identify the potential GHG impacts of the policy and develop a causal chain. To identify the intermediate effects, users should identify the stakeholders, and the inputs and activities that are needed to implement the policy.

FIGURE **6.1**

Overview of steps in the chapter



6.1.2 Identify potential GHG impacts

It is a *key recommendation* to identify all potential GHG impacts of the policy and associated GHG source categories. A method for this is provided below, and further discussion on the process is available in the *Policy and Action Standard*. There are several types of GHG impacts to consider, such as those described in Table 6.1.

Users should consider impacts across the life cycle of electricity generation. For example, biomass and large hydro energy installations may cause indirect land-use change or material displacement impacts; if RE policies support such installations, these impacts need to be taken into consideration. CDM methodologies can help with the quantification of such impacts.[17] For example, CDM methodology *ACM0002: Grid-Connected Electricity Generation from Renewable Sources* includes a calculation method for quantifying CH_4 emissions from reservoirs.

By separately identifying and categorizing in-jurisdiction and out-of-jurisdiction impacts, users can more accurately link the GHG impacts to the relevant jurisdiction's inventory, targets and goals. This separate categorization also creates transparency around any potential double counting of out-of-jurisdiction impacts between jurisdictions. In some cases, a single impact may affect both in-jurisdiction and out-of-jurisdiction emissions, and separate tracking may not be feasible.

Stakeholder consultation can help to ensure the completeness of the list of GHG impacts. Refer to the ICAT *Stakeholder Participation Guide* (Chapter 8) for information on designing and conducting consultations. Relevant stakeholders may include

TABLE **6.1**

Types of GHG impacts

Type of GHG impact	Description	Example
Positive impact versus negative impact	Impacts that cause decrease or increase in GHG emissions	*Positive:* Reduced GHG emissions from existing and new fossil fuel power plants *Negative:* Increased emissions from manufacturing of RE-based systems/equipment
Intended impact versus unintended impact	Impacts that are both intentional and unintentional based on the original objectives of the policy	*Intended:* Reduced GHG emissions from fossil fuel power plants; reduced GHG emissions from national manufacturing of fossil fuel power plant equipment *Unintended:* Increased GHG emissions in other jurisdictions; increased GHG emissions from manufacturing of equipment for renewables
In-jurisdiction impact versus 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 the geopolitical boundary.	*In-jurisdiction:* Increased GHG emissions from manufacturing of equipment for renewables *In-jurisdiction:* Reduced GHG emissions from local manufacturing of equipment for fossil fuel power plants *Out-of-jurisdiction:* Increased GHG emissions in other jurisdictions (e.g. from electricity generation)
Short-term impact versus 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 operating fossil fuel power plants on the electricity grid *Long-term:* Reduced emissions from lower energy use due to increased cost of electricity

Source: Adapted from WRI (2014).

[17] Available at: https://cdm.unfccc.int/methodologies/index.html.

departments or ministries of energy, energy regulatory commissions, energy planning offices, power producers, investors, utilities, consumers and those affected at installation sites.

Users should identify all the GHG source categories associated with the GHG impacts of the policy. Example source categories are provided in Table 6.2. Source categories are the same for both RE projects and RE policies, so users with a project background should be familiar with all the main sources.

6.1.3 Develop a causal chain

It is a *key recommendation* to develop a causal chain. A causal chain is 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. A causal chain can help identify intermediate effects and GHG impacts not previously identified, and allows users to understand visually how policies lead to changes in emissions.

Figure 6.2 shows a high-level, illustrative example of a causal chain. Causal chains will vary from policy to policy, as will the strength of the links in the causal chain. Users should create their own causal chains, most likely with more (and different) detail from that shown in Figure 6.2.

Start by making a box for the policy, then add linkages from the policy to the identified intermediate effects and GHG impacts. The causal chain represents the flow of changes expected to occur as a result of the policy. Causal chains can also include inputs and activities. The *Policy and Action Standard* provides more information about developing causal chains.

Where users are also applying the ICAT *Sustainable Development Methodology*, the causal chain can be used as a starting point for a mapping exercise that includes sustainable development impacts as well as GHG impacts.

6.2 Define the GHG assessment boundary

The GHG assessment boundary defines the scope of the assessment in terms of the range of GHG impacts. It is a *key recommendation* to include all significant GHG impacts in the GHG assessment boundary. The identified GHG impacts and the associated GHG source categories should be

TABLE **6.2**

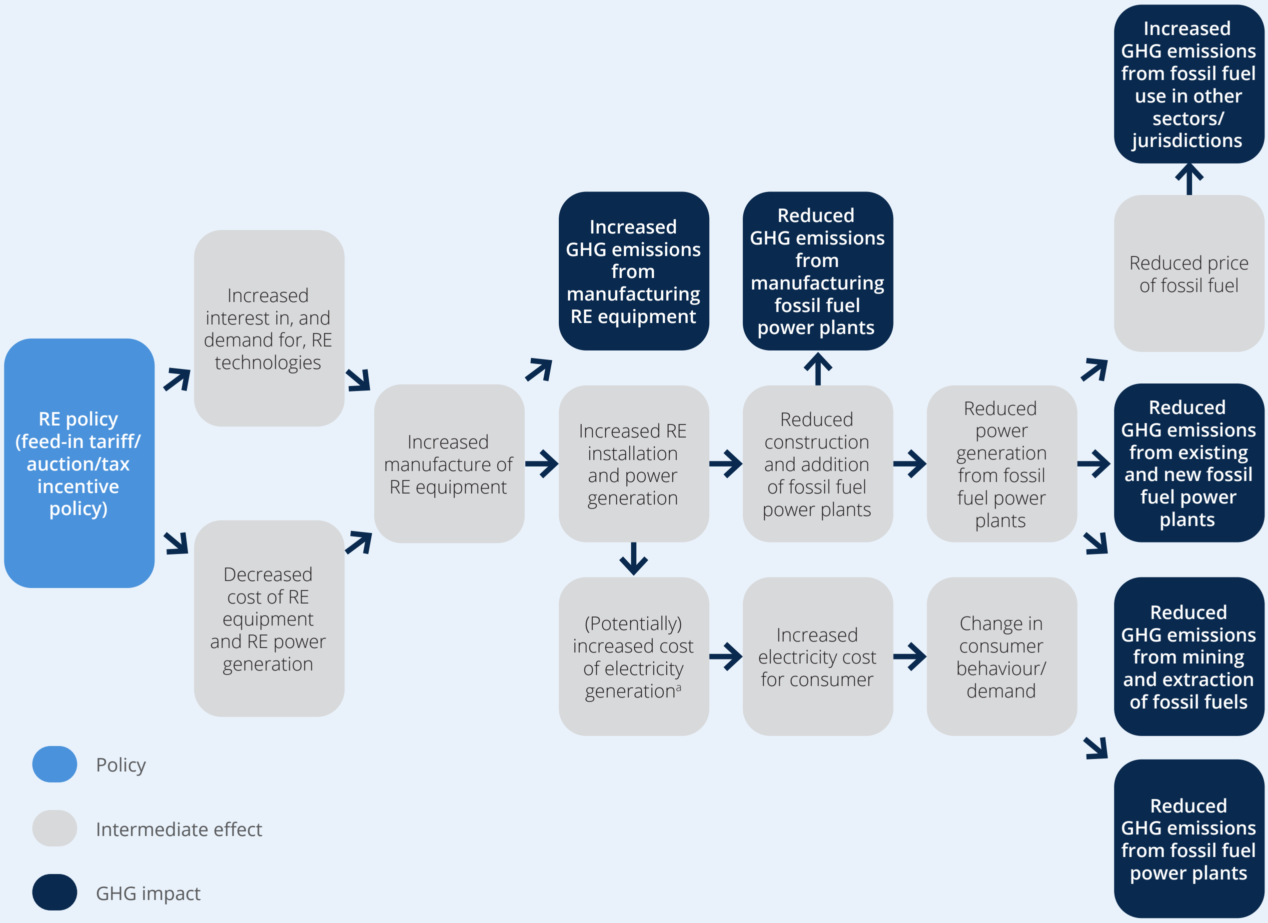
Examples of GHG sources for renewable energy policies

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	Grid-connected power plants	CO_2
Water reservoirs of hydropower 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	CO_2 emissions from combustion of fossil fuels for electricity generation in solar thermal power plants and geothermal power plants	Solar thermal and geothermal power plants	CO_2

Sources: WRI (2015); UNFCCC (2018a).

FIGURE **6.2**

Example causal chain for renewable energy policies



[a] Recent trends in renewable energy show that renewables are reaching grid parity in an increasing number of countries. Thus, the potential for this impact should be analysed carefully in each country-specific context.

categorized for magnitude and likelihood. They should be included in the GHG assessment boundary if they are categorized as moderate or major in magnitude, and very likely, likely or possible (i.e. deemed significant). The *Policy and Action Standard* provides further information about categorizing GHG impacts.

For most RE policies, only one GHG impact is likely to be significant – reduced GHG emissions from existing and new fossil fuel power plants. This is because, for most RE policies, this is the only GHG impact that is categorized as both very likely and of major magnitude.

Table 6.3 lists other GHG impacts and source categories. Users should check the list to ensure that each of the GHG impacts is categorized appropriately for the given policy, so that they can correctly identify impacts that need to be included in the GHG assessment boundary. Any GHG impacts that are categorized as moderate or major in magnitude, and very likely, likely or possible should be included in the GHG assessment boundary.

TABLE **6.3**

Example GHG impacts and source categories included/excluded in the GHG assessment boundary

GHG impact	GHG	Likelihood	Relative magnitude	Included or excluded	Explanation
Reduced GHG emissions from existing and new fossil fuel power plants	CO_2	Very likely	Major	Included	The main GHG impact of RE policies
Reduced emissions from mining of fossil fuels	CH_4	Possible	Minor	Excluded	Considered insignificant for most RE policies, and is conservative to exclude
Increased emissions from 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
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
Leakage emissions to other jurisdictions	CO_2, CH_4, N_2O	Possible	Minor	Excluded	Considered insignificant for most RE policies
Reduced emissions from lower energy use due to increased cost of electricity	CO_2, CH_4, N_2O	Possible	Minor	Excluded	Considered insignificant for most RE policies
For geothermal power plants, fugitive emissions of CH_4 and CO_2	CH_4, CO_2	Possible	Moderate	Policy dependent	Significant for RE policies involving geothermal power
For hydropower plants, emissions of CH_4 and CO_2 from water reservoirs	CH_4, CO_2	Possible	Moderate	Policy dependent	Significant for RE policies involving hydropower plants with reservoirs
For biomass power plants, emissions associated with agriculture and land-use change	CO_2, CH_4, N_2O	Very likely	Minor–major	Included	Significant for most biomass power plants

Source: Adapted from WRI (2015).
Abbreviation: N_2O, nitrous oxide.

6.3 Define the assessment period

The assessment period is the time period over which GHG impacts resulting from the policy are assessed. It is a *key recommendation* to define the assessment period.

For ex-ante assessments, the assessment period is usually determined by the longest-term impact included in the GHG assessment boundary. The assessment period 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.

For an ex-post assessment, the 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 these two dates. The assessment period for a combined ex-ante and ex-post assessment should consist of both an ex-ante assessment period and an ex-post assessment period.

Users should also consider the assessment objectives and stakeholders' needs when determining the assessment period. Where the objective is to understand the expected contribution of the policy towards achieving a country's NDC, it may be most appropriate to align the assessment period with the NDC implementation period (e.g. ending in 2030). To align with longer-term trends and planning, users should select an end date such as 2040 or 2050. In addition, users can separately estimate and report impacts over any other time periods that are relevant. For example, if the assessment period is 2020–2040, a user can separately estimate and report impacts over the periods 2020–2030, 2031–2040 and 2020–2040.

Where possible, users should align the assessment period with other assessments being conducted using ICAT methodologies. For example, where users are assessing the RE policy's sustainable development impacts using the ICAT *Sustainable Development Methodology* in addition to assessing GHG impacts, the assessment period should be the same for both the sustainable development and GHG impact assessments.

6.4 Identify sustainable development impacts (if relevant)

RE policies generate multiple sustainable development impacts in addition to their GHG impacts. Sustainable development impacts are changes in environmental, social or economic conditions that result from a policy or action – for example, changes in economic activity, employment, public health, air quality and energy security.

Refer to the ICAT *Sustainable Development Methodology* for the method for conducting an assessment of sustainable development impacts. Table 6.4 lists examples of sustainable development impacts and indicators that may be associated with RE policies, categorized according to the ICAT *Sustainable Development Methodology*. The SDGs most directly relevant to each impact category are indicated in parentheses.

6.5 Identify transformational change impacts (if relevant)

RE policies may lead to significant penetration of RE technologies, mobilize private sector investment in RE deployment and result in significant shares of RE in the energy mix of a country. A high share of renewable electricity fundamentally changes a country's electricity system and can provide a basis for further deployment of RE across the energy sector as a whole. In this way, RE policies may deliver transformational change impacts in addition to achieving GHG emissions reductions. In the context of GHG mitigation, transformational change can be understood as a fundamental, sustained systemic change that disrupts established high-GHG emissions development pathways and contributes to zero-carbon development, in line with the goals of the Paris Agreement and the SDGs. The ICAT *Transformational Change Methodology* provides guidance on assessing the transformational impacts of policies and their ability to influence the processes of change towards low-GHG emissions development, overcome barriers to systemic change, ensure a zero-carbon development and contribute to transformational outcomes.

Refer to the ICAT *Transformational Change Methodology* for more information on assessing transformational impacts of policies through an analysis of process and outcome characteristics.

TABLE **6.4**

Examples of sustainable development impacts and indicators relevant to renewable energy policies

Impact categories	Indicators
Environmental impacts	
Air quality and health impacts of air pollution (SDGs 3, 11, 12)	• Emissions of air pollutants such as particulate matter ($PM_{2.5}$, PM_{10}), ammonia, ground-level ozone (resulting from volatile organic compounds – VOCs, and nitrogen oxides – NO_x), carbon monoxide, sulfur dioxide, nitrogen dioxide, fly ash, dust, lead, mercury and other toxic pollutants (tonnes/year) • Air pollutants concentration (mg/m^3) • Aerosol particles concentration (mg/m^3) • Indoor and outdoor air quality • Morbidity (disability-adjusted life years – DALYs, quality-adjusted life years – QALYs, and averted disability-adjusted life years – ADALYs) • Mortality (avoided premature deaths per year)
Energy (SDG 7)	• Energy consumption • Energy efficiency • Energy generated by source • RE generation • RE share of total final energy consumption • Primary energy intensity of the economy (e.g. tonnes of oil equivalent/gross domestic product)
Depletion of non-renewable resources	• Consumption of mineral resources • Consumption of fossil fuels • Scarcity of resources
Social impacts	
Access to clean, reliable and affordable energy (SDG 7)	• Percentage of population with access to clean, reliable and affordable energy • Price of energy • Emissions per unit of energy • Number and length of service interruptions
Economic impacts	
Jobs (SDG 8)	• Number of people employed • Number of people unemployed • Employment rate • Unemployment rate • Number of jobs, including short-term jobs and long-term jobs in different sectors • Number of new jobs created in different sectors
New business opportunities (SDG 8)	• Number of new companies • Revenue and profit • Amount of new investment • Number of active long-term partnerships
Growth of new sustainable industries (SDGs 7, 17)	• Amount of investment in clean technology sector • Revenue and profit from clean technology sector • Number of projects

TABLE **6.4,** continued

Examples of sustainable development impacts and indicators relevant to renewable energy policies

Impact categories	Indicators
Prices of goods and services	• Energy prices
Costs and cost savings	• Fuel costs or cost savings • Health-care costs or cost savings • Economic costs of human health losses from air pollution based on social welfare indicator (ADALYs monetized in terms of social welfare valuation, based on willingness to pay – value of a statistical life estimates) or national accounts indicator (ADALYs monetized based on foregone output estimates, based on productivity/wage approaches)
Government budget surplus/deficit	• Annual revenue • Annual expenditures • Annual surplus or deficit
Energy independence	• Net imports of fossil fuels (coal, oil, natural gas)

Source: Adapted from ICAT *Sustainable Development Methodology*.

Examples of indicators for transformational impacts of RE policies are:[18]

- annual investments in RE technologies as a percentage of total investment in all energy sources
- percentage of total energy sector employees working in the RE sector
- number of new local enterprises providing RE services established
- value of RE-related procurement orders placed within the national supply chain.

[18] Singh and Vieweg (2015).

PART III

Assessing impacts

7 Estimating renewable energy addition of the policy ex-ante

This chapter provides a method for the first step of ex-ante impact assessment: estimating the RE addition that the policy can be expected to achieve. RE addition refers to the additional installation of RE capacity or electricity generation from renewable sources realized via the policy, expressed in megawatts or megawatt-hours, respectively. The expected RE addition depends on a number of factors, which are accounted for in this chapter.

Checklist of key recommendations

- Estimate the technical potential for the assessment period of the policy
- Identify policy design characteristics and account for their effect on the technical potential for the assessment period of the policy
- Identify factors that affect the financial feasibility of RE technologies and account for their effect on the technical potential for the assessment period of the policy
- Identify other barriers not addressed by the policy and account for their effect on the technical potential for the assessment period of the policy

7.1 Introduction to estimating renewable energy addition

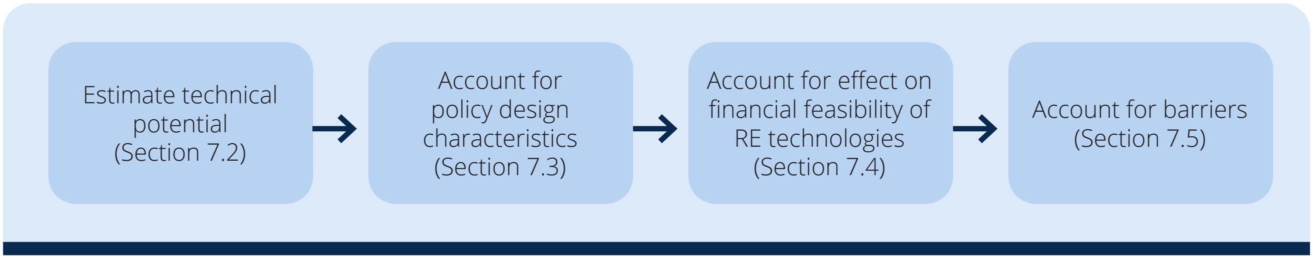
There are four steps to estimating the RE addition of the policy:

- estimate the technical potential of the policy for the assessment period
- account for policy design characteristics that influence the technical potential, such as the scope of eligibility, differentiation between technologies, payment structure, longevity of financial support, and complexity of regulatory and legal procedures
- identify factors that affect the financial feasibility of RE technologies and account for their effect on the technical potential for the assessment period (including accounting for alternative cost considerations, other policies in the sector and sector trends)
- identify other barriers that are not addressed by the policy and account for their effect on the technical potential for the assessment period.

Once these four steps are complete, users may wish to conduct a plausibility check by undertaking a benchmarking exercise. Because similar policies in similar countries often yield similar results, countries can compare their RE addition estimates with results from similar countries to ascertain whether the

FIGURE **7.1**

Overview of steps in the chapter



estimated RE addition seems reasonable. Users can refer to reports such as the REN21 Renewables Global Status Reports[19] for an overview of countries that have implemented similar policies. Where this benchmarking exercise shows significant discrepancies (between the estimated RE addition and results from other countries and policies) that cannot be easily explained, users should revisit the inputs and method used to estimate the RE addition, in an effort to refine the estimated RE addition.

Appendix C provides country examples for each of the three types of policies covered by this methodology. These are examples only, and users should use other peer country case studies that serve as appropriate benchmarks for their country context and specific policies.

7.2 Estimate the technical potential for the assessment period

The first step in estimating the RE addition resulting from the policy is to estimate the technical potential for the assessment period of the policy. In this methodology, the technical potential is defined as in the IPCC *Special Report on Renewable Energy Sources and Climate Change Mitigation*[20] (unless otherwise noted):

> Technical potential is the amount of renewable energy output obtainable by full implementation of demonstrated technologies or practices. No explicit reference to costs, barriers or policies is made. Technical potentials reported in the literature being assessed in this report, however, may have taken into account practical constraints and when explicitly stated there, they are generally indicated in the underlying report.

The users of this methodology can refer to other "potential" definitions, where relevant or useful. Box 7.1 provides a few of the most relevant definitions of different potentials.

Figure 7.2 shows three examples of how policy caps on annual capacity limits might determine the technical potential for the assessment period. A policy cap is a volume-based cap (e.g. on additional capacity installed or electricity generated) or price-based threshold (e.g. on which the support levels are determined) to set limits on policy costs.[21] In this methodology, the term "policy cap" refers to the maximum quantity of installed capacity supported by the policy for illustration purposes, unless otherwise noted.

Depending on the particular policy case, users may need to conduct additional analysis to identify the potential that is technically feasible to deploy to the end of the assessment period for a particular policy.

The technical potential for the assessment period need not be quantified when a policy cap has been set for the entire assessment period (case I). Where such a policy cap does not exist or covers only part of the assessment period (cases II and III), users estimate the technical potential using available information, such as scenario studies or databases on RE resource potentials.

7.2.1 Case I: policy with cap set for entire assessment period

For feed-in tariff policies, it is an increasingly common practice to set a cap, either at a maximum of RE addition per year or over the lifetime of the policy. Policy caps are implicit in the design of auctions and tenders, as a certain quantity is tendered and thus serves as the cap on either the number of installations, megawatts installed or electricity generated. A policy cap can be set on a periodic, annual or even monthly basis.

As shown in Figure 7.3, the aggregated periodic/annual/monthly policy caps determine the starting point of the user's analysis to estimate the addition of RE capacity over the entire assessment period (1,000 MW of RE addition, in this example). This is based on the underlying assumption that no further RE addition beyond the periodic/annual/monthly caps is supported by a given policy.

Users might reconsider using the aggregated periodic/annual/monthly cap to estimate the addition of RE capacity over the entire assessment period in the following cases:

- The policy cap is indicative and non-binding. In this case, users should carefully assess whether to use the aggregated non-binding cap to estimate the addition of RE capacity over the entire assessment period.

[19] Available at: www.ren21.net/status-of-renewables/global-status-report.

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

[21] Fruhmann (2015).

BOX **7.1**

Definition of renewable energy supply "potentials" other than the IPCC definition of "technical potential"

Theoretical potential is derived from natural and climatic (physical) parameters (e.g. total solar radiation on a continent's surface). The theoretical potential can be quantified with reasonable accuracy, but the information is of limited practical relevance. It represents the upper limit of what can be produced from an energy resource based on physical principles and current scientific knowledge. It does not take into account energy losses during the conversion process necessary to make use of the resource, nor any barriers.

Sustainable development potential is the amount of RE output that would be obtained in an ideal setting of perfect economic markets, optimal social (institutional and governance) systems, and achievement of the sustainable flow of environmental goods and services. This is distinct from economic potential because it explicitly addresses intergenerational and intragenerational equity (distribution) and governance issues.

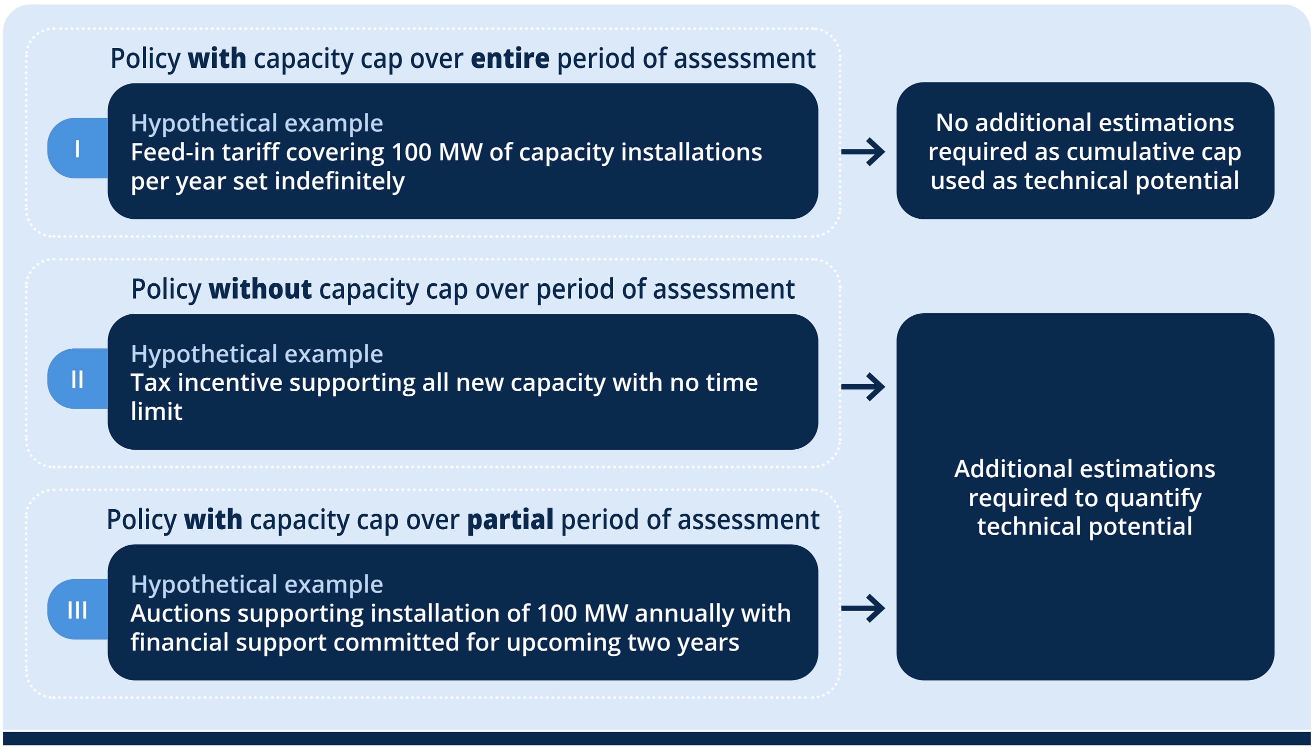
Economic potential is the amount of RE output projected when all social costs and benefits related to that output are included, there is full transparency of information, and it is assumed that exchanges in the economy install a general equilibrium characterized by spatial and temporal efficiency. Negative externalities and co-benefits of all energy uses and other economic activities are priced. Social discount rates balance the interests of consecutive human generations.

Market potential is the amount of RE output expected to occur under forecasted market conditions, shaped by private economic agents and regulated by public authorities. Private economic agents realize private objectives within given, perceived and expected conditions. Market potentials are based on expected private revenues and expenditures, calculated at private prices (incorporating subsidies, levies and rents) and with private discount rates. The private context is partly shaped by public authority policies.

Source: IPCC 2012.

FIGURE **7.2**

Three policy cases and their implications for determining the technical potential for the assessment period



Alternatively, users may follow the approach to quantifying the technical potential for the assessment period for RE policies without a cap described in Section 7.2.2.

- The policy cap is binding, but there is still potential for the policy to exceed its objective if the government decides to revise the cap. In this instance, the starting point to estimate the addition of RE capacity over the entire assessment period is still the policy cap, which might need to be adapted if the policy cap is revised. For example, a government may decide to set an artificially low cap in the beginning, when experience with the technology is lacking or where the government has decided against further deployment. As technology penetration grows, acceptance and trust may increase, leading the government to revise the RE policy cap upwards.

7.2.2 Case II: policy without cap set for entire assessment period

Where no policy cap is specified, the technical potential for the assessment period should be estimated using available studies or data on long-term technical potential for RE technologies. The long-term technical potential can be based on a study that estimates the deployment potential for a particular RE technology in a region or country during a specific time frame. Figure 7.4 shows an example of an RE policy without a cap over the period of assessment.

Based on data availability for the specific country or region, users may choose one of the following two options to estimate the technical potential. Note that these options help estimate the resource potential and not the technical potential during the assessment period. Preference should be given to the quality of the data or study.

FIGURE **7.3**

Case I – policy with cap set for entire assessment period

Hypothetical example
Feed-in tariff covering 100 MW of capacity installations per year set indefinitely

Year 1	Year 2	Year 3	Year 4	Year 5	Total over 10 years assessment period
100 MW	100 MW	100 MW	100 MW	100 MW	
Year 6	Year 7	Year 8	Year 9	Year 10	
100 MW	100 MW	100 MW	100 MW	100 MW	1,000 MW

FIGURE **7.4**

Case II – policy without cap set for entire assessment period

Hypothetical example
Tax incentive supporting all new capacity with no time limit

Year 1	Year 2	Year 3	Year 4	Year 5	Total over 10 years assessment period
-	-	-	-	-	
Year 6	Year 7	Year 8	Year 9	Year 10	
-	-	-	-	-	Estimation

Abbreviation: -, not applicable

Option 1: Estimate the long-term technical potential from national or regional specific studies
Users can refer to studies by national experts or international organizations. It is recommended that users conduct a thorough literature review of national and international studies to allow an informed decision on which estimates to use.

A variety of studies on the potential of RE in specific countries and regions are available. These studies often provide a scenario specifying a mix of possible technological options for a given country or region. Table 7.1 presents a few examples of available studies and databases for national RE potentials. Some of these studies provide potential values for different future years. For specific countries, potentials can also be obtained from studies by national institutions. In Mexico, for example, the National Atlas of Zones with High Clean Energy Potential[22] published by the Secretariat of Energy contains information about geographical areas in Mexico with high RE potential (possible, probable and proven) per technology. IRENA has published the Global Atlas for Renewable Energy,[23] a web platform that allows its users to find maps of RE resources for locations across the world.

These studies and maps look at different types of RE potentials, ranging from “technical potential” to “theoretical potential” and “economic potential”, as per the IPCC definition,[24] and break them down into national or regional levels. Users should use caution when referring to the “potential” values presented in these studies and how to make use of them in the assessment.

TABLE **7.1**

Examples of available country-specific studies for national renewable energy potentials

Name of institution	Technology coverage	Country/region coverage	Main characteristics
IRENA	√ Solar PV √ Concentrated solar power √ Wind √ Bioenergy	Global; specific studies for Africa (all continental countries),[a] Indonesia,[b] Russia,[c] south-east Europe,[d] Egypt[e] and others	Studies on renewable energy potential by country and/or technology. The REmap project assesses RE potential from the bottom up, based on country analyses done in collaboration with country experts.
Solutions Project (Stanford University)	√ Solar PV √ Concentrated solar power √ Wind √ Hydro √ Wave and tidal	138 countries[f]	Provides a vision for the transition to 100% wind, hydro and solar energy by 2050.
Global Wind Energy Council	Wind	80 countries (e.g. United States, all the European markets, India, China)	Provides country reports with (technical) potentials.

[a] IRENA (2014).
[b] IRENA (2017a).
[c] IRENA (2017b).
[d] IRENA, Joanneum Research and University of Ljubljana (2017).
[e] IRENA (2018a).
[f] https://thesolutionsproject.org/why-clean-energy/#/map/countries/

[22] Available at: https://dgel.energia.gob.mx/azel/
[23] Available at: https://irena.masdar.ac.ae/gallery/#gallery.
[24] IPCC (2011).

Option 2: Estimate the long-term technical potential using existing technology-specific databases
A number of international databases contain information on RE potentials for different RE technologies. The scope – in terms of technology and country/region coverage – varies from database to database. Whereas some databases are free of charge and publicly accessible, others are available at a cost. Table 7.2 lists available international public and private databases that provide either RE potential for a region and technology or specific parameters needed for calculating the maximum RE potential.

TABLE **7.2**

Examples of databases on renewable energy resource availability

Name of database	Private or public	Technology coverage	Geographic coverage	Main description	RE potential or data for RE potential calculation
IRENA Global Atlas for Renewable Energy[a]	Public (a free login is required to see all available maps)	Wind, solar, geothermal, biomass, ocean, hydro	All countries	A web platform coordinated by IRENA that allows users to find maps of RE resources for locations around the globe. It provides datasets, expertise and financial support to evaluate national RE potentials.	Both
NREL and USAID Renewable Energy Data Explorer (REexplorer)[b]	Public	Biomass, geothermal, hydro, solar, wave, wind	Afghanistan, Bangladesh, Central Asia, Colombia, Ghana, India, Kenya, Mexico, Nepal, Pakistan, Peru, South-East Asia (including Brunei Darussalam, Burma, Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Singapore, Thailand and Vietnam)	REexplorer provides RE data, analytical tools and technical assistance to developers, policymakers, and decision makers in developing countries. REexplorer can be used to analyse and visualize RE potential (estimated through hourly data and geospatial variables) under user-defined system scenarios.	Both
NASA Prediction of Renewable Energy Resources (POWER)[c]	Public	Wind, solar	All countries	NASA provides solar and meteorological data sets from NASA research for support of RE, building energy efficiency and agricultural needs in its POWER programme. Data are accessible by multilayer maps, and up to 20 different parameters can be selected.	Both

TABLE **7.2,** continued

Examples of databases on renewable energy resource availability

Name of database	Private or public	Technology coverage	Geographic coverage	Main description	RE potential or data for RE potential calculation
Renewables.ninja[d]	Public	Wind, solar	All countries	Renewables.ninja allows users to run simulations of the hourly power output from wind and solar. It can find past yields and predict yields in specific locations.	RE potential
PVWatts[e]	Public	Solar PV	Americas, Indian subcontinent, parts of Central Asia	PVWatts Calculator is an online free tool developed by NREL to estimate the energy production and cost of energy for grid-connected solar PV.	RE potential
PV Sol[f]	Public	Solar PV	Not specified	PV Sol is an online free tool that estimates the optimal connection of the PV module and the best-suited inverter. It also simulates the annual PV energy and performance ratio. A more extensive software tool can be purchased online.	Both
PVGIS[g]	Public	Solar PV	Europe, Africa, Americas, Asia	PVGIS is an online free tool to estimate the electricity yield of a PV system. It was developed by the Joint Research Centre from the European Commission. It gives the annual and monthly power production based on site and module specifics. The results can be visualized online or downloaded in CSV format.	Both
WindSim[h]	Public	Wind	Not specified	WindSim is used for wind farm optimization by identifying turbine locations with the highest wind speeds, to maximize power production. It uses computational fluid dynamics and 3D models of the terrain to obtain the optimized wind park layout.	RE potential
Global Energy Resources Database (Shell)[i]	Public	Solar (distributed, centralized), wind (offshore, onshore), biomass, hydro, geothermal	All countries	Provides a long-term energy production potential by 2070 (data per country and technology in energy units/year – not as a time series). How this potential is calculated is not specified.	RE potential

TABLE **7.2,** continued

Examples of databases on renewable energy resource availability

Name of database	Private or public	Technology coverage	Geographic coverage	Main description	RE potential or data for RE potential calculation
pvPlanner[j]	Public (1 month free trial) Private (after 1 month)	Solar PV	All countries (time period availability varies per country)	pvPlanner simulates PV electricity production by models developed by Solargis. It uses technical and site parameters as input and provides electricity yield, solar-in-plan irradiation and performance ratio as output. The site parameters are based on long-term annual and monthly averages. The output is delivered in PDF, XLS or CSV format.	Both
AWS Truepower's Windographer[k]	Private	Wind	Depends on the data imported. It supports all formats.	The software from Windographer can be purchased and downloaded online. It imports wind data of any kind and makes it easy to analyse. The data can be visualized, and errors can be automatically detected. The software provides several output layouts.	Both
Wind Atlas Analysis and Application Program (WAsP) from Risoe National Laboratory[l]	Private	Wind	All countries	WAsP is a software tool for wind resource assessment for single wind turbines and wind farms. It includes features for different terrains, climatic stability on site and more. The outputs consist of energy yield, wind farm efficiency, turbulence mapping and site assessment.	RE potential
PVSyst[m]	Private	Solar PV	Not specified	PVSyst provides a software tool that allows users to analyse PV technology yields, based on different configurations. The goal is to develop an optimal and reliable PV system. The software can be purchased and downloaded from PVSyst's website.	Both
3TIER Dashboard (Vaisala)[n]	Private	Wind, solar	Not specified	3TIER is a web-based application that allows users to access renewable resource data for wind (e.g. wind speed at different heights) and solar (e.g. solar irradiation).	Data for RE calculation

TABLE **7.2,** continued

Examples of databases on renewable energy resource availability

Name of database	Private or public	Technology coverage	Geographic coverage	Main description	RE potential or data for RE potential calculation
AWS Truepower (UL Renewables)[o]	Private	Wind	All countries	The Wind Resource Grids provided by AWS Truepower through Windnavigator allow users to site meteorological towers, design preliminary layouts and obtain preliminary estimates of the wind energy generated for small to multi-turbine wind projects.	Both
SolarGIS[p]	Private	Solar PV	All countries	SolarGIS provides solar electricity data that are used in the whole life cycle of solar power plants, from prospecting to development and operation.	Both
Meteonorm[q]	Private	Solar PV	All countries (time period availability varies per country)	Meteonorm's software provides solar radiation data and calculation tools to estimate solar PV power yields. The data are obtained from weather stations worldwide and include many parameters. After purchase, the tools are available as a web service or on desktop.	Both

Abbreviations: NASA, National Aeronautics and Space Administration; NREL, National Renewable Energy Laboratory; PV, photovoltaic; USAID, United States Agency for International Development

[a] http://irena.masdar.ac.ae
[b] www.re-explorer.org
[c] https://power.larc.nasa.gov/data-access-viewer
[d] www.renewables.ninja
[e] https://pvwatts.nrel.gov
[f] http://pvsol-online.valentin-software.com/#/
[g] http://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#PVP
[h] https://windsim.com
[i] www.shell.com/energy-and-innovation/the-energy-future/scenarios/shell-scenarios-energy-models/energy-resource-database.html
[j] https://solargis.info/pvplanner/#tl=Google:hybrid&bm=satellite
[k] www.windographer.com
[l] www.wasp.dk
[m] www.pvsyst.com
[n] www.3tier.com/account/login/?next=/dashboard
[o] https://aws-dewi.ul.com
[p] https://solargis.com
[q] https://meteonorm.com/en

Table 7.3 provides examples of methodologies and tools that can be used to estimate the RE potential using input data available in databases listed in Table 7.2.

To do so, users need to first consider resource factors related to the availability of RE sources, including:

- physical constraints – physical characteristics that determine or constrain the overall potential for RE extraction, such as total sun hours in a country or region
- energy content of resource – energy content that can theoretically be converted into electricity, such as wind intensity profile or solar radiation intensity
- theoretical physical potential – maximum potential of RE extraction depending on the physical characteristics and energy content of the resource.

For countries where neither national studies (option 1) nor data from international databases (option 2) are available, the user can collect local or national data. These data can be obtained from national experts (e.g. in-house experts in ministries, research groups at national universities or other research organizations, local consultants) or be informed by available data from other countries in the region that share similar circumstances. Users should look at parameters provided by the databases in Table 7.2 and the tools presented in Table 7.3 that describe calculation steps for RE potential, and list data and parameters needed for calculations. In general, users should be aware that this user-driven data-collection approach might be very time- and resource-intensive. Expert input and review should be involved at all stages.

Deriving the technical potential for the assessment period from the long-term technical potential

RE potential studies and databases presented in options 1 and 2 may only provide data on the RE resource potential. This is useful to quantify the long-term technical potential, but not the technical potential for the assessment period considered for the policy in question. In such cases, users may need to quantify the technical potential for the final year of the assessment period.

Quantification of the potential for the final year of the assessment period can be done by interpolating between the current installed capacity (or generation) and the long-term technical potential. This quantification should be done for each RE technology type. The results for each are then aggregated to obtain the total technical potential.

Users may need to make a number of assumptions to quantify the potential for a specific year, including:

- the long-term target year in which the long-term technical potential could be achieved
- the shape of the RE deployment trajectory – it can be linear, S-shaped or any other shape that the user considers realistic.

Once the RE technical potential for the final year of the assessment period is estimated, it is important to examine whether the annual growth rates in installed capacity, amount of electricity generated and share of electricity generation can be considered reasonable. For example, the IRENA database on Trends in Renewable Energy[25] provides necessary data to compare historical annual growth rates for specific technologies with the technical potential for the assessment period estimated by the user. This step will ensure robustness of obtained results and underlying assumptions.

It is also important to take into account the time required to build RE power plants. Construction of RE capacity, and therefore realization of the RE potential, takes time. Users should estimate the technical potential for the assessment period taking into account the time it takes to install RE capacity and how much capacity can practically be installed within the relevant time frame – that is, assuming no constraints imposed by policy design characteristics, economic and financial factors, and other barriers. Table 7.4 provides an overview of technology lead times from literature. Users should consider such lead times when making or cross-checking assumptions on the uptake of RE technologies.

7.2.3 Case III: policy with cap set for a portion of the assessment period

In some cases, the time frame associated with the policy cap does not match the assessment period. Figure 7.5 provides an example of an RE policy that has a shorter financial commitment from the government than the assessment period. In this case, the cap covers the first two years of the policy, while

[25] IRENA (2019b).

TABLE **7.3**

Support tools to estimate renewable energy potential per technology based on different parameters obtained from international databases

Technology	Needed/available information	Study/methodology for RE potential calculation based on available information	Calculation complexity
Solar PV	• Total solar panel area (m^2) • Solar panel yield or efficiency (%) • Annual average solar radiation on tilted panels (shadings not included) • Performance ratio, coefficient for losses (range 0.5–0.9; default value 0.75)	Photovoltaic-software.com, under Principles and Resources	Low
Solar PV	• System size (kW, DC) • Module type (std, medium, thin film) • System losses (%) • Array type (fixed open rack, fixed roof mount, 1-axis, backtracked 1-axis, 2-axis) • Tilt angle (degrees) • Azimuth angle (degrees) • DC/AC ratio (optional) • Inverter efficiency (%)	The methodology behind PVWatts calculations (see Table 7.2) can be applied to data outside the PVWatts calculator. The methodology is available from the PVWatts manual (Dobos, 2013, 2014).	Medium
Wind	• ρ = air density (kg/m^3) • A = rotor swept area (m^2) • Cp = coefficient of performance • V = wind velocity (m/s) • Ng = generator efficiency • Nb = gear box bearing efficiency	Several websites or papers available (e.g. MIT; Sarkar and Behera [2012]; Windpowerengineering.com)	Low
Biomass electricity	Depends on desired output	CDM methodologies: • *AM0007: Analysis of the Least-Cost Fuel Option for Seasonally-Operating Biomass Cogeneration Plants* • *ACM0006: Consolidated Methodology for Electricity and Heat Generation from Biomass* • *ACM0018: Electricity Generation from Biomass Residues in Power-Only Plants* • *ACM0020: Co-Firing of Biomass Residues for Heat Generation and/or Electricity Generation in Grid Connected Power Plants*	
Geothermal	Depends on desired output, but most important are: • surface temperature • heat flow • density of earth material • depth of heat source	Beardsmore et al. (2010)	Medium

TABLE **7.4**

Project lead times for renewable energy technologies

Technology	Lead time	References
Solar PV	Single rooftop: 1 day – 1 week 5–100 MW solar farms: 4–12 months >100 MW solar farms: 12–36 months	SEIA (2019) Sovacool, Gilbert and Nugent (2014) Sovacool, Nugent and Gilbert (2014) International Finance Corporation (2015)
CSP	12–36 months	Sovacool, Gilbert and Nugent (2014) Sovacool, Nugent and Gilbert (2014)
Wind	Up to 10 MW farms: 2 months Up to 50 MW farms: 6 months Contemporary average (including offshore): 12 months Offshore potential per wind turbine: 2–3 days	Sovacool, Gilbert and Nugent (2014) Sovacool, Nugent and Gilbert (2014) EWEA (2016) IRENA (2012a)
Biomass	18–57 months	Ministry of New and Renewable Energy India (2019) U.S. Energy Information Administration (2019) Sovacool, Gilbert and Nugent (2014)
Geothermal	3–5 years	Budisulistyo and Krumdieck (2015) Shortall, Davidsdottir and Axelsson (2015)

Abbreviation: CSP, concentrated solar power

the assessment considers impacts over a 10-year time frame.

In such cases, quantification of the technical potential for the assessment period may require a few considerations in addition to those described in Section 7.2.2. For example, would the policy cap for the first years lead to lock-in of a certain infrastructure that negatively affects the technical potential of the RE technologies in question? Is there a short-term need for electricity generation that will not be met through the policy to promote RE

FIGURE **7.5**

Case III – policy with cap set for a portion of the assessment period

Hypothetical example
Auctions supporting installation of 100 MW annually with financial support committed for upcoming two years

Year 1	Year 2	Year 3	Year 4	Year 5	Total over 10 years assessment period
100 MW	100 MW	-	-	-	
Year 6	**Year 7**	**Year 8**	**Year 9**	**Year 10**	
-	-	-	-	-	200 MW +estimation

Abbreviation: -, not applicable

and thus lead to the construction of large fossil fuel generation plants?

Users should use caution when determining which assumptions are realistic given the country- and policy-specific circumstances, and transparently explain all assumptions made.

7.2.4 Examples of estimating technical potential for the assessment period

The examples below illustrate how RE addition would be calculated for two types of policies – auctions (example 1) and feed-in tariff (example 2) – taking into account the various factors that need to be considered to establish a credible figure. The examples are presented in a stepwise approach to illustrate the four steps needed to develop a final estimate. Step 1 is shown in Boxes 7.2 and 7.3.

It is important to note that the examples presented relate to increases in RE generation capacity (i.e. MW) for purposes of illustration and simplicity, even though many policies, including auctions and feed-in tariffs, support the purchase of electricity (i.e. MWh). Capacity factors, which are used to calculate electricity generated from installed capacity, are introduced in Chapter 8.

BOX **7.2**

Auctions (example 1) – estimating technical potential for the assessment period for a tender policy with a partial policy cap

1. Estimate technical potential for the assessment period

The policy is designed to increase specific quantities of installed RE capacity over three consecutive years. The policy is administered by a public authority that has set up three different rounds of tenders, one each year. Power producers will submit bids for these three tenders, and a number of winners will be selected to construct the total amount of installed capacity tendered for that year. The following quantities of RE are scheduled to be tendered:

- 2020 – 20 MW
- 2021 – 60 MW
- 2022 – 70 MW.

The assessment period is from 2020 to 2030. Because capacity additions are only specified for the first three years of the assessment period, the user follows the approach outlined under **Case III: policy with cap set for a portion of the assessment period** (in Section 7.2.3).

The user refers to the total specified tendered capacities of 150 MW between 2020 and 2022 as a starting point, while making an informed additional assumption for the period between 2023 and 2030.

The Ministry of Energy, which is responsible for the policy's design and implementation, emphasizes its intention to continue the policy after 2022. Ministerial staff indicate that the cap for 2022 was set based on a realistic assumption for the annual addition of RE capacity in the particular country context once initial challenges were overcome. The user decides to assume that RE capacity is added at the rate reached by the policy in the third year (i.e. 70 MW per year for 2023–2030). Therefore, 640 MW is estimated to be the technical potential up to 2030.

640 MW

BOX **7.3**

Feed-in tariff (example 2) – estimating technical potential for the assessment period for a feed-in tariff policy without a policy cap

1. Estimate technical potential for the assessment period

As the feed-in tariff policy specifies no policy cap for any of the assessment period years, the user follows the approach outlined under **Case II: policy without policy cap set for entire assessment period** (in Section 7.2.2).

A national university with expertise and a progressive energy department produces estimates for the maximum RE resource potential in the country, which they have been updating on a yearly basis for their own research purposes.

In a workshop session, the university experts explain their estimates for the RE resource potential, and the underlying assumptions on all resource and technical factors, to ministry representatives. Both groups jointly conclude that the long-term technical potential for the respective technologies is:

- solar energy – 1,500 MW
- wind energy – 800 MW.

The experts further analyse capacity and, given the trajectory of RE implementation, determine that it is practical to install the following by 2030 (NDC target year):

- solar energy – 900 MW
- wind energy – 400 MW.

Therefore, the overall technical potential of the feed-in tariff policy across technologies for the assessment period by 2030 is determined to be **1,300 MW**.

1,300 MW

7.3 Account for policy design characteristics

Several design characteristics common to RE policies influence their impact. These include the scope of eligibility, differentiation between technologies, payment structure, longevity of financial support, and complexity of regulatory and legal procedures. It is a *key recommendation* to identify policy design characteristics and account for their effect on the technical potential for the assessment period of the policy.

Tables 7.5–7.7 list the main design characteristics for the three different types of RE policies and describe how each influences the technical potential for the assessment period. Specifically, Table 7.5 presents design characteristics for feed-in tariffs, Table 7.6 presents design characteristic for auction policies, and Table 7.7 presents design characteristics for tax incentives.

Users should use these tables to:

- identify design characteristics that are likely to influence the RE technical potential in their country context
- describe how the identified policy design characteristics are expected to influence RE deployment
- estimate the overall influence of these characteristics on the RE technical potential for the assessment period of the policy.

TABLE **7.5**

Feed-in tariff policies – influence of policy design characteristics on technical potential for the assessment period

Design characteristic	Description	Influence on technical potential for the assessment period
Eligibility	• Project owner • Technology • Size • Location	• The narrower the eligibility conditions of the feed-in tariff policy, the lower the probability that the policy achieves its technical potential for the assessment period.
Tariff differentiation	• RE type • Project size • Resource quality • Technology application • Ownership type • Geography • Local content	• Differentiated tariffs are able to tap into a larger share of the GHG emissions reduction potential; lower tariffs for less expensive RE technologies may lower the probability that the policy achieves its technical potential for the assessment period.
Payment structure	• Fixed-price or premium-price policies	• For both types of payment structures, if the resulting end price is above the levelized cost of electricity or other feasibility calculations done by power producers, this should not reduce the probability that the policy achieves its technical potential for the assessment period.
Utility's role	• Purchase obligation • Guaranteed grid connection	• The lack of purchase obligation or guaranteed grid connection may lower the probability that the policy achieves its technical potential for the assessment period, because of decreased security and certainty for investors.
Contract and payment duration	• Contract periods (short term, medium term, long term)	• A short contract period in combination with a relatively low feed-in tariff might lower the probability that the policy achieves its technical potential for the assessment period because of a lack of certainty for power producers and their investors. Conversely, a short contract period with a relatively high feed-in tariff might be attractive, since it allows the initial investment to be recouped relatively quickly. • Longer contract periods mean higher risks for power producers; power producers may lack confidence in the government's ability or will to sustain the feed-in tariff over time; and their own costs are more difficult to forecast further out. Longer contract periods might therefore lower the policy's technical potential for the assessment period.
Opt-out options	• Contractual opt-out options for power producers to sell energy on the free market	• Power producers gain contractual flexibility, after a certain time, to sell their electricity on the free market instead of receiving the feed-in tariff. This can increase investment interest in country contexts where RE technologies might achieve cost parity in the near- to mid-term future.
Forecasting	• Forecast obligation	• Forecasting obligations require power producers to provide hourly predictions of power production to participate in the market. The actual production under the estimated forecast is charged the highest price on the market for the non-produced amount of energy. This presumably has a small effect on the likelihood that the policy achieves its technical potential for the assessment period, but may slightly increase project costs.

TABLE **7.5**, continued

Feed-in tariff policies – influence of policy design characteristics on technical potential for the assessment period

Design characteristic	Description	Influence on technical potential for the assessment period
Grid access	• Transmission • Interconnection	• A lack of grid priority for RE electricity presumably lowers the probability that the policy achieves its technical potential for the assessment period, because of decreased security and certainty for investors.
Policy adjustments	• Payment adjustments (fixed adjustments, regular adjustments, inflation adjustments) • Programme adjustments	• Downward adjustment of feed-in tariff prices or premiums may decrease the probability that the policy achieves its technical potential for the assessment period if done ineffectively, and may also lead to resistance.

Sources: Adapted from Cory, Couture and Kreycik (2009); Couture et al. (2010); UNEP (2012); UNESCAP (2012).

TABLE **7.6**

Auction policies – influence of policy design characteristics on technical potential for the assessment period

Design characteristic	Description	Influence on technical potential for the assessment period
Auction demand and auction design	• Choice of the volume auctioned, and differentiation between different technologies and project sizes (technology-neutral auctions or technology-specific auctions, and stand-alone or systematic auctioning policies)	• The volume auctioned directly affects the size of the technical potential for the assessment period. • Suboptimal auction design and/or incomplete pre-analysis on conditions for successful tendering may affect the auction's effectiveness and decrease the likelihood that the policy will achieve its technical potential for the assessment period.
Longevity of the PPA	• PPA signed with the preferred bidder • Contract provides power producers with a fixed price for a certain number of years and guaranteed purchase for all generation	• Without the provision of longevity annuities, which safeguard against risks for power producers and investors, and lower the costs of financing, there is a reduced likelihood that the technical potential for the assessment period will be achieved.
Qualification requirements	• Power producers eligible to participate in the auction and requirements related to reputation • Equipment and production site selection • Securing grid access • Instruments to promote local socioeconomic development	• A lack of qualification criteria for bidders may decrease the likelihood that expected capacity is successfully installed and that the technical potential for the assessment period is achieved. • High and costly qualification requirements may exclude small-scale or new power producers, since such potential bidders may lack required resources; this may decrease the likelihood that the technical potential for the assessment period is achieved. • Identification of sites that lack ideal resources and secured grid connection potentially increases risks to investors, thus decreasing the likelihood that the technical potential for the assessment period is achieved.

TABLE **7.6,** continued

Auction policies – influence of policy design characteristics on technical potential for the assessment period

Design characteristic	Description	Influence on technical potential for the assessment period
Winner selection process	• Bidding procedure • Requirements of minimal competition • Winner selection criteria • Clearing mechanism and marginal bids • Payment to the auction winner	• Competitive bidding (in seal-bid or descending clock auction) can lead to underbidding due to an incentive for bidders to bid as low as possible to increase their chances of securing a contract, which may decrease the likelihood that the technical potential for the assessment period is achieved. • Experience suggests that underbidding is widespread and contract failure rates remain high, leading to slower growth.
Sellers' contractual liability requirements	• Commitments to contract signing • Contract schedule • Remuneration profile and financial risks • Nature of the quantity liabilities • Settlement rules and underperformance penalties • Delay and underbuilding penalties	• High overall liability requirements may deter potential bidders, possibly decreasing the likelihood that the technical potential for the assessment period is achieved. • The less predictable and stable the institutional and regulatory framework, the higher bidders' perceived risk in the auctioning process and the lower the probability that the technical potential for the assessment period is achieved. • The lack of sellers' liability requirements provides an incentive for drastic underbidding, lowering the probability that the technical potential for the assessment period is achieved.

Sources: Adapted from IRENA (2013, 2015a); Agora Energiewende (2014).
Abbreviation: PPA, power purchase agreement

TABLE **7.7**

Tax incentive policies – influence of policy design characteristics on technical potential for the assessment period

Design characteristic	Description	Influence on technical potential for the assessment period
Type of tax incentive	• Reduced or complete tax exemption or refunds • Deductibles • Tax credits • Different payment schedules • Fiscal stability incentives	• Tax incentives that are too low provide insufficient incentives for eligible entities to install additional RE capacity, thus lowering the probability that the technical potential for the assessment period is achieved. • Incentive policies incentivize RE in different ways: tax credits reducing the tax liability for (a portion of) the cost of purchasing and installing RE capacity lead to direct cost saving; fiscal stability incentives that shield certain RE technologies from potential future changes in fiscal regimes or from additional fees create a stable investment environment; decreased stability and low level of incentives lower the probability that the technical potential for the assessment period is achieved.

TABLE **7.7,** continued

Tax incentive policies – influence of policy design characteristics on technical potential for the assessment period

Design characteristic	Description	Influence on technical potential for the assessment period
Scope of application	• Pre-investment expenses related to RE projects • Sale of electricity • Carbon credits and other ancillary income • RE-specific taxes or concession fees • Services and equipment • Civil works	• A narrow scope of tax incentive (potentially) decreases the incentive for eligible entities to install additional RE capacity, lowering the probability that the technical potential for the assessment period is achieved. • Restricted eligibility that is limited to few RE technologies may lower the probability that the technical potential for the assessment period is achieved, because eligible entities have less flexibility to choose the most appropriate technology.

Sources: Adapted from OECD (2011); North Carolina Solar Center (2012); IRENA (2015b).

To estimate the overall influence of each policy characteristic on the technical potential for the assessment period of the policy, users can follow the following steps:

1. Make a first order estimate of how each policy design characteristic might influence the expected RE addition for the assessment period. Depending on the type of design characteristics, this can be done by specifying a total capacity value to be deducted (e.g. 200 MW from the entire potential) or a percentage factor (e.g. 5% of the entire potential) to be applied to the expected RE addition of the policy for the assessment period. This first order estimate can be informed by previous experience with other policies (in-country or external) or literature in the field.

2. Consult with stakeholders and/or experts (e.g. experts in power systems, electricity sector policy or electricity grids) to validate and, where necessary, revise the first order estimates. In case of high uncertainty and diverging expert opinions, users could also apply an uncertainty range to indicate this difference in judgment (e.g. 150–200 MW or 5–10%).

3. Deduct the first order estimates from the technical potential for the assessment period to reflect the impact of policy design characteristics.

7.3.1 Examples to account for policy design characteristics

BOX **7.4**

Auctions (example 1) – using policy design characteristics to refine expected renewable energy addition for the assessment period

1. Estimate technical potential for the assessment period (from Box 7.2) – **640 MW**

2. Account for policy design characteristics

The design characteristics for the auction policy are as follows:

- **Auction demand/auction design** – technology-specific stand-alone auctions
  - **2020** – 10 MW of solar, 10 MW of wind
  - **2021** – 30 MW of solar, 20 MW of wind, 10 MW of biomass
  - **2022** – 30 MW of solar, 30 MW of wind, 10 MW of biomass
  - **2023–2030** – 30 MW of solar, 30 MW of wind, 10 MW of biomass (all annually).
- **Longevity of the power purchase agreement (PPA)** – duration of tariff is 25 years for solar, 20 years for wind and 20 years for biomass.
- **Qualification requirements** – pre-qualification phase with requirements to display experience, as well as financial and technical capacity to implement projects.
- **Winner selection process** – one-round winner selection based on price and quota of energy (with no ceiling price), with several bidders selected.
- **Sellers' liabilities requirements** – penalties for delay and underperformance determined in PPA, guarantee paid at signature of PPA, termination of PPA as last resort.

Because of a lack of specific quantification methods, a qualitative approach is used to estimate the influence of each policy design characteristic (above) on the technical potential for the assessment period that can be realized by the policy.

To start, the user made first order estimates of how each policy design characteristic might influence the technical potential for the assessment period. These estimates were discussed in a consultation workshop with national energy sector experts. The conclusions suggest that the policy design characteristics that are likely to affect the technical potential for the assessment period are as follows:

1. The **predefined qualification requirements** are likely to directly reduce the technical potential for the assessment period. The consultation revealed that only a small number of companies have sufficient financial and technical capacity to implement projects. These qualification requirements were introduced to ensure the successful implementation of the auctioned capacity. However, since the industry needs a few years to develop further expertise, the expected RE addition of the policy for the assessment period analysed is reduced by 60 MW from 640 MW (the technical potential for the assessment period determined in the previous step) to 580 MW.
2. The **sellers' liability requirements** are likely to reduce the expected RE addition of the policy for the assessment period because a number of potential power producers cannot provide the required guarantee at the signature of the PPA. These liability requirements were introduced to ensure the successful implementation of the auctioned capacity. After consultation with the two industry experts and a review of the current project pipeline in the country, it is estimated that this reduces the maximum achievable impact by a further 30 MW, from 580 MW to 550 MW.
3. After analysing whether the specifications of the **longevity of the PPA** might reduce the expected RE addition of the policy, no further downward adjustments have been made because the duration has been set after consultation with power producers to ensure a sufficiently long PPA duration.

After accounting for all policy design characteristics, the expected RE addition of the policy for the assessment period is expected to be **550 MW** (compared with 640 MW originally).

550 MW

BOX **7.5**

Feed-in tariff (example 2) – using policy design characteristics to refine expected renewable energy addition for the assessment period

1. Estimate technical potential for the assessment period (from Box 7.3) – **1,300 MW**

2. Account for policy design characteristics

The design characteristics for the feed-in tariff are as follows:

- **Eligibility** – the only technology eligible under the feed-in tariff is solar PV.
- **Tariff differentiation** – higher feed-in tariffs for small projects and lower tariffs for large-scale projects (set to give rates of return of 5–8%).
- **Payment structure** – premiums offered above prevailing retail rates for electricity.
- **Utility role** – government-owned single buyer with guaranteed purchase.
- **Contract and payment duration** – premium is offered over period of 15 years.
- **Forecasting** – no forecasting requirements.
- **Grid access** – grid priority transmission and dispatch for RE.
- **Policy adjustments** – only inflation adjustments over lifetime of feed-in tariff.

Because of a lack of specific quantification methods, a qualitative approach is used to estimate the influence of each design characteristic (above) on the technical potential for the assessment period of the policy.

To start, the user made first order estimates of how each policy design characteristic might influence the technical potential for the assessment period. These estimates were discussed in a consultation workshop with national energy sector experts. The analysis reveals that the policy design characteristics that are most likely to affect the technical potential for the assessment period are as follows:

1. The **scope of eligibility** is expected to directly reduce the technical potential for the assessment period, since only solar PV installations are eligible. As a result, the technical potential for the assessment period for wind energy, which was determined to be 400 MW, is deducted from 1,300 MW, leaving 900 MW as the technical potential of the policy.
2. The approach of offering a **premium** on top of prevailing market prices for electricity is expected to reduce the technical potential for the assessment period, because the partial dependence on the electricity market price introduces a level of uncertainty that would not exist if the entire feed-in price was fixed. A local consultancy conducted a representative survey of potential power producers and investors (both small scale and large scale) on how this uncertainty might affect future RE deployment. Based on this survey, the local consultants estimate that the uncertainty reduces the technical potential for the assessment period by only about 60 MW (conservative estimate), because most power producers have found ways to deal with the uncertainty (e.g. through integrating it into the rest of their portfolio). This reduces the technical potential for the assessment period to 840 MW.
3. The **contract and payment duration** of 15 years is expected to be too short for several large-scale solar PV projects because power producers would require contracts with payment durations of 20–25 years. A consultation with two local experts on RE investments, which includes a review of the projects currently in the pipeline in the country, reveals that, under these conditions, about 6% of the projects in the pipeline would not be built. This means that the technical potential for the assessment period would be further reduced by 40 MW (conservative estimate) to 800 MW.

After accounting for all policy design characteristics, the refined technical potential for the assessment period is expected to be **800 MW** (compared with 1,300 MW originally).

800 MW

7.4 Account for effect on financial feasibility of renewable energy technologies

RE policies can provide financial incentives that directly influence the financial feasibility of RE technologies and, in turn, the expected RE addition of the policy for the assessment period. It is a *key recommendation* to identify factors that affect the financial feasibility of RE technologies and account for their effect on the technical potential for the assessment period of the policy. Existing cost–benefit analyses (e.g. conducted in the policy design phase) should be used as a basis here and should be updated as needed.

In this step, users make an initial estimate of the effect of the policy on the financial feasibility of RE technologies (Section 7.4.1). Users should then account for alternative cost considerations, other policies in the sector and sector trends. The effect of financial barriers on the expected RE addition of the policy for the assessment period is considered separately in the barrier analysis (Section 7.5).

7.4.1 Identify factors that affect the financial feasibility of renewable energy technologies

Users should identify the level of incentive provided by the policy and its effect on the financial feasibility of RE technologies. Where possible, they should build upon existing cost–benefit analyses. The cost–benefit analyses should be updated to reflect recent developments, and confirm their continued applicability and completeness.

A number of factors need to be considered. First are factors that are directly related to RE deployment, including the following:

- **Cost of the technology in the local market** – includes capital costs, operations and maintenance costs, and fuel (e.g. biomass) costs. Mark-ups may arise in local markets as a result of inexperience with a given technology in the country – for example, a shortage of engineers that necessitates bringing in outside expertise. Technology costs in local markets can also be driven by advances in knowledge, which reduce technology costs over time.

- **Technical characteristics of the technology applied in the local market** – include capacity of the technology, load characteristics and operational lifetime of the technology.

- **Project financing** – includes financing sources and their conditions, such as interest rates and duration of loans. Project finance generally comes in three forms: equity, private debt and public debt financing. These can be captured in the weighted average cost of capital (WACC), which is the rate a company is expected to pay, on average, to compensate all its investors. The formula for calculating the WACC is provided in Appendix B.

- **Rate of return considerations by financiers/investors** – the internal rate of return (IRR) is the compounded annual rate of return a project is expected to generate over time.[26] The IRR is the discount rate at which the net present value of the project is zero (i.e. the average discount rate at which the cash benefits and costs of a project over time are exactly equal).

Second are a number of factors related to the electricity market, including the following:

- **Cost and technical characteristics of alternative technologies** – includes capital costs, operations and maintenance costs, and fuel costs of fossil fuel and nuclear power plants.

- **Electricity price in the local market** – the wholesale market price is the price power producers receive for selling electricity to the grid. The price depends on the type of market and the time when the electricity will feed into the grid.[27] It can also be a price that is agreed directly between two parties, independently of an exchange body supervising the trade (over-the-counter).

- **Variations in the RE resource potential** – RE resource potentials vary widely across regions and different locations. For example, wind resources may be higher in some parts of the country than others; this directly influences wind turbine load capacity and therefore financial feasibility.

The combination of these factors determines how financially feasible RE technologies are in a given country context. The following data sources, prioritized from top to bottom, may be

[26] Jeffery (2014).

[27] Next Kraftwerke (2016).

useful in determining the financial feasibility of RE technologies:

- calculations made during policy set-up
- national cost studies (e.g. from low emissions development strategies)
- global cost estimates (e.g. from the IRENA RE technology costs with a country-specific resolution[28]).

7.4.2 Evaluate financial feasibility of RE technologies

It is important to be able to evaluate the financial feasibility of specific RE technologies. To do so, users can follow the steps below.

Step 1: Calculate the levelized cost of electricity for different renewable energy technologies
The first step in evaluating the financial feasibility of RE technologies is to calculate the "levelized cost of electricity" (LCOE), a commonly used metric for comparing costs across different power-generating technologies. Because the LCOE is the unique cost of an energy project, representing the present value of the costs over the lifetime of the project, it can be used to analyse the financial feasibility of different technologies. As a result, the LCOE is often taken as a proxy for the average price that an energy project must receive in a market to break even over its lifetime.

Appendix A provides further information on how to calculate the LCOE. Users can also refer to publicly available LCOE quantification tools (e.g. the Excel spreadsheet tool provided by Agora Energiewende[29]), the GACMO tool of the United Nations Environment Programme and the Technical University of Denmark,[30] or development tools tailored to country-specific circumstances. In some country contexts, users can use more sophisticated LCOE tools – for example, to assess financial de-risking policy options (using the Derisking Renewable Energy Investment methodology of the United Nations Development Programme[31]). Other methods used by public and private investors, and policymakers can also be used in this context.

The financial feasibility of technologies can be estimated by comparing the LCOE for the given RE technology with either the policy's tariff rate (for feed-in tariff and auction policies) or the generation costs of technologies that will be displaced by the RE technology (for tax incentive policies). For the latter comparison, these can be:

- the LCOE for existing plants, if it is clear which fossil fuel plants will be displaced as a result of the policy
- the average electricity generation costs across the electricity grid
- the LCOE for power plants that would have been built in the absence of the policy.

The LCOE should be calculated separately for each RE technology. Since the LCOE of RE power plants might vary widely, depending on geographical conditions such as the wind and solar resource, a location differentiation should also be considered. For example, users might conduct separate calculations for solar PV installations in different regions of the country if the solar potential can be divided into different geographic areas. The proximity of a prospective RE installation site to energy demand centres may also be an important cost consideration because it affects the costs of transmission, which can be significant for long distances.

Project financiers may compare the WACC (see Appendix B) underlying the LCOE with the IRR to evaluate the profitability of a project. In general, the IRR for a given project needs to be equal to or greater than the WACC if the project is to be profitable (i.e. positive net present value).[32] Companies often set a minimum acceptable IRR before investing in a project.

Step 2: Compare the LCOE with financial incentives provided by renewable energy policies
By comparing the LCOE for a given technology and location with the financial incentive provided by the RE policy, users can evaluate whether the policy

[28] Available at: www.irena.org/costs.

[29] Available at: www.agora-energiewende.de/en/publications/calculator-of-levelized-cost-of-electricity-for-power-generation-technologies.

[30] Available at: www.cdmpipeline.org/.

[31] Available at: www.undp.org/content/undp/en/home/librarypage/environment-energy/low_emission_climateresilientdevelopment/derisking-renewable-energy-investment.html.

[32] Belyadi, Fathi and Belyadi (2017).

makes investment in RE technologies financially feasible.

In the absence of an RE policy, users would normally compare the LCOE with the price they could negotiate in an over-the-counter contract or the (average) wholesale market price of electricity in the market they would sell into. The term "wholesale market price" refers to a more complex situation. In reality, the wholesale market price depends on the particular situation in the country that dictates specific market prices with which RE technologies have to compete. The price depends on the type of market, but also on the time when the electricity will feed into the grid. In many countries, the technology will have to compete with several different prices, depending on the time when the electricity is fed into the grid and how far in advance the price will be set, among other things. An electricity wholesale market price that represents an average price should be chosen.

When evaluating the impact of an RE policy on the financial feasibility of RE technologies, users should combine the LCOE of the particular technology with the financial incentive provided by the policy, and compare that with the electricity wholesale market price (or a combination of prices in the case of premium policies). Possible conclusions that can be drawn from this step of the assessment include the following:

- **LCOE > electricity tariff or wholesale market price.** Where a given RE technology has higher costs, on average, than the tariff or wholesale market price chosen, or financial incentives provided by the policy, the technology is likely to diffuse only in niches. If no such niches exist, the technology is not likely to diffuse at all.

- **LCOE < electricity tariff or wholesale market price.** Where a given technology has lower costs, on average, than the costs of current technologies or financial incentives provided by the RE policy, the technology is likely to diffuse. For these calculations, users can assume that the financial analysis does not further restrict the technical potential for the assessment period of the policy.

- **LCOE < electricity tariff or wholesale market price for certain financing options, or a limited number of projects only.** The technology may only be feasible for a limited number of cases (e.g. only for wind sites with a wind speed higher than a certain threshold).

Users should use caution when making comparisons between calculated LCOE and feed-in-tariffs or power purchase agreement prices because these require additional considerations – for example, the duration of the payment introduced by a respective policy compared with the economic life of assets. The IRENA *Renewable Power Generation Costs in 2017* report presents two examples of how such factors can affect the results of the analysis when comparing the LCOE with an electricity tariff, given country- and context-specific circumstances (see Box 1 in the report).[33] In general, users should always aim to consult with national or international experts to discuss the methodological approach chosen and the underlying assumptions.

Users evaluating tax incentive policies can account for such policies' financial implications by including a tax factor in their LCOE calculations that quantifies the impact of income taxes, the depreciation tax shield and investment tax credits. This tax factor includes the investment tax credit, the effective corporate income tax rate, the allowable tax depreciation rate over time, and the capitalization discount for depreciation purposes. Such adjusted LCOE calculations can further account for the fact that the assumed useful life of an investment for tax purposes is usually shorter than the economic life. In the case of a production tax credit (PTC), for example, a dollar-for-dollar subsidy in terms of a fixed premium per kilowatt-hour of produced electricity is added separately to the LCOE calculation while also accounting for the tax credit's lifetime.

Detailed explanation of how to include both investment tax credits (ITCs) and PTCs can be found in *Levelized Cost of Electricity Calculator: a User Guide* by Stanford Graduate School of Business (using ITCs and PTCs in the United States as an example).[34] Alternatively, a methodology developed by the Pontificia Universidad Javeriana Colombia in its publication *Effects of Incentives for Renewable Energy in Colombia* provides detailed guidance on how to incorporate tax deductions on the investment and accelerated depreciation on assets into LCOE calculations.[35]

[33] Available at: www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf.

[34] Available at: http://stanford.edu/dept/gsb_circle/cgi-bin/sustainableEnergy/GSB_LCOE_User%20Guide_0517.pdf.

[35] Available at: www.redalyc.org/articulo.oa?id=47751131007.

Step 3: Account for other cost considerations in a national context (if relevant)
As discussed in the previous steps, the electricity generated by RE technologies will usually be fed directly into the grid. Therefore, the LCOE is compared with the electricity market wholesale price to identify the financial feasibility of such technology in a competitive market setting, or the financial incentive provided by an RE policy.

In some country contexts, however, alternative cost considerations need to be accounted for when analysing the financial feasibility of certain RE technologies from the perspective of the investor. This crucially depends on the country context and the policy design characteristics.

For example, if a tax incentive policy is eligible regardless of whether the electricity is fed into the grid or consumed by the investor directly (without ever being fed into the grid), households or industrial entities (as the investors in solar PV installations) might install additional RE capacity even if the LCOE is above the electricity wholesale market price. This is because the investors (i.e. households and/or industrial entities) compare the location-specific electricity production costs plus the granted financial support with the prices they pay, as end consumers, for the consumption of electricity from the grid.

These end-consumer prices can be well above the electricity wholesale market price because they include transmission, distribution and system costs. In such cases, users should replace what is referred to as wholesale market price in step 2 with the cost of the alternative (i.e. the end-consumer price):

- **Residential customer's own consumption** (ideally with net metering in place) – comparison of production costs plus financial support with end-consumer prices.
- **Industrial generation for own consumption**
  - Separate analysis should be done for all RE technologies considered.
  - Calculations provide users with an indication of whether there will be any capacity extension; if so, analysis will indicate the specific technologies (and possibly areas) where this applies.
  - End-consumer prices for industrial entities should be compared with RE production prices (with or without feed-in tariff or tax incentive).
  - The feasibility of analysis depends on regulations in the jurisdiction (e.g. whether "off-site" generation is allowed and, if so, whether policies on transmission exist).

If industrial entities and/or households install RE capacity for their own consumption under a given policy (under which financial support is granted regardless of whether the electricity is fed into the grid), this might result in higher overall capacity for RE deployment than would be generated by comparing LCOEs with wholesale market prices. Again, users might need to account for regional differences and conduct separate analyses for different regions.

Users should consider whether such additional analysis is necessary given the country context and policy design characteristics of the respective policy.

Step 4: Consider the effect of other policies in the sector (if relevant)
Other policies in the sector may affect the financial feasibility of RE technologies. They may also enable or impede the implementation of the policy, and may continue into the future or be discontinued. Policies that may interact with the financial feasibility of RE technologies include:

- emissions trading programmes, which through GHG emissions pricing may provide an additional incentive for RE technologies by increasing the cost of alternative technologies
- taxes, such as energy or carbon taxes
- energy regulations, such as mandatory closing of inefficient plants, and quotas for fuels
- subsidies, such as fossil fuel subsidies, or direct and indirect electricity subsidies.

The guidance provided in Section 5.2.2 may also be helpful in determining the effects of other policies.

Step 5: Consider the effect of sectoral trends (if relevant)
Sectoral trends can reinforce or counteract RE policies and the financial feasibility of RE technologies; they may affect electricity tariffs or wholesale market prices. Sectoral trends to be considered include:

- changes in fossil fuel prices that can cause shifts between fossil fuels (e.g. shift from coal to natural gas due to lower costs of natural gas), or alter the financial feasibility of RE power plants

- public support or opposition to certain technologies, such as offshore wind turbines
- global trends in technology costs, whether these relate to RE technologies (e.g. falling costs of solar PV panels) or to fossil fuel–based plants, including carbon capture and storage
- shifts in consumer behaviour, such as increasing demand for renewable electricity.

To identify relevant trends, users can refer to sectoral studies on national or global developments in the sector. They can also consult with national experts and relevant stakeholders from universities, ministries, the private sector or the public. For example, users could refer to recent studies on global and local price development for fossil fuels to evaluate whether the projected trends significantly affect the overall financial feasibility of RE technologies in comparison with traditional fossil fuel technologies (e.g. cost reductions of natural gas due to accelerated fracking exploration).

The existence and impact of sectoral trends are highly dependent on national sectoral circumstances. Careful evaluation is needed of how, and to what extent, such trends affect the financial feasibility of renewables.

7.4.3 Examples of using financial factors to refine the technical potential for the assessment period

BOX **7.6**

Auctions (example 1) – using financial factors to refine expected renewable energy addition of the policy for the assessment period

1. Estimate technical potential for the assessment period (from Box 7.2) – **640 MW**

2. Account for policy design characteristics (from Box 7.4) – **550 MW**

3. Account for effect on financial feasibility of RE technologies

Since the auction policy provides separate auctions by technology and there is no ceiling price for the auction, the financial feasibility assessment does not result in a downward revision of the technical potential for the assessment period. However, access to financing in the country is very limited, and only a small number of private investors are willing to invest in RE. This limits the number of plants that can be constructed.

A consultation with two national experts on project finance in the electricity generation sector provides further insights. A comparison of the estimated investment finance needed for all tendered electricity capacity with the estimated financing available for private entities shows that the overall achievable RE addition with the existing financing is 400–500 MW. To be conservative, and given the high uncertainty, the expected RE addition of the policy for the assessment period, after accounting for financial feasibility, is refined to **450 MW**.

450 MW

BOX **7.7**

Feed-in tariff policy (example 2) – using financial factors to refine expected renewable energy addition of the policy for the assessment period

1. Estimate technical potential for the assessment period (from Box 7.3) – **1,300 MW**

2. Account for policy design characteristics (from Box 7.5) – **800 MW**

3. Account for effect on financial feasibility of RE technologies

The LCOE calculations for the country revealed costs between 10 cents/kWh and 17 cents/kWh for various locations. Since the solar potential can be roughly divided into four geographic areas, four different representative full load hour estimates were used to estimate these location-specific LCOE costs. The feed-in tariff rate is fixed at 13 cents/kWh. Solar PV will likely be developed in only two of the four geographic areas in which the LCOE is above the wholesale electricity price (i.e. the feed-in tariff rate). As the two regions in which no solar PV will be developed have a total maximum capacity of 100 MW (relatively low as a result of low solar radiation and swampy regions where only limited capacity could be installed), this reduces the technical potential for the assessment period of the policy from **800 MW** to **700 MW**.

Since both stand-alone and rooftop installations are eligible under the feed-in tariff, financial factors should not further reduce the technical potential for the assessment period in the two geographic areas with higher solar potential, as both areas have meaningful electricity loads and ample space available to build the plants.

The feed-in tariff provides a large degree of certainty to the investor, thereby attracting financing even from risk-averse sources. However, access to finance in general is limited in the country. Even with the guarantee provided by the feed-in tariff, the number of investors will be small. Therefore, after consultation with financial experts in the country, the technical potential for the assessment period is further refined from **700 MW** to **600 MW**.

600 MW

7.5 Account for barriers

Several barriers can hinder RE deployment, including technical, regulatory, institutional, market, financial, infrastructure, awareness and public acceptance barriers. Such barriers also indirectly reflect risks for investors, financiers or other actors to develop and implement RE projects in a given country context. It is a *key recommendation* to identify other barriers not addressed by the policy and account for their effect on the technical potential for the assessment period of the policy. The barrier analysis focuses only on those barriers not directly addressed by the policy being assessed.

Users should follow the steps below to identify barriers and account for their effect on the technical potential for the assessment period of the policy.

7.5.1 Step 1: Identify barriers

Table 7.8 lists barrier categories, and provides descriptions and examples for each. This categorization can be used to identify and describe barriers to RE deployment in the geographic area of the policy, and to note if no barriers are identified for a given barrier category.

TABLE **7.8**

Barrier categories

Barrier category	Description	Examples
Technical	• Technical standards (e.g. uniform engineering or technical criteria, methods, processes and practices) lacking for some RE technologies • Lack of sufficient technology providers • Insufficient transmission and distribution infrastructure to connect new RE capacity to the grid, especially where RE resource potential is highest	• No technical standard exists for a biomass technology that is eligible under the policy. • There is a limited number of technology providers for a certain technology that is eligible under the policy. • Outdated transmission and distribution infrastructure prevents grid connection of newly installed capacity (e.g. no transmission lines exist to connect wind generation in remote areas).
Regulatory and policy uncertainty	• Insufficient clarity and transparency in existing regulations or in the development of new policies	• Lack of transparency in policy set-up of feed-in tariff policy and history of ad hoc changes in regulation increase uncertainty, which discourages market actors from participating in the policy.
Institutional and administrative	• Lack of strong and dedicated institutions to carry out policies • Permits for new RE plants are difficult to obtain, approval procedures are lengthy and cumbersome, or there is a lack of spatial planning for RE • Unclear procedures and responsibilities, and/or complex interactions and lack of coordination between the various authorities involved • Other barriers in the energy system, such as existing industry, infrastructure and energy market regulation; intellectual property rights; tariffs on international trade; and allocation of government financial support	• Several institutions claim responsibility for implementation of the policy. • Procedures on how to participate in, or receive assistance from, the policy are unclear, which discourages market actors.
Market	• Inconsistent pricing structures that put renewables at a disadvantage • Asymmetrical information between market actors • Market power and subsidies for fossil fuels • Blockage of incumbent actors and limited access of new actors to the market • Import tariffs and technical barriers that impede trade in renewables • Access to market	• Existing fossil fuel subsidies (direct or indirect) prevent large-scale RE deployment through the policy. • Incumbent market actors have an information advantage, and direct or indirect influence on policy design process, which limit access for new market actors. • High import tariffs or domestic content requirements hinder deployment of technologies.
Financial or budgetary	• Absence of adequate funding opportunities and financing products for RE • Financing unreasonably costly for RE technologies • Concerns about possible devaluation of asset value • Disproportionately high transaction costs in relative terms • Total budget available for policy measures (e.g. for tax incentives, feed-in tariffs)	• Insufficient funding is available in the domestic context as a result of high up-front costs of RE investments. • Substantial concerns about financial solvency of state-owned utilities discourage market actors from using the policy.

TABLE 7.8, continued

Barrier categories

Barrier category	Description	Examples
Infrastructure	• Lack of flexibility of the energy system (i.e. of the electricity grid to integrate or absorb RE) • Energy markets are not prepared for RE (e.g. integration of intermittent energy sources, grid connection and access are not fairly provided) • Higher grid connection costs for RE	• History of technical problems with grid infrastructure prevents decentralized access of RE to the grid.
Lack of awareness of RE and skilled personnel	• Insufficient knowledge about availability, benefits and performance of RE • Insufficient numbers of skilled workers, and lack of training and education • Lack of general information and access to data relevant to RE deployment (e.g. deficient data about natural resources) • Lack of experience and expertise among the relevant stakeholders, including project sponsors and power producers, investors and financiers, and regulators and authorities	• Insufficient skilled workers are available for installation of wind turbines.
Public acceptance and environmental	• Linked to experience with planning regulations and public acceptance of RE • Lack of research into the more complex interactions between RE technologies and the environment • Competition with other interests in the geographic area (e.g. fishing, shipping and aviation, recreational use of land, archaeological and historical heritage interests, civil and military airport interests)	• Public acceptance of the policy is low because of perceived high economic and social costs, and a lack of understanding and misleading information. • Environmental concerns exist as a result of major investments in new infrastructure, particularly overland transmission lines.

7.5.2 Step 2: Evaluate severity of barriers

Next, evaluate the severity of barriers using a predefined scale, such as a scale from 1 to 5, with 1 indicating low impact and 5 indicating very severe impact. Barriers that are considered to be very severe are those that entirely inhibit the policy from having any impact. Barriers will most likely inhibit a given aspect of the policy and not the entire policy.

The evaluation can involve document analysis, expert judgment and stakeholder consultations.[36] GIZ suggests two distinct methods to rate different barriers – simultaneous rating and pairwise comparison – which are summarized in Table 7.9. Both methods are based on surveys of experts, which are recommended to be carried out as a series of structured interviews. It is also recommended that the interviews be carried out with at least five experts from the fields of politics, business and finance, and science.[37] For example, users may conduct a survey of a small representative sample of investors to assess the severity of barriers relating to perceived investment risks. This allows users to better quantify the subsequent (negative) impact of a given barrier on the RE capacity to be developed over time.

[36] Refer to the ICAT *Stakeholder Participation Guide* (Chapter 8) for information on designing and conducting consultations.

[37] Partnership on Transparency in the Paris Agreement (n.d.).

TABLE **7.9**

Brief description of the simultaneous rating and pairwise comparison methods

Method	Description
Simultan-eous rating	Experts are asked to give a total score out of 100 to each individual barrier according to the barrier's significance. The ratings of the individual experts are then summarized as averages. If the ratings of the experts deviate significantly from one another, the experts should be asked for their rating again after they have been consulted about the results of the first round of the survey in the form of average values (Delphi survey). The significance of the barriers is then calculated, based on the average of the ratings from the second survey round. A problem with this method is the difficulty of estimating the relative severity of barriers for all combinations of the existing decision options. Often, the overall score given is perceived as fictitious. In addition, the test people tend to concentrate too heavily on fully assigning the points.
Pairwise compar-ison	The problems associated with the simultaneous rating method can be avoided using the pairwise comparison as a part of an analytic hierarchy process, in which barriers are compared with one another qualitatively. A ranking scale is used, which simplifies the assessment so that only a comparative rating needs to be provided (e.g. "equivalent", "more significant"). The qualitative comparison leads to a quantitative rating. These quantitative ratings are entered into a rating matrix, in which all comparison pairs are allocated a quantitative rating.

Example matrix of a pairwise comparison of the significance of barriers

Number of barriers identified	Rating matrix							Standardised matrix V								Weighting vector W
zu: Compare	Barrier A	Barrier B	Barrier C	Barrier D	Barrier E	Barrier F	Barrier G	Barrier A	Barrier B	Barrier C	Barrier D	Barrier E	Barrier F	Barrier G	Row total	Weighting factor w1
Barrier A:	1	0.2	5	2				0.15	0.1	0.4	0.2				0.92	0.23
Barrier B:	5	1	4	5				0.75	0.61	0.3	0.6				2.27	0.57
Barrier C:	0.2	0.25	1	0.5				0.03	0.15	0.08	0.1				0.32	0.08
Barrier D:	0.5	0.2	2	1				0.07	0.12	0.17	0.12				0.48	0.12
Barrier E:																
Barrier F:																
Barrier G:																
Column total	6.7	1.7	12.0	8.5												1.00

Only the values in red have been filled out. In this case, four barriers were compared, where for example barrier B was rated as entirely more significant than barriers A and D and a great deal more significant than barrier C. After the conversion using the standardised matrix V, the weighting factors of the relative significance of the barriers are produced in the last column (in blue).

Source: Fichtner Consulting

Source: Adapted from GIZ (www.transparency-partnership.net/sites/default/files/klimawirkungen_engl_l3_3.pdf).

Further guidance on how to account for barriers on the expected RE addition of the policy for the assessment period is provided in in Section 7.5.4.

7.5.3 Step 3: Identify policies that may help overcome barriers

For each barrier identified, identify policies or actions in the country that may overcome or increase the barrier, and describe how, and to what extent, such policies and actions may help overcome the barrier. The evaluation of the effect of the barrier is then adjusted accordingly.

7.5.4 Step 4: Determine effect of barriers on technical potential for the assessment period

Determine how the barriers effect the expected RE addition of the policy for the assessment period, as follows:

1. Determine the effect of each barrier on the expected RE addition of the policy for the assessment period. For example, the outcome of the barrier analysis might indicate that a barrier reduces the expected RE addition of the policy for the assessment period by x%. The reduction can take place on two different levels, depending on the design of the policy.

    a. General level – the barrier affects the entire policy (e.g. barriers that hinder the deployment of all RE technologies). In this case, the effect of the barrier on the expected RE addition of the policy for the assessment period applies to the entire policy's impact.

    b. Technology level – the barrier only affects one specific RE technology supported by the policy (e.g. specific barriers that hinder the deployment of solar PV installations). In this case, the effect of the barrier on the expected RE addition of the policy for the assessment period only applies to the policy's expected RE addition for the assessment period for this specific technology.

For barriers that are categorized as very severe, identify the precise aspect of the expected RE addition of the policy for the assessment period or RE resource potential to which the barrier relates (e.g. wind energy in a particular region). Reduce the impact of the policy to zero for this aspect of the expected RE addition of the policy for the assessment period.

2. Determine overlaps between the barriers. Identify whether, and to what degree, the impacts of the barriers overlap, and account for this overlapping effect.

3. Account for the effect of all barriers on the expected RE addition of the policy for the assessment period. Calculate the potential impact of all barriers while accounting for the potential overlap. This outcome may be supported with an uncertainty range to express uncertainty about the likelihood and magnitude of one or more barriers (e.g. express the refined technical potential for the assessment period as a range of megawatts, as illustrated in Boxes 7.8 and 7.9).

Table 7.10 provides a template that can be modified as needed to help users account for a variety of barriers.

Where users choose not to use the approach in Section 7.5.5, they can use country-specific studies that identify barriers and account for their effect, or use expert judgment to assist them in their assessment. Other tools are also available, such as the GIZ barriers-to-objectives weighting method,[38] which provides a quantitative method for evaluating barriers on a project level. Such tools could be used to account for barriers or in support of the steps outlined below.

7.5.5 Examples of accounting for other barriers

Boxes 7.8 and 7.9 provide examples of accounting for other barriers for an auction policy and feed-in tariff policy, respectively.

[38] Available at: www.transparency-partnership.net/sites/default/files/klimawirkungen_engl_l3_3.pdf, Chapter 4.

TABLE **7.10**

Sample template for barrier analysis

Step 1		Step 2	Step 3	Step 4		
Barrier category	**Barrier description**	**Severity of barrier**	**Other policies addressing barrier**	**Impact factor**	**General level/ technology level**	**Overlap with other barrier(s)**
Specify the overarching barrier category.	Describe the specific barrier and explain how it may affect the policy.	Provide severity of barrier on a scale of 1 to 5, with 1 indicating low impact and 5 indicating very severe impact.	Provide analysis on whether other existing policies may help to overcome this barrier.	Provide the effect of the barrier on the technical potential for the assessment period of the policy. The technical potential for the assessment period can also be provided with an uncertainty range.	Specify whether the impact factor applies on a general level or a technology-specific level.	Provide analysis on whether, and to what extent, the barrier overlaps with other existing barriers.

Source: Adapted from GIZ (www.transparency-partnership.net/sites/default/files/klimawirkungen_engl_l3_3.pdf).

BOX **7.8**

Auctions (example 1) – accounting for other barriers to refine expected renewable energy addition of the policy for the assessment period

1. **Estimate technical potential for the assessment period** (from Box 7.2) – **640 MW**

2. **Account for policy design characteristics** (from Box 7.4) – **550 MW**

3. **Account for effect on financial feasibility of RE technologies** (from Box 7.6) – **450 MW**

3. **Account for other barriers**

In **step 1**, the main barriers for the auction policy are identified using the list of barrier categories in Table 7.8:

- **Technical** – none
- **Regulatory and policy uncertainty** – none
- **Institutional and administrative** – none
- **Market** – high domestic fossil fuel subsidies
- **Financial or budgetary** – financing costs relatively high for power producers
- **Infrastructure** – grid infrastructure is not flexible enough to be linked to numerous RE installations
- **Lack of awareness of RE and skilled personnel** – none
- **Public acceptance and environmental** – none.

In **step 2**, the severity of each identified barrier is evaluated using expert judgment and ratings. None of the barriers are rated as very severe:

- High domestic fossil fuel subsidies – 1 (low).
- Financing costs relatively high for power producers – 2 (low to medium).
- Problems with flexibility of grid infrastructure – 3 (medium).

No other policies help overcome the barriers in **step 3**.

In **step 4**, the overall impact factor applied to the auctions is estimated using the barrier analysis. Identification of barrier-specific impact factors is based on expert judgment:

- **High domestic fossil fuel subsidies** – minus 2–5% (general level) based on experience with fossil fuel subsidies in the past.
- **Financing costs relatively high for power producers** – minus 5–10% (general level) based on market analysis of how available financing options for investors affect RE deployment and a survey with a representative sample of investors.
- **Problems with flexibility of grid infrastructure** – minus 10% (general level) based on analysis of current status of grid infrastructure and planned improvements over the course of the assessment period.

The identified barriers do not overlap. For this reason, the barrier-specific impacts can be aggregated, with the impact totalling between 17% and 25%, accounting for the uncertainty range for the overall impact of the identified barriers. As a result of the barrier analysis, the auctions will increase RE capacity by between **338 MW** and **374 MW**. The range represents the uncertainty for the specific impact of the identified barriers.

338–374 MW

BOX **7.9**

Feed-in tariff (example 2) – accounting for other barriers to refine expected renewable energy addition of the policy for the assessment period

1. **Estimate technical potential for the assessment period** (from Box 7.3) – **1,300 MW**

2. **Account for policy design characteristics** (from Box 7.5) – **800 MW**

3. **Account for effect on financial feasibility of RE technologies** (from Box 7.7) – **600 MW**

3. **Account for other barriers**

In **step 1**, the main barriers for the feed-in tariff are identified using the list of barrier categories in Table 7.8:

- **Technical** – no technical standard for rooftop solar PV installations, which has resulted in no domestic technology providers for rooftop solar PV installations.
- **Regulatory and policy uncertainty** – history of numerous ad hoc policy changes and adjustments, leading to a general lack of transparency and uncertainty for market actors.
- **Institutional and administrative** – permits for new RE plants are difficult to obtain because approval procedure is lengthy, non-transparent and cumbersome.
- **Market** – existing fossil fuel subsidies for low- and medium-income households.
- **Financial and budgetary** – concerns about financial solvency of only state-owned utilities with history of defaults.
- **Infrastructure** – none.
- **Lack of skilled personnel** – lack of skilled personnel to install solar PV panels.
- **Public acceptance and environmental** – none.

In **step 2**, the severity of each identified barrier is evaluated and rated on a scale of 1 to 5, with 5 indicating very severe:

- No technical standard and no domestic technology providers for rooftop PV installations – 5 (very severe).
- Policy uncertainty due to history of ad hoc policy changes and adjustments – 2 (low to medium).
- Slow and non-transparent permit approval process – 3 (medium).
- Existing fossil fuel subsidies for low- and medium-income households – 1 (low).
- Concerns about financial solvency of only state-owned utilities with history of defaults – 3 (medium).
- Lack of skilled personnel to install solar energy panels – 2 (low to medium).

In **step 3**, other policies are identified that may help the feed-in tariff policy overcome barriers to RE deployment. For example, a separate policy enacted to fix the slow and non-transparent permit approval process addresses this barrier. The Ministry of Energy is currently carrying out a comprehensive reform of its entire approval processes as a result of new anti-corruption legislation. Thus, the permit approval process will be entirely redesigned to promote a faster and more transparent process. Even though the reform process may require a transitional phase, it is deemed sufficient to overcome the barrier.

BOX **7.9,** continued

Feed-in tariff (example 2) – accounting for other barriers to refine expected renewable energy addition of the policy for the assessment period

1. **Estimate technical potential for the assessment period** (from Box 7.3) – **1,300 MW**

2. **Account for policy design characteristics** (from Box 7.5) – **800 MW**

3. **Account for effect on financial feasibility of RE technologies** (from Box 7.7) – **600 MW**

3. **Account for other barriers**

In **step 4**, the effect of barriers on the technical potential for the assessment period is estimated. The extent of this effect is based on expert judgment:

- **No technical standard and no domestic technology providers for rooftop solar PV panels** – barrier is categorized as very severe (in step 2), indicating that few installations can be expected for rooftop solar PV installations under the feed-in tariff policy. A national university had estimated that 50 MW of the 800 MW technical potential for the assessment period of the policy directly links to rooftop installation, so this figure is reduced by 50% to 25 MW, which is subtracted from the policy's impact of 600 MW, resulting in 575 MW.
- **Policy uncertainty due to history of ad hoc policy changes and adjustments** – minus 5–8% (applies to total expected RE addition of the policy for the assessment period), based on the assessment on how policy uncertainty affects investor behaviour using survey data with a small representative sample of investors.
- **Slow and non-transparent permit approval process** – barrier is overcome by other policy intervention to reform permit approval process (discussed under step 3).
- **Existing fossil fuel subsidies for low- and medium-income households** – minus 3–4% (general level), based on experience with household behaviour in the past.
- **Concerns about financial solvency of only state-owned utilities with history of defaults** – minus 20–30% (general level), based on the assessment on how policy uncertainty affects investor behaviour using survey data with a small representative sample of investors.
- **Not enough skilled personnel to install solar energy panels** – minus 20% (technology level), based on market assessment of the number of skilled personal to install solar energy panels.

As the impact of the lack of skilled personnel to install solar PV panels partially overlaps with the impact of no domestic technology providers for rooftop solar PV panels, the barrier-specific impact cannot be aggregated. As the overlap accounts for about 5%, the total effect of the barriers is between 43% and 57%.

The barrier analysis therefore suggests that the feed-in tariff will increase RE generation between **262 MW** and **329 MW**. The range represents the uncertainty associated with the identified barriers.

262–329 MW

7.6 Summary of examples

The two examples illustrate how important it is to account for any factors that will affect the deployment of RE. Tables 7.11 and 7.12 summarize the results of examples 1 and 2, respectively, including the adjustments made for each of the factors accounted for, both in terms of reduced impact and the percentage of the technical potential these reductions represent.

In the case of auctions, each of the adjustments made to account for policy characteristics, financial feasibility and other barriers was of the same order – around 15% of the technical potential. The feed-in tariff example, however, illustrates how policy design characteristics can have a disproportionate

TABLE **7.11**

Summarized results for example 1, Box 7.8 – auctions to increase renewable energy

Step	RE addition (MW)	Adjustment	% reduction
Step 1: Estimate technical potential	640	-	-
Step 2: Account for policy design characteristics	550	–90	14
Step 3: Account for financial feasibility	440	–110	17%
Step 4: Account for other barriers	338–374	–66 to –102	10–16

Abbreviation: -, not applicable

TABLE **7.12**

Summarized results for example 2, Box 7.9 – feed-in tariff to increase renewable energy

Step	RE addition (MW)	Adjustment	% reduction
Step 1: Estimate technical potential	1,300	-	-
Step 2: Account for policy design characteristics	880	–500	38
Step 3: Account for financial feasibility	600	–200	15
Step 4: Account for other barriers	262–329	–271 to –338	21–26

Abbreviation: -, not applicable

impact on deployment of RE. In that example, a full 38% of the technical potential was reduced by policy design characteristics. It is important to note that, in the latter example, other barriers also reduced the deployment of RE significantly.

Users should use caution when accounting for different factors, given the large impacts any of these can have on the final figure.

8 Estimating GHG impacts of the policy ex-ante

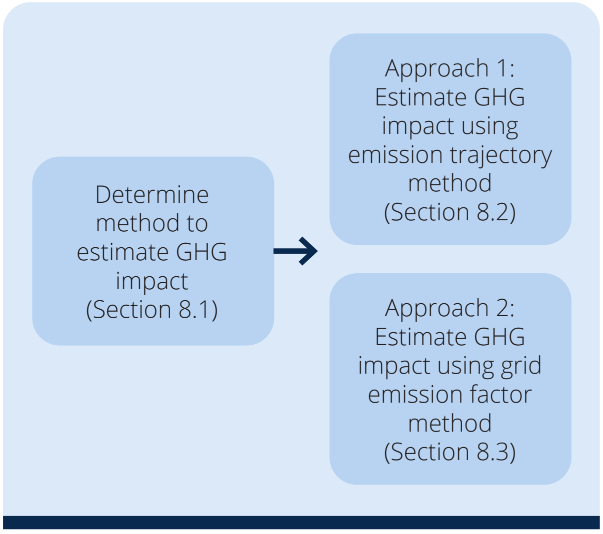
This chapter provides a method for the second step of ex-ante impact assessment: translating estimated RE addition in the policy scenario into GHG impacts. The GHG impacts can be expressed either as a GHG emissions level or as GHG emissions reductions achieved by the policy.

Checklist of key recommendations

- Choose the method for estimating GHG impacts based on the objectives of the assessment, and the policy's expected impact and time frame
- Estimate the emissions trajectory using energy models, where feasible, and otherwise using the method for limited data availability
- Estimate the GHG impact using a grid emission factor calculated using the CDM combined margin emission factor approach or emission factor modelling

FIGURE **8.1**

Overview of steps in the chapter



8.1 Determine method to estimate GHG impacts from renewable energy addition

Users should choose between two methods for translating estimated RE addition into GHG impacts: the emissions trajectory method and the grid emission factor method.

The emissions trajectory method develops a trajectory for future emissions from the electricity grid based on the expected future mix of generating technologies. The method involves making assumptions about the future electricity mix. It can be done using limited data or more complex models that model the energy sector development in detail. The resulting emissions trajectory can be used either as a stand-alone assessment to determine whether the trajectory is on track to meet a target, or in combination with a baseline scenario to determine the emissions reductions.

The grid emission factor method assumes that the RE addition displaces grid electricity, and calculates the GHG impacts of the policy based on the emission factor of the current and expected future electricity grid. This method is appropriate for policies with a limited impact on the grid, since it uses simple assumptions about the future development of the entire energy sector. Users assume that the generated electricity resulting from the policy will displace carbon-intensive electricity generation and, to a certain extent, replace future carbon-intensive capacity additions. The grid emission factor reflects the emissions intensity of carbon-intensive electricity generation being displaced by the RE addition. For installations that feed into the electricity grid, this is equal to the grid emission factor, which serves as the baseline emission factor.[39]

Table 8.1 provides further information about the two methods.

[39] A simple online tool to estimate avoided emissions based on average emissions in a specific country is available at https://irena.org/Statistics/View-Data-by-Topic/Climate-Change/Avoided-Emissions-Calculator.

TABLE **8.1**

Brief description of the simultaneous rating and pairwise comparison methods

Method	Approach	Objective	Advantages	Disadvantages
Emissions trajectory	Sectoral emissions are modelled	• To estimate sectoral GHG emissions levels achieved after an intervention • To estimate GHG emissions reductions from interventions (by comparing baseline GHG emissions with policy GHG emissions) • *Especially suitable for larger-scale interventions*	• Dynamic; accounts for interactions between the RE technologies incentivized by the policy and the electricity mix over time • Emissions level calculations; not necessary to develop a baseline scenario	• Low level of standardization; many models are commonly used (e.g. LEAP), although there is no standardized approach for developing emissions trajectories
Grid emission factor	Emission factors reflect emissions intensity of displaced technology	• To estimate GHG emissions reductions from interventions • *Especially suitable for single projects or other smaller-scale interventions*	• High level of calibration; methodologies have been developed for a wide range of GHG emissions reduction interventions under the CDM, and revised and improved over time • Methods are widely accepted and used for project-level analysis, including through harmonization efforts of bilateral and multilateral funds • Energy sector model not needed; may be easier to use than emissions trajectory method	• Relatively static; methods account for future development (e.g. operating margin method) but only to a limited extent • Assumptions about the baseline scenario may be contested • More challenging to estimate GHG impacts over longer time frames

It is a *key recommendation* to choose the method for estimating GHG impacts based on the objectives of the assessment, and the policy's expected impact and time frame.

Users should choose between the emissions trajectory method and grid emission factor method considering the following issues.

8.1.1 Impact on the energy system

The policy may have a different degree of impact on the energy system and the energy mix in the sector.

The degree of impact on the energy mix further depends on two factors: the size of the energy system and the size of the intervention.

The current share of variable renewable energy (VRE) generation in the energy system can give a rough indication of whether a system can accommodate additional VRE generation without needing major changes or experiencing major challenges. IEA[40] has classified energy systems in four phases according to the challenges the system faces when adding

[40] IEA (2017a).

VRE (Figure 8.2). This classification is based on the share of VRE generation, the size of the system, transmission infrastructure, existing operation practices and existing levels of flexibility (e.g. hydropower facilities and interconnection to other systems) in the system. Energy systems in phases 1 and 2 can easily accommodate additional VRE generation, whereas systems in phases 3 or 4 would need to increase their flexibility to accommodate additional VRE generation. Although there is no clear number for the share of VRE generation in the system that defines a phase, the data roughly indicate that systems with a current share of VRE generation:

- of less than 5% correspond to phase 1
- of 5–10% correspond to phase 2
- of more than 10% correspond to phases 3 and 4.

Based on the correlation between current VRE generation share and the phase of the energy system, users can use the grid emission factor method or the emissions trajectory method to estimate GHG impacts from adding VRE to a system, as shown in Figure 8.2. In general, the emissions trajectory method can be used for a country with an energy system at any stage, but, because of its relative complexity and data intensity, this method is more appropriate for systems with larger shares of VRE. The grid emission factor method is more appropriate for energy systems that currently have a small share of VRE (i.e. less than 10%).

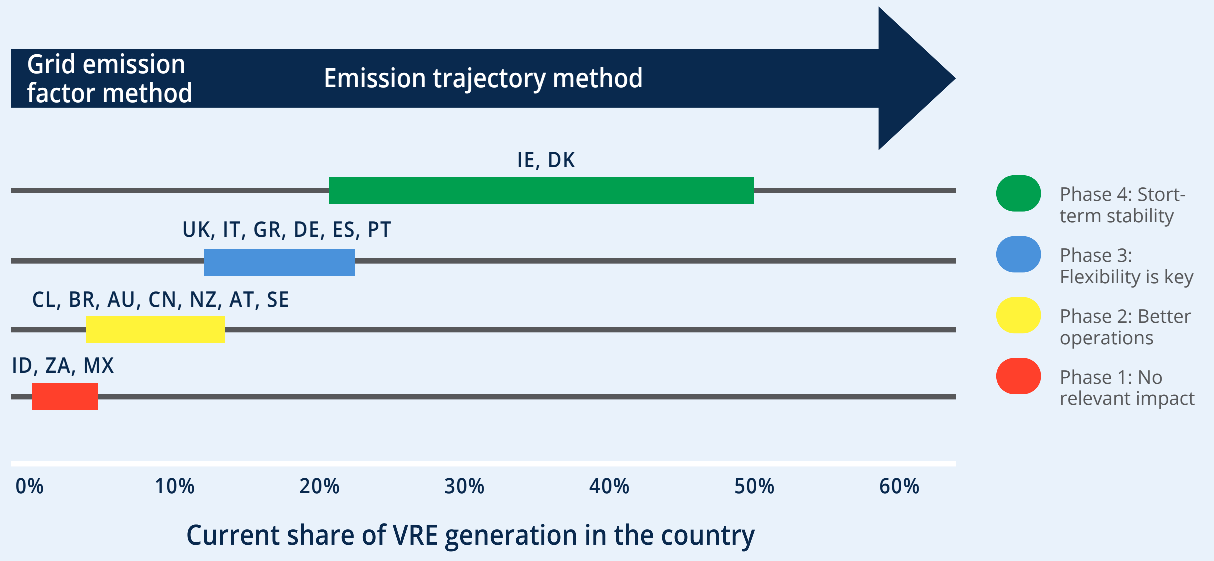
8.1.2 Time frame of the intervention

Interventions with shorter time frames (e.g. single projects, or policies with shorter time frames) will have less impact on the energy system, whereas interventions with longer time frames are likely to have a larger impact.

Users should also choose whether they want to estimate a GHG *emissions level*, or GHG *emissions*

FIGURE **8.2**

Guide to which assessment method is recommended, based on a country's current variable renewable energy share in the energy mix and the phase of its energy system



Abbreviations: AT, Austria; AU, Australia; BR, Brazil; CL, Chile; CN, China; DE, Germany; DK, Denmark; ES, Spain; GR, Greece; ID, Indonesia; IE, Ireland; IT, Italy; MX, Mexico; NZ, New Zealand; PT, Portugal; SE, Sweden; UK, United Kingdom; ZA, South Africa.
Source: IEA (2017a).
Note: Phases of the energy systems in this graph are indicative and based on IEA (2017a). Phases overlap in terms of VRE shares in the energy mix. The ranges and phase classification represent the status of a variety of countries in 2016.

reductions achieved by the policy, based on the objectives of the assessment:

- **GHG emissions level.** This is especially appropriate for determining whether policies are on track to meet goals, such as NDCs or RE targets, and to inform goal setting. The emissions trajectory method should be used for meeting these objectives (the grid emission factor method is not designed for these objectives).

- **GHG emissions reductions.** This is especially appropriate for assessing the effectiveness of policies, improving their design and implementation, and reporting on implementation progress – for example, in the context of achieving NDCs. Either the emissions trajectory method or the grid emission factor method can be used to meet these objectives.

Where the results of the assessment will be used in the GHG accounting of an NDC, users should consider aligning the base year for the assessment with the base year of the NDC and related targets. For this purpose, input parameters (e.g. activity data, emission factors, socioeconomic data) used to estimate baseline emissions of RE policies should be aligned with similar parameters used for setting NDC targets, and relevant GHG accounting and reporting under the Paris Agreement.

8.2 Approach 1: Estimate GHG impacts using emissions trajectory method

An emissions trajectory is used either on its own (to determine whether the GHG emissions trajectory is on track to meet an RE target) or in combination with a baseline scenario (to determine the GHG emissions reductions the policy is estimated to achieve). The steps below are followed for estimating emissions trajectories for both policy scenarios and baseline scenarios.

It is a *key recommendation* to estimate the emissions trajectory using energy models, where feasible, and otherwise using the method for limited data availability. If the user is determining GHG emissions reductions, the same approach should be used for both the baseline scenario and the policy scenario.

Where the results of the assessment will be used to meet the reporting requirements of the transparency framework, users should consider aligning the parameters used for the emissions projections of RE policies with those used to develop sectoral projections to meet relevant reporting requirements. This includes the time frame – that is, the starting and final years of the projections developed for RE policies should be the same as the starting and final years of the energy sector projections. Some parameters used for the projection of GHG impacts of RE policies can also be used as key indicators for projections developed to meet reporting requirements of the transparency framework.

8.2.1 Estimate emissions trajectory using an energy model

Several institutions have developed globally applicable models to support countries with analysing their energy policy and forecasting GHG emissions under different scenarios. Table 8.2 provides an overview of a few selected energy system analysis models. Users can use these and other suitable models to estimate the emissions trajectory. The RE addition calculated in Chapter 7 should be used as an input for these models, such that the resulting emissions trajectory is based on the additional RE deployment that the policy is expected to achieve.

The Climate Smart Planning Platform[41] provides an in-depth overview of a wide array of analytical models, tools, methods, procedures and guides for assessment of policy and investment implementation. This overview can inform users' choice.

8.2.2 Determine emissions trajectory using method for limited data availability

Where data availability is limited, users should follow the three steps set out below.

[41] Available at: www.climatesmartplanning.org.

TABLE **8.2**

Overview of selected energy system analysis models

Criterion	TIMES	LEAP	EnergyPLAN	PROSPECTS+	GACMO
Developer	IEA – ETSAP	Stockholm Environment Institute	Sustainable Energy Planning Research Group at Aalborg University, Denmark	NewClimate Institute and Climate Action Tracker	UNEP DTU
Purpose of model	• Model of energy system • GHG emissions from energy system	• Model of energy system • GHG emissions from energy system	Model of energy system	• Model of energy system • GHG emissions from energy system	• Development of business-as-usual scenario • GHG emissions from energy system
Complexity	Complex	Medium–complex	Medium–complex	Simple–medium	Simple
Sectors covered	• **Energy supply:** all primary energy sectors, incl. heat • **Energy demand:** industry, commercial and tertiary, households, transportation	• **Energy supply** • **Energy demand:** household, industry, transport, commercial • Non-energy sector emissions can be added	• **Energy supply:** all primary energy sectors, incl. heat • **Energy demand:** industry, transport, cooling, desalination • **Storage and balancing**	• **Energy supply:** electricity and heat generation • **Energy demand:** transport, residential and commercial buildings, cement, steel, other industry, oil and gas production, agriculture, waste	• **Energy supply:** only fossil fuel • **Energy demand:** agriculture, energy efficiency, infrastructure and industry, transport
Cost calculations	Yes	Yes	Yes	No	Yes
Technology coverage	**Conventional:** oil (all), gas, coal (incl. lignite), nuclear **RE:** wind, solar, biomass, hydro. Single plant granularity	• **Conventional:** oil (all), gas, coal (incl. lignite), nuclear • **RE:** biomass (gasification, pyrolysis, digestion), waste, wind, hydro, solar (PV and CSP), geothermal, biofuel	• **Conventional:** nuclear, gas, oil, coal • **RE:** wind (onshore and offshore), solar (PV and CSP), wave, hydro, tidal, biomass, geothermal • **Storage**	• **Conventional:** nuclear, gas, oil, waste, coal • **RE:** hydro, geothermal, biomass, wind, solar, marine, waste, biofuel	• **Conventional:** oil (gasoline LPG, jet fuel, diesel, heavy fuel oil), coal (incl. lignite), gas, nuclear • **RE:** geothermal, hydro, wind, solar, biomass

TABLE 8.2, continued

Overview of selected energy system analysis models

Criterion	TIMES	LEAP	EnergyPLAN	PROSPECTS+	GACMO
Modelling environment	Excel-based input code in GAMS	Proprietary software; runs only on Windows	Freeware for Windows; code in Delphi Pascal	Excel	Excel
Free or at purchase	At purchase (fees vary)	At purchase (fees vary) Free (for government agencies in lower- and low–middle-income countries)	Free (on registration)	Free (available on request)	Free
URL	http://iea-etsap.org/index.php/etsap-tools/model-generators/times	http://sei-us.org/software/leap	www.energyplan.eu/getstarted	https://newclimate.org/2018/11/30/prospects-plus-tool/	www.cdmpipeline.org

Abbreviations: CSP, concentrated solar power; ETSAP, Energy Technology Systems Analysis Program; LPG, liquefied petroleum gas

Step 1: Project future electricity demand

The starting point for any energy supply emissions trajectory is to understand how electricity demand develops over time. Choose between the following approaches, or a combination of these approaches:

1. **Use existing country-specific electricity demand forecasts.** Potential data sources include the ministry of energy, national energy research institutes and international agencies, such as IEA. Where possible, use national data sources that are widely accepted among policymakers, and developed or endorsed by the government.

2. **Where country-specific data and resources are not available, data may be scaled down from regional scenarios.** The easiest approach is to apply growth rates of electricity demand from the regional scenarios to the historical data on electricity demand available for the country. However, consider how representative the regional development is of national development. For example, the IEA World Energy Outlook database includes Canada, the United States and Mexico in the North American region. Applying the growth rate for North America to historical data for Mexico would underestimate the growth in the energy sector, because Mexico's current levels of RE are much lower than those of the United States and Canada.

3. **Estimate the future electricity demand.** Where no electricity demand forecast for the country or region is available, simple assumptions can be made to estimate the electricity growth in the sector.

   a. Extrapolate historical growth rates. Extrapolate historical data on electricity demand using linear or other trends that align with historical development.

   b. Link electricity demand to population growth. Calculate current demand per capita and use population growth projections to estimate future total demand.

   c. Link electricity demand to growth in gross domestic product (GDP). This assumes that electricity growth and GDP growth are coupled. Bear in mind that certain processes have led to their decoupling, and make additional assumptions about autonomous energy efficiency improvements occurring in the economy.

Step 2: Project future electricity generation
The next step is to calculate the total required electricity production by accounting for transmission and distribution losses, as well as the power plants' own use of electricity:

Equation 8.1

$$\textit{Total electricity generation}_i = \frac{\textit{Total electricity demand}_i\ [\text{MWh}]}{1 - \textit{TransmissionAndDistributionLoss}\ [\%] - \textit{OwnUse}\ [\%]}$$

Historical transmission and distribution losses (percentage of gross electricity generation) for most countries are available free of charge from the World Development Indicators database.[42] Five-year averages of transmission and distribution losses per region, as well as minimum, maximum and median values from individual countries, are shown Table 8.3. If relevant, absolute transmission and distribution losses can be estimated by multiplying the share of transmission and distribution losses (percentage of output) by the future electricity output (in MWh).

TABLE **8.3**

Brief description of the simultaneous rating and pairwise comparison methods

Region	Transmission and distribution losses (% of output), average (2010–2014)
East Asia and Pacific	5.6
Europe and Central Asia	8.0
Middle East and North Africa	13.1
Sub-Saharan Africa	11.5
Latin America and Caribbean	15.0
Central Europe and the Baltics	7.7
Caribbean small states	9.4
OECD members	6.4
Least developed countries: United Nations classification	15.9
World	8.2
Minimum (Singapore)	2.3
Median	11.2
Maximum (Togo)	68.7

Source: World Development Indicators (https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS)
Abbreviation: OECD, Organisation for Economic Co-operation and Development
Note: Minimum, maximum and median values are calculated from the average between 2010 and 2014 for all available countries.

[42] Available at: https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS.

The global average of own use of electricity by electricity producers is about 5% of total generation.[43] There is a large range across countries, depending on the composition of the power generation capacity of a country, as well as the vintage structure.

Step 3: Project future electricity mix
The next step is to develop projections on future electricity mix. First calculate electricity generation by technology, based on the current electricity mix. This information can be obtained from national sources (e.g. ministry of energy) and international sources.[44] To estimate the future electricity mix, choose between the following approaches, or a combination of these approaches:

1. **Assume that the share of different technologies in the electricity mix remains as is.** Use data on the shares of different technologies from the most recent year for which data are available and increase (or decrease if electricity demand is falling) all of them in proportion to their current mix. This can be the best assumption where the future energy mix development is unknown.

2. **Continue historical trends for the shares of different technologies in the electricity mix.** Carry past sectoral trends into the future. This approach can lead to unreasonable results for longer time frames where certain shares have experienced high growth rates in the past, but are unlikely to do so in the future. Apply individual adjustment to account for factors such as those listed in Table 8.4.

3. **Assume that certain technologies decrease more (or less) than others.** This approach is realistic under the following conditions.

    a. There is evidence that a certain technology will be more relevant in the future energy system than in an alternative system. For example, a national study may forecast the development of the future energy mix from trends such as the replacement of certain technologies by natural gas. A country's climate strategy may be leading towards the decarbonization of the power sector. In such a case, the bridge technology (such as natural gas), may be preferred over coal.

    b. Changes in system characteristics are now favouring certain technologies over others. For example, as shares of intermittent RE sources such as wind and solar become increasingly significant, the energy mix shifts from being baseload focused towards a more flexible market regime, which may, in turn, favour certain technologies – such as natural gas – over others.

[43] Authors' calculations based on IEA (2018).

[44] International sources include IEA, "Data and statistics" (https://www.iea.org/statistics); the U.S. Energy Information Administration, "International energy statistics" (https://www.eia.gov/world/international/data/browser); and The Shift Project Data Portal. "Electricity by source" (http://www.theshiftdataportal.org/energy#Electricity).

TABLE **8.4**

Factors to consider when assuming a continuation of historical trends in the electricity mix

Factor	Example and brief explanation	Reference
Investment in electricity generation technologies	**Short term** The time needed to develop, build and commission power plants varies across technologies. Whereas some may have lead times of months, others may have lead times of years. Comparing trends in investment costs for different technologies can also provide a short-term indication of the kinds of power plants that will likely be built in the future. **Middle to long term** The lifetime of a power plant varies across technologies. Whereas wind and solar have lifetimes of at least two decades, conventional power plants, such as coal or nuclear, may have longer lifetimes. Recent investment in electricity generation technologies can give a rough indication of the kind of power plants a country has in the pipeline and an overview of how the future electricity share would look in the mid- to long term.	**Historical investment:** BNEF (2019) (private); Frankfurt School–UNEP Collaborating Centre and BNEF (2018); IEA (2018b); IRENA (2019c) **For technology lead times,** see Table 7.4 **For technology lifetimes,** see IEA and NEA (2015); Eurek et al. (2016)
Status of abundance of natural resources in the region/country	**Renewable resources** Renewable energies such as hydro, geothermal or wind are constrained to the places where that resource is abundant. If these resources have already been exploited significantly, it is unlikely that additional power plants from these technologies would be built in a country/region. By comparing a resource map and existing power plants, users can get a sense of the possible future addition of a certain kind of technology. **Conventional resources** Studies[a] have shown that countries with high production of fossil fuels, and thus high energy self-sufficiency, have the lowest share of RE generation. Thus, it is likely that if historically a country has had abundance of fossil fuel resources, its VRE addition is likely to lag behind.	National or international databases on natural resources (see Tables 7.1 and 7.2)
Historical and projected fuel prices	As a main component of the LCOE, fuel prices may indicate if it is economically attractive to develop and invest in a particular technology. An indication of historical and projected costs of fuels may give an indication of the financial feasibility of certain technologies over others (together with the technology's LCOE).	Lazard (2018); IRENA (2018b, 2019a); see also Appendix A
Existing subsidy schemes for certain technologies	Similar to fuel prices, subsidies influence a technology's LCOE. Subsidies include policies that artificially decrease energy prices or production costs of power generation technologies. If a particular technology is subsidized, its price is artificially lowered. This results in subsidized technologies having an economic advantage over non-subsidized ones. For example, the existence of fossil fuel subsidies may hinder the transition to RE generation technologies because subsidies result in underpricing of fossil fuel generation. Likewise, if one renewable generation technology is subsidized while another is not, the non-subsidized technology will be less economically attractive, thus hindering its implementation. In this sense, having an overview of existing subsidies in a country may give an indication of a country's future energy mix.	IEA (2017b, 2018c)

TABLE **8.4,** continued

Factors to consider when assuming a continuation of historical trends in the electricity mix

Factor	Example and brief explanation	Reference
Type of system and system changes to accommodate higher shares of VRE	As the share of VRE increases in an electricity system, it is important to allow for measures that help balance supply and demand. Such measures are called "flexibility measures" and can include the following: **Demand-side management.** These measures reduce disturbances in a grid, helping to balance demand and supply. As the share of VRE generation increases, supply depends to a greater extent on the availability of natural resources (e.g. wind and sun), thus requiring greater flexibility. These measures include peak shaving, valley filling, load shifting and conservation. **Energy efficiency and demand reduction policies.** Energy demand reduction is essential for increasing the share of renewables in the energy system. Absolute reduction of energy consumption leads to lower electricity demand, meaning that less RE is needed to achieve full decarbonization. **Energy storage.** Given the variability of natural resources, electricity storage also helps balance supply and demand. Energy that is produced when demand is low can be later used when demand increases. Hydro capacity can also be used as storage. **Transmission and distribution infrastructure (including interconnection).** Increasing VRE electricity generation may require additional transmission and distribution infrastructure. VRE power plants are located in areas where the resource is available, but these may not always correspond with locations where the electricity will be consumed. Also, an electricity system that is interconnected with other systems provides greater flexibility. **VRE in grid codes.** Grid codes specify the required behaviour of a generator in the electricity system. If VRE sources are integrated, the system is better prepared to deal with disturbances. **Electricity markets.** These include capacity market mechanisms, and market-based measures for energy storage and demand-side management.	Recent capacity additions: IRENA (2019d) Factors that may affect changes in an energy system are presented in Table 7.10. Energy efficiency: Castro-Alvarez et al. (2018) General: World Bank (2018) NewClimate Institute, Germanwatch and Allianz SE (2018) Own analysis adapted from de Villafranca Casas et al. (2018)

[a] Pfeiffer and Mulder (2013); Papiez, Smiech and Frodyma (2018).

It is important to consider policy interactions within a country when developing the emissions trajectory. Where the policy is embedded in an integrated energy policy and/or other polices are in place that influence the generation mix, consider the effect these interactions have on the calculation of the remaining electricity generation.

After estimating the future electricity demand (step 1) and the future electricity mix (step 2), cross-check assumptions (including views on compound annual growth rates for electricity demand or future electricity mix development) through consultation with national sectoral experts.

Step 4: Calculate total CO_2 emissions from electricity generation

Apply technology-specific emission factors to the electricity generation mix to estimate the emissions level, using one of the following approaches.

Use future technology-specific emission factors available in national studies or other sources. Unlike the emission factors described in Section 8.3, these do not change significantly in response to changes in the electricity mix, so results from existing sectoral modelling exercises can be used.

Calculate technology-specific emission factors using historical emissions (tCO_2/MWh), which are readily available from the IEA CO_2 Emissions from Fuel

Combustion database[45] or can be calculated from national statistics (see equation 8.2).

Equation 8.2

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

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.

Table 8.5 shows average emission factors of specific power plant types in different regions of the world.

Future specific emissions can be derived using the following approaches:

1. Assume that they remain constant – that is, that there is no improvement in the energy efficiency of technologies and that the fuel composition stays the same.

2. Assume that they improve over the years – that is, that there are energy efficiency improvements for the technology. However, this is only realistic where current plants will be retrofitted or where the construction of more-efficient plants is planned, so it is important to carefully consider how probable this is. For coal, based on the IEA World Energy Outlook 2018 scenarios, the average power plant efficiency improvement (and thus the

TABLE 8.5

Average emission factors (2012–2016) of specific power plant types in different regions

	Average emission factor ($MtCO_2$/GWh)							
Power plant technology	World	Africa	Americas	Asia	Europe	Oceania	OECD total	Non-OECD total
Anthracite-fired power plant	0.97	NA	0.93	0.96	1.00	NA	0.84	1.03
Other bituminous coal-fired power plant	0.91	1.04	0.91	0.91	0.89	0.88	0.88	0.93
Sub-bituminous coal-fired power plant	0.96	NA	0.95	0.99	1.09	0.87	0.94	1.00
Lignite-fired power plant	1.05	1.35	1.04	1.12	0.98	1.28	1.03	1.11
Natural gas–fired power plant	0.45	0.46	0.42	0.47	0.39	0.50	0.41	0.50
Crude oil–fired power plant	0.88	0.85	1.06	0.87	NA	NA	0.62	0.97

Sources: Based on IEA (2018a); IEA CO2 Emissions from Fuel Combustion database (www.oecd-ilibrary.org/energy/data/iea-co2-emissions-from-fuel-combustion-statistics_co2-data-en).

Abbreviations: NA, not available; GWh, gigawatt-hour; OECD, Organisation for Economic Co-operation and Development

Note: The regions correspond to the United Nations classification (https://population.un.org/wpp/DefinitionOfRegions).

[45] Available at: www.oecd-ilibrary.org/energy/data/iea-co2-emissions-from-fuel-combustion-statistics_co2-data-en.

emissions intensity) of 1–10% over the period 2016–2030 can be expected, depending on the amount of new, more efficient coal power plants built. For gas, the improvement rates could be higher (5–10%) for the same time period, and even above 10% where power plants are retrofitted or replaced by better technology (e.g. single cycle to combined cycle). For oil, it is realistic to assume no change, as no significant advances in power plant technologies are expected in the future.

Users should then apply technology-specific emission factors (tCO_2/MWh) to each technology (% MWh) in the electricity generation mix to calculate the emissions trajectory. The emissions trajectory is expressed in units of tCO_2e emitted in a given year, stated for each of the years for which the trajectory is being developed.

8.2.3 Calculate GHG emissions reductions (if relevant)

Where the objective is to estimate the GHG emissions reductions of a policy, users should determine a baseline scenario and estimate the associated emissions trajectory. GHG emissions reductions achieved by the policy are the difference between the policy scenario emissions trajectory and the baseline scenario emissions trajectory. An example of how to estimate these when limited data are available is given in Box 8.1.

The baseline scenario emissions trajectory should be estimated by following the same steps used for estimating the policy scenario emissions trajectory (set out in Sections 8.2.1 and 8.2.2). The same approach used for the policy scenario (energy model versus method for limited data availability) should be used for the baseline scenario.

The following should be considered when determining the baseline scenario:

- Which policies should be included and what time frames do they have?
- Which non-policy drivers and/or sectoral trends should be included?
- How would the sector have developed without the policy? What assumptions should be made regarding technologies that would have been implemented in the absence of the policy?

The policies covered by this methodology and/or other policies can be included in the baseline scenario. The sources of data for developing assumptions on such policies may include government policies, regulations and plans; forecasting models; expert interviews; and market assessment studies for supply and demand projections.

Users should also develop assumptions on non-policy drivers and sectoral trends, including load forecasts, fuel prices, grid storage capacity, RE technology prices, population and GDP.

Users could consider developing multiple baselines rather than just one, each based on different assumptions. This approach produces a range of possible emissions reduction scenarios.

The last step is to calculate the GHG emissions reductions achieved by the policy. This is calculated by subtracting, for the given year, the emissions associated with the policy scenario from the emissions associated with the baseline scenario.

BOX **8.1**

Example of estimation of GHG reductions from renewable energy policy as the difference between policy scenario emissions trajectory and baseline scenario emissions trajectory (using proxies because of limited data availability)

Example – GHG emissions reduction from RE policy using the emissions trajectory method with limited data availability

When data availability in a country is limited, users can estimate emissions reductions from RE policies using proxies. In this example, the country under assessment has neither an estimate of future electricity demand nor a baseline emissions scenario. The period of assessment is from the last current available year until 2030. In this example, calculations are shown only for 2030; in reality, they can (and should) be applied to intermediate years, as needed.

1. Estimate baseline scenario emissions trajectory — **61.7–82.3 $MtCO_2$/year**

Step 1: Project future electricity demand

Future electricity generation can be estimated by taking electricity demand per capita and future population projections as proxies, and assuming transmission and distribution losses.

The first step is to estimate current electricity demand per capita in the country by using current (or last available year) data for total electricity demand and population. Total electricity demand and total population per country can be obtained from international sources (such as the IEA statistics data browser,[44] the Enerdata "Global energy statistical yearbook",[45] World Bank population data[46] or United Nations population data[47]) or national sources (such as ministries of energy, or departments for data and statistics). For most countries, time series of electric power consumption per capita are readily available.[48]

For a hypothetical country, electricity demand per capita in 2017 is calculated as follows:

$$EDpC_t \left[\frac{kWh}{capita}\right] = \frac{TED_t \left[\frac{kWh}{year}\right]}{Pop_t \left[\frac{capita}{year}\right]}$$

$$EDpC_{2017} = \frac{12 \text{ x } 10^{10}\ kWh/year_{2017}}{40 \text{ x } 10^{6}\ capita_{2017}} = \frac{3{,}000\ kWh}{capita}$$

where *EDpC* is electricity demand per capita, *TED* is total electricity demand, *Pop* is total population and *t* is the year.

For future years, a range can be estimated by using the following assumptions:

- Electricity demand per capita will remain constant (one end of the range).
- Historical trends will continue in the future (other end of the range).

If historical data indicate that electricity demand per capita in a country has significantly increased or decreased in the past years, it is preferable to assume a continuation of this trend. To adapt the current $EDpC_t$, first estimate the growth rate of the past years GR_t.

[46] Available at: https://www.iea.org/statistics.

[47] Available at: https://yearbook.enerdata.net/electricity/electricity-domestic-consumption-data.html.

[48] Available at: https://data.worldbank.org/indicator/sp.pop.totl.

[49] Available at: https://population.un.org/wpp/DataQuery.

[50] Sources include World Bank (2019). Electric power consumption (kWh per capita) (https://data.worldbank.org/indicator/eg.use.elec.kh.pc); and the Climate Action Tracker (https://climateactiontracker.org/data-portal).

BOX **8.1,** continued

Example of estimation of GHG reductions from renewable energy policy as the difference between policy scenario emissions trajectory and baseline scenario emissions trajectory (using proxies because of limited data availability)

For our hypothetical country, these are the historical trends and estimated growth rates:

t (year)	2005	2010	2015	2017
$EDpC_t$ (kWh/capita)	2,300	2,600	2,900	3,000
GR_t (%/year)	-	2.5	2.2	1.7

Abbreviation: -, not applicable

The compound annual growth rate (GR_t) is estimated using the following formula:

$$GR_{t2} = \left[\left(\frac{EDpC_{t2}}{EDpC_{t2}} \right)^{\frac{1}{t2-t1}} - 1 \right] \text{x } 100$$

The compound annual growth rate between 2005 and 2010 is:

$$GR_{2005-2010} = \left[\left(\frac{2{,}600 \left[\frac{kWh}{capita}\right]_{2010}}{2{,}300 \left[\frac{kWh}{capita}\right]_{2005}} \right)^{\frac{1}{2010-2005}} - 1 \right] \text{x } 100 = 2.5\%$$

The average growth rate for the entire period (between 2005 and 2017) is then

$$GR_{2005-2017} = \left[\left(\frac{3{,}000 \left[\frac{kWh}{capita}\right]_{2017}}{2{,}300 \left[\frac{kWh}{capita}\right]_{2005}} \right)^{\frac{1}{2017-2005}} - 1 \right] \text{x } 100 = 2.2\%$$

Energy sector experts from national universities are consulted, and the consensus is that energy demand is likely to grow at 2.2% per year.

To estimate the future emissions, we multiply the *EDpC* range by the projected population (*Pop*). World population prospects are available from the United Nations[49] up to 2100. Population in our country is expected to increase from 40 million in 2017 to 45 million in 2030.

Thus, the future total electricity demand (*TED*) range in 2030 is estimated as follows:

- Lower end – assuming electricity demand per capita will remain constant

$$TED^{min}_{2030} = 3{,}000 \left[\frac{kWh}{capita}\right]_{2010} \text{x } 45\text{x}10^6 \; capita \text{ x } \frac{1GWh}{10^6 kWh} = 135{,}000 GWh$$

- Upper end – assuming electricity demand per capita will continue increasing with the same growth rate as in the past

$$EDpC_{2030} = EDpC_{2017} \text{ x } (1+GR_{2015-2017})^{(2030-2017)} + 1$$

$$EDpC_{2030} = 3{,}000 \left[\frac{kWh}{capita}\right]_{2017} \text{ x } (1+2.2\%)^{13} + 1 = 4{,}002 \left[\frac{kWh}{capita}\right]_{2030}$$

$$TED^{max}_{2030} = 4{,}002 \left[\frac{kWh}{capita}\right]_{2010} \text{x } 45\text{x}10^6 \; capita \text{ x } \frac{1GWh}{10^6 kWh} = 180{,}074 GWh$$

[51] United Nations Department of Economic and Social Affairs, Population Division (2017).

BOX **8.1,** continued

Example of estimation of GHG reductions from renewable energy policy as the difference between policy scenario emissions trajectory and baseline scenario emissions trajectory (using proxies because of limited data availability)

Step 2: Project future electricity generation

Future electricity generation is the sum of electricity demand, transmission and distribution (*T&D*) losses, and own use of electricity by generators.

For our hypothetical country, we will assume 6.2% *T&D* loss (based on Section 8.2.2) and 5% of own use.

To estimate total electricity generation (*TEG*), we simply apply equation 8.1:

$$TEG_{2030}^{min} = \frac{TED_{2030}^{min}}{1 - T\&D_{loss}[\%] - OwnUse[\%]} = \frac{135{,}000GWh}{1 - 11.2\%} = 152{,}027GWh$$

$$TEG_{2030}^{max} = \frac{TED_{2030}^{max}}{1 - T\&D_{loss}[\%] - OwnUse[\%]} = \frac{180{,}074GWh}{1 - 11.2\%} = 202{,}786GWh$$

Step 3: Estimate the development of technologies in electricity mix

The next step is to break down total electricity generation into generation technologies.

To estimate the future energy mix, one can use the current energy mix (or that of the last available year). This information can be obtained from national sources (e.g. ministry or department of energy) and international sources.[50]

For our hypothetical country, the electricity generation mix in 2017 (last available year) comprises:

Technology	Coal	Oil	Gas	Nuclear	Hydro	Solar PV	Wind	Geothermal	Biomass
Share (%)	17	10	40	5	10	10	5	3	0

For the future electricity mix up to 2030, we will consider the following factors (see Table 8.4):

In our hypothetical country:

- no investment has been made in biomass, oil or geothermal electricity generation in the past 5 years; for nuclear, no investment has been made in the past 20 years
- the current generation technologies under construction include gas, solar PV and wind
- we know (from the national resources database) that there is potential for solar PV, geothermal, wind and hydropower generation
- subsidies exist for oil, coal and gas generation
- historical costs for oil, gas and coal have been continuously increasing in the past 20 years. Future projections from international sources indicate that prices will continue to increase in the near future.

Based on the information above, we can assume that no new nuclear power plant will be built between 2017 and 2030 (thus, the share for nuclear will slightly decrease); the share for coal, oil, biomass or geothermal will likely not increase (it might slightly decrease); electricity generation from solar PV, wind and gas will slightly increase; and hydropower generation could remain steady or even increase, as there is still potential in the country.

[52] International sources include IEA, "Data and statistics" (https://www.iea.org/statistics); the U.S. Energy Information Administration, "International energy statistics" (https://www.eia.gov/world/international/data/browser); and The Shift Project Data Portal. "Electricity by source" (http://www.theshiftdataportal.org/energy#Electricity).

BOX **8.1,** continued

Example of estimation of GHG reductions from renewable energy policy as the difference between policy scenario emissions trajectory and baseline scenario emissions trajectory (using proxies because of limited data availability)

Therefore, we assume the following share for 2030:

Technology	Coal	Oil	Gas	Nuclear	Hydro	Solar PV	Wind	Geothermal	Biomass
Share (%)	15	10	42	3	10	12	6	2	0

Finally, the electricity generation per technology in 2030 (baseline) is estimated by multiplying the technology share (%) by the estimated TEG range (GWh/year):

Technology	Coal	Oil	Gas	Nuclear	Hydro	Solar PV	Wind	Geo-thermal	Bio-mass
Min (GWh/year)	22,804	15,203	63,851	4,561	15,203	18,243	9,122	3,041	0
Max (GWh/year)	22,849	15,232	63,976	4,570	15,232	18,279	9,139	3,046	0

With the breakdown of electricity generation by technology, we now estimate emissions for this baseline.

Step 4: Calculate emissions levels based on technology-specific emission factors

To estimate the absolute emissions from the baseline scenario emission trajectory, we apply emission factors (EF) per technology to the estimated total electricity generation per technology. We also consider intensity improvements for these factors.

The emission factors per technology are assumed based on Table 8.5:

Technology	Coal	Oil	Gas
EF (tCO_2/MWh)	0.97	0.88	0.45

We can assume that, as a result of plant retrofit and additional capacity of power plants with better technology, these emission factors will improve by 1% for coal and by 8% for gas, leading to the following emission factors:

Technology	Coal	Oil	Gas
EF (tCO_2/MWh)	0.96	0.88	0.41

We then multiply emission factors per technology by the projected electricity generation per technology. We then estimate absolute emissions from electricity generation as the sum of emissions from all technologies:

Technology	Coal	Oil	Gas	Total
Min ($MtCO_2$/year)	21.9	13.4	26.4	**61.7**
Max ($MtCO_2$/year)	29.2	17.8	35.3	**82.3**

Thus, the emissions levels from the baseline scenario emissions trajectory in 2030 are between 61.7 $MtCO_2$/year and 82.3 $MtCO_2$/year.

BOX **8.1**, continued

Example of estimation of GHG reductions from renewable energy policy as the difference between policy scenario emissions trajectory and baseline scenario emissions trajectory (using proxies because of limited data availability)

2. Estimate policy scenario emissions trajectory	61.4–81.8 $MtCO_2$/year

We now take into account the implementation of RE policies.

The country has decided to focus on its solar potential to transition to a low-carbon power sector by 2030. To this end, an uncapped feed-in tariff policy for solar power has been implemented to promote uptake of solar power. In a first step, users estimate the technical potential for the assessment period of the policy as 1,200 MW (total RE potential, of which 800 MW is solar power). Assessment of the policy design characteristics therefore reduces this potential to 800 MW (the solar portion). Financial factors and the barrier analysis further reduce the policy's impact to 237–314 MW (for details see Table 7.8). This translates to generation of 375–497 GWh/year in 2030, assuming annual average operation of 330 days per year at an average annual capacity factor of 20% for solar for the country.[51]

We estimate the specific yield for solar PV in terms of the capacity factor as:

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

$$Specific\ yield_{solar\ PV} = 0.2 \times 330 \frac{days}{year} \times 24 \frac{h}{day} = 1{,}584 \frac{MWh/year}{MW}$$

We can then estimate the range of electricity generation potential (EG) from introducing the feed-in tariff for solar PV policy as:

$$EGmin_{2030} = 237MW \times 1{,}584 \frac{MWh/year}{MW} = 375GWh/year$$

$$EGmax_{2030} = 314MW \times 1{,}584 \frac{MWh/year}{MW} = 497GWh/year$$

As explained in Section 8.2.2 (step 3) we then need to re-examine the future electricity mix by taking into account factors such as the interaction of other policies, the country's electricity system type, and changes needed for the system to accommodate higher shares of VRE (see Table 8.4). After examination of these parameters in the country, we then assume that the solar PV generation originated from the feed-in tariff will replace coal generation.

Implementation of the solar PV feed-in tariff policy would increase VRE share to 20% in 2030, meaning that flexibility in the system would become very important. The country:

- has an electricity system that is interconnected to neighbouring countries' electricity systems
- has implemented policies for energy demand reduction (e.g. energy efficiency)
- has hydro capacity that could partially be used for storage.

Therefore, other than additional transmission and distribution infrastructure, the country's system can accommodate the VRE addition without the need for further changes.

53 Users might refer to national databases on capacity factors or capacity factors of a relevant benchmark country (e.g. see the overview of annual capacity factors for different technologies provided by the U.S. Energy Information Administration at https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_b).

BOX **8.1**, continued

Example of estimation of GHG reductions from renewable energy policy as the difference between policy scenario emissions trajectory and baseline scenario emissions trajectory (using proxies because of limited data availability)

Thus, the final generation per technology in 2030 is:

Technology	Coal	Oil	Gas	Nuclear	Hydro	Solar PV	Wind	Geo-thermal	Bio-mass
Min (GWh/year)	22,429	15,203	63,851	4,561	15,203	18,619	9,122	3,041	0
Max (GWh/year)	29,921	20,279	85,170	6,084	20,279	24,832	12,167	4,056	0

The next step is to estimate the emissions levels for the policy scenario emissions trajectory.

Similar to step 4 above, users can estimate the absolute emissions from the policy scenario emissions trajectory by applying emission factors per technology to the estimated total electricity generation per technology, while considering intensity improvements for these factors. Using the same assumptions as before for emission factors per technology and improvements in technologies over time, the absolute emissions from electricity generation are estimated as the sum of emissions from all technologies:

Technology	Coal	Oil	Gas	Total
Min ($MtCO_2$/year)	21.5	13.4	26.4	**61.3**
Max ($MtCO_2$/year)	28.7	17.8	35.3	**81.8**

Thus, the emissions levels from the policy scenario emissions trajectory are 61.4–81.8 $MtCO_2$/year.

3. Estimate GHG reductions from RE policy as the difference between policy scenario emissions trajectory and baseline scenario emissions trajectory

0.4–0.5 $MtCO_2$/year in 2030

Finally, the GHG reductions in 2030 from the RE policy (*EmRed*) are estimated by subtracting the estimated emissions in the policy scenario from the estimated emissions in the baseline scenario:

$$EmRed_{2030}^{min} = 61.7\frac{MtCO_2}{year} - 61.3\frac{MtCO_2}{year} = 0.4\frac{MtCO_2}{year}$$

$$EmRed_{2030}^{max} = 82.3\frac{MtCO_2}{year} - 81.8\frac{MtCO_2}{year} = 0.5\frac{MtCO_2}{year}$$

8.3 Approach 2: Estimate GHG impacts using grid emission factor method

The grid emission factor method uses simple assumptions about the development of the electricity sector and can be useful for policies with a limited impact on the grid. Many RE technologies do not result in any direct emissions; their grid emission factor is zero.[54] For others, such as biomass and large-scale hydro, there are associated emissions that need to be accounted for.

It is assumed that the generated RE electricity resulting from the RE policy will displace carbon-intensive electricity generation and, to a certain extent, replace future carbon-intensive capacity additions. The grid emission factor reflects the emissions intensity of the carbon-intensive electricity generation being displaced by the RE addition (expressed in tCO_2e/MWh).

It is a *key recommendation* to estimate the GHG impact using a grid emission factor calculated using the CDM combined margin approach or emission factor modelling. The two approaches for calculating the grid emission factor are discussed in Section 8.3.1. The GHG impact of the policy is then calculated by multiplying the grid emission factor with the estimated RE addition (Section 8.3.2).

8.3.1 Calculate grid emission factor

CDM combined margin approach

Grid emission factors have been used to assess the emissions impacts of projects under the CDM, and for bilaterally and multilaterally funded mitigation projects. The combined margin emission factor looks at the emissions impact of an addition of RE capacity to an electricity grid on the operation of existing plants (the operating margin) and future capacity additions (the build margin). A range of guidance and tools are available to help users calculate the emission factors of their grids. Table 8.6 provides an overview of key relevant resources.

The CDM Tool to Calculate the Emission Factor for an Electricity System listed in Table 8.6 outlines a method to calculate a combined margin emission factor. The combined margin is a blended emissions factor that is based on emission factors of existing power plants (operating margin) and on future capacity additions (build margin). Appendix D provides information about using the CDM Tool to Calculate the Emission Factor for an Electricity System, along with related guidance and resources for country-specific emission factors.

Emission factor modelling

Emission factor modelling can be used to capture changes in the electricity grid's structure over time and the impact of policies on the load characteristics of the grid.

Emission factor models use historical performance data from power plants. Emission factors are calculated by developing statistical models for variables that affect the emissions intensity of the grid. These variables include electricity export and import, trading and, to a limited extent, changes in power supply and demand. The United States Environmental Protection Agency AVERT (Avoided Emissions and Generation Tool) is an example of such a statistical model.[55] AVERT uses hourly and unit-level historical generation data, and models avoided emissions through implementation of energy efficiency or RE.

Emission factor models are useful because they reflect variations in load and frequent changes in emissions (e.g. hourly differences) based on power plants supplying to the grid. They are especially beneficial for countries with significant power imports, because they accurately capture the emissions intensity of the grid. In spite of these advantages, data used in these statistical models reflect historical emissions performance and do not adequately capture future changes in grid composition, infrastructure, policies and pricing. Where users intend to capture these trends, projection-based energy modelling approaches, discussed in Section 8.2.1, may be more useful.

8.3.2 Calculate GHG emissions reductions

The GHG emissions reductions achieved by the policy are calculated by multiplying the grid emission factor with estimated RE addition (estimated in Chapter 7). This is the GHG impact of the policy.

Where the policy involves hydro or biomass power plants, additional emissions may have to be subtracted to take account of CH_4 emissions

[54] The lifetime GHG emissions caused by the construction and operation of RE installations can reasonably be excluded, as they are roughly equivalent to emissions that would be caused by the construction and operation of fossil fuel power plants.

[55] Available at: https://www.epa.gov/statelocalenergy/avoided-emissions-and-generation-tool-avert.

TABLE **8.6**

Resources available for estimating emission factors based on the combined margin approach

Resources	Description	Source
CDM Tool to Calculate the Emission Factor for an Electricity System	• Detailed guidance providing calculation methodology • Country users use country-level data to calculate grid emission factors • Developed by UNFCCC secretariat	https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v2.pdf/history_view
IGES List of Grid Emission Factors	• Database of country-specific grid emission factors • Collated from information provided in project design documents • Developed by IGES and regularly updated	https://pub.iges.or.jp/pub/list-grid-emission-factor
IGES CDM Grid Emission Factor Calculation Sheet	• Excel-based calculation sheet based on the CDM tool • Uses country-level emission factor data collated from project design documents • Developed by IGES	https://pub.iges.or.jp/pub/iges-cdm-grid-emission-factor-calculation
IFI Approach to GHG Accounting for Renewable Energy Projects	• Guidelines for renewable energy projects	www.nib.int/filebank/a/1449216433/c78bcf00c64ba92b3a73673a2217be4d/5023-Joint_GHG_RE.pdf

Abbreviations: IFI, International Financial Institution; IGES, Institute for Global Environmental Strategies; UNFCC, United Nations Framework Convention on Climate Change

associated with reservoirs and emissions associated with growing energy crops, respectively. CDM methodologies provide guidance on estimating such emissions.

8.3.3 Example of calculating GHG impacts using grid emission factor method

BOX **8.2**

Example of calculating GHG impacts for a tender policy

The country generates 500,000 GWh/year of electricity. Its generation mix comprises 50% coal (250,000 GWh/year), 40% gas (200,000 GWh/year) and 10% hydro (50,000 GWh/year).

A tender policy for RE is introduced that consists of three rounds of tenders with the following breakdown: 40 MW in 2017, 100 MW in 2018 and 500 MW in 2019 (total 640 MW).

The tender policy is expected to contribute to a national target of 1,000 MW of RE capacity by 2025.

The technical potential for the assessment period of the tender policy (640 MW) is reduced by 14% after the assessment of its design characteristics. Thus, the tender policy is expected to lead to 550 MW of RE deployment by 2025. This is further reduced to 450 MW after the assessment of factors that affect financial feasibility.

A series of barriers are subsequently identified that further reduce the impact of the tender policy by 17–25%. Thus, the RE addition of the tender policy is estimated to be 338–374 MW (42–47% lower than the technical potential for the assessment period).

This estimate translates to a generation potential of 3,875–4,336 GWh of power between 2017 and 2025, assuming 24 hours per day and 330 days of annual operation with a 25% capacity factor (considered appropriate to the country context), while accounting for the yearly capacity addition.

This exercise highlights the limitations of the tender policy to achieve the RE target.

The government wants to estimate the GHG emissions reductions associated with the RE addition and chooses to use the grid emission factor approach.

The Ministry of Energy consults with regulatory commissions and utilities to define the spatial boundary of the grid. It decides to include both utilities and independent power producers in the spatial boundary of the grid. Power imports and exports are also included in the assessment. The operating margin and build margin of the grid are calculated. Using a simple operating margin and build margin, and typical weightings used under the CDM for solar and wind ($w_{OM} : w_{BM}$ = 0.75:0.25), the combined margin emission factor (*EF*) is calculated using the equation

$$EF_{grid,CM,y} = EF_{grid,OM,y} \times w_{OM,y} + EF_{grid,BM,y} \times w_{BM,y}$$
$$EF_{grid,CM,y} = 0.82\ tCO_2\ e/MWh$$

The generation potential due to the RE addition (*EG*) is

$$\sum EG_y = 3{,}875\ GWh\ to\ 4{,}336\ GWh$$

The estimated GHG emissions reduction (*EmRed*) of the RE tender policy between 2017 and 2025 is

$$EmRed = \left[EF_{grid,CM,y} \times \sum EG_y\right] = 3{,}177{,}297\ tCO_2e\ \text{ to } 3{,}555{,}546\ tCO_2e$$
$$= 3.18\ MtCO_2e\ \text{ to } 3.56\ MtCO_2e$$

9 Estimating GHG impacts of the policy ex-post

Ex-post impact assessment is a backward-looking assessment of the GHG impacts achieved by a policy to date. The GHG impacts can be assessed during the policy implementation period or in the years after implementation. Ex-post assessment involves estimating achieved RE addition and the consequential GHG impacts. In contrast to ex-ante estimates of GHG emissions, which are based on assumptions about future RE deployment, ex-post estimates of emissions are based on observed (monitored) data collected during the policy implementation period. Users who are estimating ex-ante GHG impacts only can skip this chapter.

Checklist of key recommendations

- Estimate achieved RE addition using monitored values for the parameters described in the monitoring plan
- Estimate the GHG impacts of the policy over the assessment period, for each GHG source included in the GHG assessment boundary

9.1 Introduction to estimating GHG impacts ex-post

Estimating GHG impacts ex-post has three main objectives. These are described below, with an indication of the sections of this chapter that are relevant to each.

9.1.1 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

Users may want to compare achieved RE addition with a policy cap. A policy cap generally reflects the ambition or the expected amount of RE addition that policymakers are aiming to achieve. Users might also want to assess the extent to which a policy has contributed to a separate target, such as a national RE target. Lastly, users may want to compare the ex-post estimated policy scenario emissions with a sectoral target for emissions in the energy sector.

For objective 1, it is not necessary to develop a baseline scenario, and users follow the method in Section 9.3.

9.1.2 Objective 2: Compare achieved renewable energy addition or GHG emissions reductions with a baseline scenario

Users may want to compare the achieved RE addition with what would have happened in the absence of the policy. This requires determining a baseline scenario, which also serves as the basis for calculating baseline emissions and GHG emissions reductions.

FIGURE **9.1**

Overview of steps in the chapter

Estimate or update baseline emissions (Section 9.2)	→	Estimate achieved RE addition (Section 9.3)	→	Estimate GHG impacts (Section 9.4)

Users develop a baseline scenario under which an equivalent amount of electricity is generated as in the policy scenario, but from business-as-usual sources rather than via the RE addition that results from the policy. All other variables (such as economic trends) are kept the same as in the policy scenario. The baseline scenario is used to estimate either the GHG emissions trajectory or the GHG emissions reductions.

To achieve objective 2, users follow the methods in Sections 9.2, 9.3 and 9.4.

9.1.3 Objective 3: Compare achieved renewable energy addition or GHG emissions reductions with an ex-ante assessment

Users may want to compare an ex-ante (expected) RE addition with achieved RE addition, to ascertain whether a policy is performing in line with expectations. Likewise, they may want to compare the GHG emissions reductions achieved by a policy with the reductions estimated in an ex-ante assessment.

This can provide an indication of the impact of policy design characteristics and other factors on the RE addition (i.e. the factors set out in Chapter 7). For example, if the achieved RE addition is greater than the expected RE addition, this could indicate that other policies are interacting with, or adding further incentive to, the policy (e.g. where a renewable portfolio standard is achieved using a feed-in tariff policy). Alternatively, if the achieved RE addition is lower than the expected RE addition, it could be that other policies have counteracted the policy's intended impact or that the policy is not as effective as originally predicted.

This exercise can help users avoid double counting through the aggregation of emissions reductions from interacting policies. It can also be used to check whether all the assumptions that were made during the ex-ante assessment were correct. Lastly, comparisons between ex-ante and ex-post assessments can inform subsequent improvements of ex-ante assessments. These comparisons may become part of an ongoing process to refine future assessments.

To achieve objective 3, users follow the method in Sections 9.3 and 9.4.

9.1.4 Considerations for the desired level of accuracy

When selecting methods to estimate ex-post GHG impacts, users should consider the objectives, the level of accuracy needed to meet the stated objectives, the availability and quality of relevant data, the accessibility of methods, and capacity and resources for the assessment.

Users can follow a low-accuracy approach for their assessment, which may entail collecting aggregate data on energy generation from government agencies and/or using auxiliary electricity consumption emission factors based on the most common source of auxiliary generation for the country. An intermediate-accuracy approach may involve using clustered data on energy generation from electricity purchasers or distribution companies, and/or using auxiliary electricity consumption emission factors based on the most common source of auxiliary generation within the regions where the clusters are located. A high-accuracy approach can involve using disaggregated metered data on electricity imports and exports, and disaggregated fuel consumption data for auxiliary generation.

9.2 Estimate or update baseline emissions (if relevant)

To estimate the GHG emissions reductions achieved by the policy, baseline emissions need to be estimated. Baseline emissions should be recalculated each time an ex-post assessment is undertaken. If using the emissions trajectory method, users should update the baseline emissions by following the steps in Section 8.2.3. If using the grid emission factor method, users should skip this step (emissions reductions are estimated based on the RE addition and updated grid emission factor, in Section 9.4).

9.3 Estimate achieved renewable energy addition

It is a *key recommendation* to estimate achieved RE addition using monitored values for the parameters described in the monitoring plan. This achieved RE addition can be estimated in terms of RE capacity addition or RE electricity generation addition. Two main parameters to monitor are installed RE capacity and net electricity supplied to the electricity grid from

RE. Further guidance on indicators, parameters and monitoring plans is provided in Chapter 10.

Where users have no, or limited, monitored data for the policy, the achieved RE addition may have to be estimated using the best data available. See the considerations for the desired level of accuracy in Section 9.1.4 for further guidance on choosing an approach.

9.4 Estimate GHG impacts

The achieved RE addition should be translated into GHG impacts by following the method set out in Chapter 8, using monitored (rather than projected) data for the ex-post policy scenario. Chapter 10 lists all the relevant indicators and parameters for which data should be gathered to translate achieved RE addition into ex-post GHG impacts.

It is a *key recommendation* to estimate the GHG impacts of the policy over the assessment period, for each GHG source included in the GHG assessment boundary. For the emissions trajectory method, users should calculate the GHG impacts of the policy by subtracting baseline emissions (estimated in Section 9.2) from the ex-post policy scenario emissions for each source category included in the GHG assessment boundary.

For the grid emission factor method, users should calculate the GHG impacts of the policy by multiplying the updated grid emission factor by the RE addition (expressed in GWh).

PART IV

Monitoring and reporting

10 Monitoring performance over time

Monitoring serves two objectives: evaluation of the policy's performance (monitor trends in performance parameters to understand whether the policy is on track and being implemented as planned) and estimation of the policy's GHG impacts. This chapter provides guidance on monitoring the performance of policies during the implementation period, and collecting data for estimating RE addition and GHG impacts ex-post. Users estimating GHG impacts ex-ante without monitoring performance can skip this chapter.

Checklist of key recommendations

- Identify the key performance indicators that will be used to track performance of the policy over time and define the parameters necessary to estimate GHG emissions ex-post
- Create a plan for monitoring key performance indicators and parameters
- Monitor each of the indicators and parameters over time, in accordance with the monitoring plan

10.1 Identify key performance indicators and parameters

To estimate RE addition and GHG impacts ex-post, users collect data on a broad range of indicators and parameters to be monitored during the implementation period. A key performance indicator is a metric that helps track the performance of the policy. A parameter is a variable such as activity data or an emission factor that is needed to estimate emissions.

It is a *key recommendation* to identify the key performance indicators that will be used to track performance of the policy over time and define the parameters necessary to estimate GHG emissions ex-post. The selection of indicators and parameters should be tailored to the policy, the needs of stakeholders, the availability of existing data and the cost of collecting data. Table 10.1 provides example key performance indicators for the types of policies covered by this methodology, and Table 10.2 provides example parameters. Users should adapt the indicators and parameters as needed for the specific polices being assessed. Some of the indicators and parameters listed in the tables can also serve as inputs to monitoring progress towards implementation and achievement of NDCs, and meeting the reporting requirements of the enhanced transparency framework under the Paris Agreement.

FIGURE **10.1**

Overview of steps in the chapter

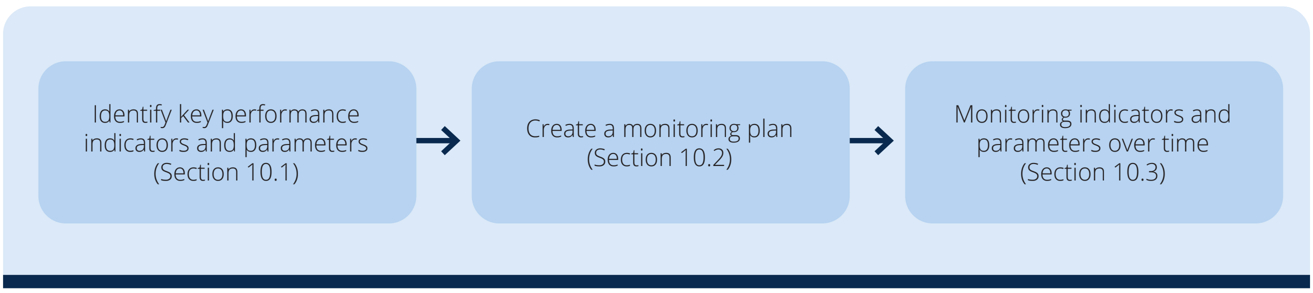


TABLE **10.1**

Example key performance indicators for renewable energy policies

Key performance indicator	Definition	Examples
Inputs	Resources that go into implementing a policy	• Financial resources for implementing and administering the policy
Activities	Administrative activities involved in implementing the policy	• Level of tariff or premium by technology or installation (feed-in tariff policy, auction policy) • Sum of tariff or premium payments (feed-in tariff policy, auction policy) • Sum of tax deductions given to end user (tax incentive policy) • Funds collected (tax incentive policy)
Intermediate effects	Changes in behaviour, technology, processes or practices	• Amount of capacity auctioned versus installed (auctions) • Share of installations that achieve tax breaks (tax incentive policy) • Capacity utilization factor of RE installations (all policies) • Number of RE plants by stage: planned, under construction, operational (all policies)
Sustainable development impacts	Changes in relevant environmental, social or economic conditions that result from the policy	• Cost savings achieved (all policies) • Employment generated (all policies) • Number of households with reduced energy costs (all policies) • Number of new business and/or investment opportunities (all policies) • Air quality (all policies)

Source: Adapted from WRI (2014).

TABLE **10.2**

Example parameters for estimating the GHG impacts of renewable energy policies

Parameter and unit	Potential sources of data	Parameter type	Suggested monitoring frequency
General			
Installed RE capacity (MW)	Monitoring reports and surveys, installation registers by federal energy agencies	Measured	Monthly or annual
Net electricity supplied to the electricity grid from RE (GWh)	Meter readings taken jointly by grid utility and power producer representatives	Calculated as the difference between quantity of electricity exported to the grid and quantity of electricity imported from the grid, as measured by electronic energy meters at the grid delivery point	Continuous measurement; monthly recording
Emissions trajectory method			
Electricity mix (GWh per technology)	Monitoring reports and surveys, installation registers by federal energy agencies, electricity market regulator	Measured	Monthly or annual
Technology-specific emission factors	National studies or other relevant sources	Calculated for each fuel source and/or type of technology	Annual
Grid emission factor method			
Grid emission factor (tCO_2e/MWh)	National statistics for grid-connected power plants	Calculated as the combination of operating and build margin by applying suitable weights	Most recent three years of data are used to recalculate operating margin every year
Operating margin (tCO_2e/MWh)	National statistics for grid-connected power plants	Calculated using methods specified in tools such as the CDM Tool to Calculate the Emission Factor for an Electricity System	Most recent three years of data are used to recalculate operating margin every year
Build margin (tCO_2e/MWh)	National energy strategies, national energy modelling, utility investment plans/ permitting documents	Calculated using methods specified in tools such as the CDM Tool to Calculate the Emission Factor for an Electricity System	Most recent year data are used to recalculate build margin every year

Source: Adapted from WRI (2014).

10.2 Create a monitoring plan

A monitoring plan is the system for obtaining, recording, compiling and analysing data and information important for tracking performance and estimating GHG impacts. A monitoring plan is important to ensure that the necessary data are collected and analysed. It is a *key recommendation* to create a plan for monitoring key performance indicators and parameters. Where feasible, users should develop the monitoring plan during the policy design phase (before implementation), rather than after the policy has been designed and implemented.

10.2.1 Monitoring period

The policy implementation period is the time period during which the policy is in effect. The assessment period is the time period over which the GHG impacts resulting from the policy are assessed. The monitoring period is the time period over which the policy is monitored. There can be multiple monitoring periods within the assessment period.

At a minimum, the monitoring period should include the policy implementation period. It is useful if the monitoring period also covers pre-policy monitoring of relevant activities before implementation of the policy and post-policy monitoring of relevant activities after the implementation period. Depending on the indicators being monitored, it may be necessary to monitor some indicators over different time periods than others.

Users should strive to align the monitoring period with those of other assessments being conducted using other ICAT assessment guides. For example, if assessing sustainable development impacts using the ICAT Sustainable Development Methodology in addition to assessing GHG impacts, the monitoring periods should be the same.

10.2.2 Institutional arrangements for coordinated monitoring

Information on key performance indicators and parameters can be dispersed among a number of institutions. Given the wide variety of data needed for impact assessment and the range of stakeholders involved, strong institutional arrangements serve an important function. They play a central role in coordinating monitoring. A technical coordinator, coordinating team or body is often assigned to lead monitoring, reporting and verification (MRV) processes in which responsibilities have been delegated to different institutions. Since data can be widely dispersed between institutions, the coordinating body oversees the procedures for data collection, management and reporting.

Countries may already have institutions in place as part of a national MRV system. In this case, users can consider expanding the national MRV system to also monitor the impact of the policy. Where strong institutional arrangements do not yet exist, countries can determine the governmental body with the adequate capacity and authority to be responsible for the MRV system and to establish the necessary legal arrangements. Institutional mandates help to strengthen the procedures and the system, and may also help secure funding from the government to ensure the continuity of the process. Users can refer to the United Nations Framework Convention on Climate Change (UNFCCC) *Toolkit for Non-Annex 1 Parties on Establishing and Maintaining Institutional Arrangements for Preparing National Communications and Biennial Update Reports*, as well as other sources, for support on establishing or improving the institutional arrangements for a robust MRV system.[56]

10.2.3 Considerations for a robust monitoring plan

To ensure that the monitoring plan is robust, consider including the following elements in the plan:

- **Roles and responsibilities.** Identify the entity or person that is responsible for monitoring key performance indicators and parameters, and clarify the roles and responsibilities of the personnel conducting the monitoring.
- **Competencies.** Include information about any required competencies and any training needed to ensure that personnel have necessary skills.
- **Methods.** Explain the methods for generating, storing, collating and reporting data on monitored parameters.
- **Frequency.** Key performance indicators and parameters can be monitored at various frequencies, such as monthly, quarterly or annually. Determine the appropriate frequency of monitoring based on the needs

[56] Available at: http://unfccc.int/files/national_reports/non-annex_i_natcom/training_material/methodological_documents/application/pdf/unfccc_mda-toolkit_131108_ly.pdf.

of decision makers and stakeholders, cost and data availability. In general, the more frequently data are collected, the more robust the assessment will be. Frequency of monitoring can be consistent with measurement conducted under the national MRV system.

- **Collecting and managing data.** Identify the databases, tools or software systems that are used for collecting and managing data and information.

- **Quality assurance and quality control (QA/QC).** Define the methods for QA/QC to ensure that the quality of data leads to confidence in the assessment results. QA is a planned review process conducted by personnel who are not directly involved in data collection and processing. QC is a procedure or routine set of steps performed by the personnel compiling the data to ensure the quality of the data.

- **Record keeping and internal documentation.** Define procedures for clearly documenting the procedures and approaches for data collection, as well as the data and information collected. This information is beneficial for improving the availability of information for subsequent monitoring events, documenting improvements over time and creating a robust historical record for archiving.

- **Continual improvement.** Include a process for improving the methods for collecting data, taking measurements, running surveys, monitoring impacts, and modelling or analysing data. Continual improvement of monitoring can help reduce uncertainty in GHG estimates over time.

- **Financial resources.** Identify the cost of monitoring and sources of funds.

10.3 Monitor indicators and parameters over time

It is a *key recommendation* to monitor each of the indicators and parameters over time, in accordance with the monitoring plan. The frequency of monitoring is dependent on stakeholder resources, data availability, feasibility, and the uncertainty requirement of reporting (e.g. under the enhanced transparency framework, biennial transparency reports must be submitted every two years, as of 2024) or estimation needs. The monitoring plan should include an iterative process for balancing these dependencies. Where monitoring indicates that the assumptions used in the ex-ante assessment are no longer valid, users should document the difference and account for the monitored results when updating ex-ante estimates or when estimating ex-post GHG impacts.

11 Reporting

Reporting the results, methodology and assumptions used is important to ensure that the impact assessment is transparent, and gives decision makers and stakeholders the information they need to properly interpret the results. This chapter provides a list of information that is recommended for inclusion in an assessment report.

Checklist of key recommendations

- Report information about the assessment process and the GHG impacts resulting from the policy (including the information listed in Section 11.1)

11.1 Recommended information to report

It is a *key recommendation* to report information about the assessment process and the GHG impacts resulting from the policy (including the information listed below[57]). Where two or more assessment guides are applied to the policy, the general information and policy description only need to be reported once. For guidance on providing information to stakeholders, refer to the ICAT *Stakeholder Participation Guide* (Chapter 7).

General information

- The name of the policy assessed
- The person(s) or organization(s) that did the assessment
- The date of the assessment
- Whether the assessment is an update of a previous assessment and, if so, links to any previous assessments

[57] The list does not cover all chapters in this document because some chapters provide information or guidance that is not relevant to reporting.

Chapter 2: Objectives of assessing the GHG impacts of renewable energy policies

- The objective(s) and intended audience(s) of the assessment

Chapter 4: Using the methodology

- Opportunities for stakeholders to participate in the assessment

Chapter 5: Describing the policy

- A description of the policy, including the recommended information in Table 5.1. Whether the assessment applies to an individual policy or a package of related policies; if a package is assessed, which policies are included in the package
- Whether the assessment is ex-ante, ex-post, or a combination of ex-ante and ex-post

Chapter 6: Identifying impacts: how renewable energy policies reduce GHG emissions

- If identifying GHG impacts (Section 6.1), a list of all GHG sources for the policy identified, using a causal chain, showing which impacts are included in the GHG assessment boundary
- A list of potential GHG impacts that are excluded from the GHG assessment boundary, with justification for their exclusion
- The assessment period

Chapter 7: Estimating renewable energy addition of the policy ex-ante

- An estimate of the technical potential for the assessment period that the policy is expected to achieve
- A refined estimate after accounting for policy design characteristics
- A refined estimate after accounting for factors that affect the financial feasibility of RE technologies
- A refined estimate after accounting for barriers (Section 7.5 provides a sample template for the barrier analysis)

- The estimated RE addition of the policy upon completion of the steps in Sections 7.1–7.5
- The method or approach used to assess uncertainty
- An estimate or description of the uncertainty and/or sensitivity of the results, to help users of the information properly interpret the results

Chapter 8: Estimating GHG impacts of the policy ex-ante

- The method chosen (approach 1 or approach 2) for estimating GHG impacts based on the objectives of the assessment, and the policy's expected impact and time frame
- Where using approach 1
  - An estimate of the emissions trajectory using an energy model or the method for limited data availability
  - The calculated GHG emissions reductions (if relevant)
- Where using approach 2
  - An estimate of the grid emission factor using the combined margin approach or emission factor modelling
  - The calculated GHG emissions reductions
- Any methodologies and assumptions used to estimate GHG emissions reductions, including any models used
- All sources of data used to estimate GHG emissions reductions, including activity data, emission factors and assumptions
- The method or approach used to assess uncertainty
- An estimate or description of the uncertainty and/or sensitivity of the results, to help users of the information properly interpret the results

Chapter 9: Estimating GHG impacts of the policy ex-post

- An estimate of the achieved RE addition using monitored values for the indicators and parameters described in the monitoring plan
- Total annual and cumulative policy scenario emissions and removals over the GHG assessment period
- The methodology and assumptions used to estimate policy scenario emissions, including the emissions estimation methods (including any models) used
- The ex-post GHG impact estimate calculated using the emissions trajectory method or the grid emission factor method
- The method or approach used to assess uncertainty
- An estimate or description of the uncertainty and/or sensitivity of the results, to help users of the information properly interpret the results

Chapter 10: Monitoring performance over time

- A list of the key performance indicators used to track performance over time and the rationale for their selection
- Sources of key performance indicator data and monitoring frequency

Additional information (if relevant)

- How the policy is modifying longer-term trends in GHG emissions
- The economic, social and environmental (sustainable development), and transformational impacts of the policy.
- The type of technical review undertaken (first, second or third party), the qualifications of the reviewers and the review conclusions. More guidance on reporting information related to technical review is provided in Chapter 9 of the *Technical Review Guide*.

APPENDICES

Appendix A: Overview of the levelized cost of electricity method for renewable energy sources

The LCOE is the unique cost of an energy project, representing the present value of the costs over the lifetime of the project.

The LCOE is defined as the price of electricity "required for an energy project where revenues would equal costs, including a return on the capital invested equal to the discount rate".[58] An electricity price above this value would result in greater economic return on the investment, and an electricity price below the LCOE would result in a lower economic return.

The generic formulae to calculate the LCOE of RE technologies are as follows,[59] and the variables and parameters are listed in Table A.1:

Equation A.1

$$LCOE = \frac{\sum_{t=1}^{n} = \frac{I_t+M_t+F_t}{(1+d)^t}}{\sum_{t=1}^{n} = \frac{E_t}{(1+d)^t}}$$

Equation A.2

$$E_t = P_t \times 8760 \times CF_t$$

TABLE **A.1**

Input parameters and description for calculation of the project levelized cost of electricity

Input parameter	Description	Unit
LCOE	The average lifetime levelized cost of electricity generation	USD/kWh
I_t	Investment expenditures in year *t*	USD
M_t	Operational and maintenance costs in year *t*	USD
F_t	Fuel costs in year *t*	USD
E_t	Electricity generation in year *t*	kWh
d	Discount rate (or weighted average cost of capital)	%
n	Economic lifetime of the system	Years
P_t	Power generation capacity of the system	kW
CF_t	Capacity factor in year *t*	Dimensionless

58 IRENA (2018b).

59 IRENA (2018b).

Given the capital-intensive nature of most RE technologies and the fact that fuel costs are low (zero for many RE technologies), the WACC, also referred to as the discount rate *d*, used to evaluate the RE project has a critical impact on the LCOE.[60] For more information on the WACC, see Appendix B.

The LCOE of RE technologies varies by RE technology, country and project size. It is determined taking into account the RE resource at a project site, capital and operating costs, and the performance/efficiency of the RE technology. When a policy has a wide geographical coverage with different physical conditions for RE generation (e.g. wind power), it is recommended that LCOEs are calculated specifically for each region or location.

IRENA provides input values for LCOE (USD/kWh), total investment costs (USD/kW) and capacity factors for different RE technologies across different regions.[61]

[60] IRENA (2018b).

[61] IRENA (2018b, 2019a).

Appendix B: Overview of the weighted average cost of capital for renewable energy sources

Financing is an important part of the electricity generation cost. Project finance generally comes in three different forms: equity, private debt financing and public debt financing. In the calculations, these are captured in the WACC. The WACC is the rate a company is expected to pay, on average, to compensate all its investors. Section 7.4.1 explains the use of the WACC in financial feasibility calculations.

To calculate a WACC, we refer to the UNFCCC methodological tool on investment analysis developed for CDM projects.[62] WACCs are calculated using equation B.1. Table B.1 provides the input parameters and assumptions to calculate the WACC. The UNFCCC tool also provides default values for the cost of equity (r_e).

Equation B.1

$$WACC = r_e \times W_e + r_d \times W_d \times (1 - T_c)$$

TABLE **B.1**

Assumptions in the calculation of the weighted average cost of capital

Input parameter	Description	Unit
r_e	Cost of equity (expected return on equity)	Dimensionless
W_e	Percentage of financing that is equity	Dimensionless
r_d	Cost of debt	Dimensionless
W_d	Percentage of financing that is debt	Dimensionless
T_c	Corporate tax rate	Dimensionless

[62] UNFCCC (2018b).

For policy impact assessments, users may want to quantify a more generalized WACC that is broadly applicable to a range of RE projects that are expected to be installed under a policy. In such cases, users may use the WACCs developed by IRENA for region-level calculations of the LCOE[63] presented in Table B.2.

TABLE B.2

Economic lifetime and weighted average cost of capital used for levelized cost of electricity calculations

	Economic life (years)	Weighted average cost of capital, real	
		OECD and China	Rest of the world
Wind power	25	**7.5%**	**10%**
Solar PV	25		
CSP	25		
Hydropower	30		
Biomass for power	20		
Geothermal	25		

Source: IRENA (2018b).
Abbreviations: OECD, Organisation for Economic Co-operation and Development

[63] IRENA (2018b).

Appendix C: Example renewable energy policies

This appendix provides examples of RE policies from a number of countries, and case studies of RE policies from the literature. This information can be used to support the benchmarking exercise users can undertake after calculating RE addition.

TABLE **C.1**

Example feed-in tariff policies

Country	Main design characteristics	Main barriers and challenges	Achieved impact
Algeria (Nganga, Wohlert and Woods, 2013) FiT introduced in 2004 (Meyer-Renschhausen, 2013); 2014 for PV (PwC and Eversheds, 2016)	• All RE technologies eligible • Tariff differentiation with tariff premiums ranging between 80% and 300% • Government-owned single buyer with guaranteed purchase up to the annual production quota • FiTs are offered over a project's lifetime	• **Market barrier:** Significant subsidies available for conventional energy sources that reduce the price for all consumers • **Regulatory and policy uncertainty barrier:** Regulatory obstacles • **Financial barrier:** Lack of available capital (BETTER, 2013) • **Institutional and administrative barrier:** Regulatory and bureaucratic uncertainty and inefficiency (BETTER, 2013) • **Policy design challenge:** Insufficient level and variability of tariffs	• No single project has become operational, as of February 2013
Tanzania (Nganga, Wohlert and Woods, 2013) FiT introduced in 2009 (Weischer, 2012)	• Eligible projects must be at least 100 kW and export no more than 10 MW • No differentiation based on technology, size, fuel type or application, but depending on whether the SPP is grid connected or mini-grid • Payment duration of 15 years • 100% of energy purchased by utility and independent power producers	• **Financial barrier:** Solvency of state-owned utility (TANESCO) • **Infrastructure barrier:** Underdeveloped grid and problems with grid stability • **Financial barrier:** Low-interest financing as key challenge for SPP developers (with interest rates of 12–15% and payback periods of only 7–10 years, as of February 2013) • **Regulatory and policy uncertainty barrier:** Complicated regulatory requirements coordinated by several agencies (Weischer, 2012) • **Lack of awareness and skilled personnel:** Lack of experience in RE projects. Lack of confidence among stakeholders due to inexperience • **Public acceptance and environmental barrier:** Conflicts over land ownership and water rights (Weischer, 2012)	• 24.4 MW of newly developed capacity as of February 2013 • Additional 60 projects of a combined 130 MW in the pipeline as of February 2013

TABLE **C.1**, continued

Example feed-in tariff policies

Country	Main design characteristics	Main barriers and challenges	Achieved impact
Thailand (Beerepoot et al., 2013; ADB, 2015) Feed-in premium introduced in 2007, revised in 2009. Solar FiT introduced in 2013 (Tongsopit, 2014)	• Technologies eligible are biomass, biogas, municipal solid waste, wind, mini- and micro-hydropower, and solar; however, purchase of solar energy through the premium programme has been suspended • Feed-in premium rates for RE are differentiated by technology capacity, location, use as diesel replacement and installed capacity • 100% of energy purchased by Thai power utilities (EGAT, PEA and MEA) • Projects are eligible for support for 7–10 years • FiT programme for solar (Tongsopit, 2014))	• **Regulatory and policy uncertainty barriers:** Weak regulation and lack of transparency (Tongsopit and Greacen, 2012; Pacudan, 2014). Conflicting laws (Chaianong and Pharino, 2015). Uncertainty over future policy (Tongsopit, 2014). • **Techno-economic barriers:** Technical barriers, including severe energy shortages (Chaianong and Pharino, 2015) • **Public acceptance and environmental barrier:** Lack of public discourse (Tongsopit and Greacen, 2012) • **Lack of awareness and skilled personnel:** Limited number of skilled workforce in various technologies (Sawangphol and Pharino, 2011). Lack of domestic production of PV and wind (Chaianong and Pharino, 2015) • **Market barriers:** High capital investment, especially for PV (break-even point of 7–9 years). Fluctuation of fossil fuel price (Sawangphol and Pharino, 2011). • **Institutional and administrative barriers:** Lack of coordination among implementing bodies (Pacudan, 2014). Complex permitting process (Tongsopit, 2014) • **Policy design challenge:** Planning barriers (Tongsopit and Greacen, 2012) • **Market barrier:** Absence of consumer demand (Tongsopit and Greacen, 2012)	• 215.66 MW of installed capacity for rooftop solar PV as of 2012 (Chaianong and Pharino, 2015)

TABLE **C.1,** continued

Example feed-in tariff policies

Country	Main design characteristics	Main barriers and challenges	Achieved impact
United Kingdom (UK Department of Energy and Climate Change, 2015) FiT introduced in 2010	• Technologies eligible are solar PV, onshore wind, hydropower, anaerobic digestion and micro combined heat and power (micro CHP) • Tariff differentiation with higher tariffs for less mature technologies and small-scale installations • Tariffs were set to give rates of return of 5–8%	• **Regulatory and policy uncertainty barrier:** Policy risk and uncertainty result from changing policies, including financial support policies (Renewable Energy Association, 2015). These changes include large digressions in the FiT and impending solar FiT review (European Forum for Renewable Energy Sources, 2015) • **Lack of awareness and skilled personnel:** Insufficient skilled workers for installation of microgeneration technologies (Tallat-Kelpšaitė and Aaskov, 2015) • **Institutional and administrative barrier:** The objectives of Ofgem (UK's independent national energy regulator) are not aligned with national and European RE and green economic objectives (Tallat-Kelpšaitė and Aaskov, 2015) • **Policy design challenge:** Problems with FiT cost control mechanism for small-scale anaerobic digestion exist • **Policy design challenge:** The financial support for FiT technologies is unbalanced. While there is adequate support for PV, other technologies do not receive enough support to encourage similar investments (Tallat-Kelpšaitė and Aaskov, 2015)	• 3,567.40 MW of installed RE capacity over period of operation (April 2010 to March 2015), with total of 682,511 installations • PV accounts for 83.46% of all installed capacity, and wind accounts for 11.47% of all installed capacity
Uruguay (IRENA, 2015e) ***Only FiT policy for biomass in 2010 covered in this overview;*** however, note hybrid FiT/net metering policy for microgeneration in 2010, and hybrid policy of FiT and auction for PV in 2013 (Glemarec, Rickerson and Waissbein, 2012)	• Only eligible technology is biomass • Production capacity up to 20 MW (Government of Uruguay, 2010) • Payment duration of up to 20 years	• **Institutional and administrative barriers:** Significant barriers in licensing process for wind (Glemarec, Rickerson and Waissbein, 2012). Lack of experience in issuing permits for micro hydro (Terra and Schenzer, 2014). Absence of a regulated tariff for cogeneration as of 2012 (Garmendia, 2012)	• While the initial proposals received under the FiT totalled 354 MW of capacity, as of late 2014 only 0.6 MW was installed, with 43 MW in the pipeline (IRENA, 2015e)

Abbreviations: FiT, feed-in tariff; SPP, solar power plant

TABLE **C.2**

Example auctions and tender policies

Country	Main design characteristics	Main barriers and challenges	Achieved impact
Brazil (IRENA, 2013, 2015d) Laws adopted in 2004	• Auctions for wind, solar, small-scale hydro, large-scale hydro and conventional power sources • Projects contracted in auction required to start delivery after 3–5 years • PPAs are typically secured for 30 years for hydro, and 20 years for wind and biomass • 100% of the energy is bought in competitive bids with guaranteed revenue for power producers • Several prerequisites for bidders to participate in bidding process • Bidders have to deposit several guarantees including a bid bond of 1% of project's investment cost and a project completion bond of 5% of project's investment cost • Additional reserve energy auctions	• **Institutional and administrative barrier:** Difficulty in financing and problems getting environmental permits approved • **Infrastructure barrier:** Problems accessing the grid that lead to delays (Tiedemann, 2015) • **Policy design challenge:** The hybrid system of auctioning may allow the "winner's phenomenon", where bidders underbid to win the auction and ultimately undergo economic losses (Ferroukhi et al., 2015) • **Policy design challenge:** The auctioning process may last too long (Ferroukhi et al., 2015)	• Total of 62 GW has been contracted through 25 auctions for new capacity, including 9 GW of RE-based electricity generation auctions between 2005 and 2013 • 443 new generation projects for all technologies, including conventional power, with 60% renewables (40% large-scale hydro and 20% other RE)
China (IRENA, 2013) Auctions between 2003 and 2007 (IRENA, 2013)	• Auctions for wind (onshore and offshore), solar PV and CSP • Selection in one stage based on price (following the "lowest price wins" criterion) or weighted score from price and local content • Duration of tariff is 25 years for onshore wind and 30 years for offshore wind (including 4-year construction period) • No specific compliance rules nor clear penalties for non-compliance	• **Market barrier:** Information errors during the first and second bidding rounds that presented risks for bidders (Steinhilber, 2016) • **Lack of awareness and skilled personnel:** Lack of experience by bidders (Steinhilber, 2016). Lack of sufficiently stringent procedures to qualify bidders (Azuela et al., 2014) • **Regulatory and policy uncertainty barriers:** Conflicting policies and absence of penalties (Steinhilber, 2016). Lack of clear compliance rules such as ex-post change of location and Investment uncertainty (Held et al., 2014). • **Institutional and administrative barrier:** Lack of coordination between the auction organizer and the State Oceanic Administration (responsible for management of sea areas) (Azuela et al., 2014)	• Total of 8.64 GW of capacity contracted between 2003 and 2011 (7.3 GW of onshore wind; 10 MW of solar PV; 280 MW of CSP; 1.0 GW of offshore wind) (IRENA, 2013)

TABLE **C.2,** continued

Example auctions and tender policies

Country	Main design characteristics	Main barriers and challenges	Achieved impact
Morocco (IRENA, 2013) Tendering of hydro projects since 1960, legislation revised in 2010. Wind projects tendered since 1998 (Ecofys, 2013)	• Technology-specific auctions for wind (onshore), hydro and solar CSP in designated locations and for maximum capacity installed • Selection process with pre-qualification phase (experience, financial, technical capacity) and evaluation phase (technical specifications, financial aspects, industrial integration) • Duration of tariff is 20 years for wind and 25 years for solar • Penalties for delay and underperformance determined in PPA, guarantee paid at signature of PPA and termination of PPA as last resort	• **Institutional and administrative barriers:** Complex tendering system that involve five international financing institutions with different sets of procurement rules and processes (Ecofys, 2013). The tendering process is long, and implementation of the requirements is still unclear (Ecofys, 2013). • **Regulatory and policy uncertainty barrier:** Details for contracting projects are not transparent to the public (Ecofys, 2013) • **Infrastructure barrier:** Issues with integrating renewable power into the transmission grid system • **Overcoming potential barrier:** Stable political and regulatory environment, and Morocco's experience with independent power producers are essential in attracting investors • **Overcoming potential barrier:** Establishment of governing agency for solar energy (MASEN) was instrumental in the successful management of CSP solar auction • **Overcoming potential barrier:** Adoption of the public–private partnership model was crucial in de-risking the large-scale projects	• Total of 310 MW of RE capacity contracted between 2011 and 2012 (150 MW of wind; 160 MW of solar) • In March 2016, Morocco tendered a total of 850 MW of wind energy capacity to be installed on five wind farms (El Yaakoubi, 2016)
Peru (IRENA, 2013) Start of auctioning scheme in 2009 (IRENA, 2015a)	• Technology-specific auctions targeting solar, biomass and waste, wind, small hydro and geothermal • Selection in one round without a pre-qualification phase based on price and quota of energy (with ceiling price) • Duration of tariff 20 years (in the form of a PPA) • Performance bonds deposited by the power producers to secure completion of projects • Compliance with volume of energy generation contracted is ensured by penalizing shortages	• **Market barrier:** Gas-powered plants have preference over hydro plants through tax incentives (IRENA, 2012b). • **Institutional and administrative barriers:** Environmental impact assessment for hydro can be a hurdle (IRENA, 2012b). Problems with environmental permits and agreement with local people exist. The low level of technical barriers to participate in the auctions increases the risk of delays and non-execution (Ecofys, 2013) • **Lack of awareness and skilled personnel:** Feasibility studies, technical knowledge and a comprehensive legal framework are missing for geothermal (IRENA, 2012b)	• Total of 639 MW of RE capacity contracted between 2009 and 2011 across 36 projects (142 MW wind, 80 MW solar; 23 MW biomass, 4 MW biomass and 180 MW small hydro) • 236 MW of capacity operated as of December 2012 (GIZ, 2015)

TABLE **C.2**, continued

Example auctions and tender policies

Country	Main design characteristics	Main barriers and challenges	Achieved impact
Peru, continued	• Almost no administrative barriers due to high bidding guarantees and low pre-qualification requirements (GIZ, 2015)	• **Regulatory and policy uncertainty barrier:** Access to finance for RE projects is unregulated (Ecofys, 2013)	• Cumulative capacity for solar 184.5 MW as of July 2016 (SolarPower Europe, 2016)
South Africa (IRENA, 2013) The RE Independent Power Producer Procurement, REIPPP, was introduced in August 2011, last round in 2014 and planned auctions for 2016	• Technology-specific volume targeted across five auctions • Selection process with first phase (bidders have to meet minimum criteria related to legal, financial, technical and environmental requirements) and second phase (price 70%, economic development including local content 30%) • Duration of tariff is 20 years • Contracts terminated for bidders who fail to meet their commitment under the PPA • Current technologies considered within the PPA programme are onshore wind, CSP, solar PV, small hydro, biomass, biogas, landfill gas and co-generation from agricultural waste of by-products (del Río, 2015)	• **Institutional and administrative barriers:** Auction process complex and not automated. External transaction advisers are needed (Eberhard, Kolker and Leigland, 2014). Administrative hurdles (IRENA, 2013) • **Lack of awareness and skilled personnel:** Little provision of local capacity building and knowledge transfer (IRENA, 2013) • **Financial barrier:** High transaction costs for both the government and bidders (Eberhard, Kolker and Leigland, 2014) • **Financial barrier:** Eskom is the grid operator and single buyer, which makes power producers vulnerable to its responses (Ecofys, 2013) • **Policy design challenge:** As of August 2012, there were no successful bids for biomass, biogas or landfill gas technologies, possibly because of low price ceilings (IRENA, 2013) • **Policy design challenge:** Short timespans between auctions may negatively affect competition (del Río, 2015)	• Total of 2.46 GW of RE capacity contracted between 2011 and 2013 of 5.93 GW auctioned over the same period (1.2 GW of onshore wind, 200 MW of CSP, 1.05 GW of solar PV, 14.3 MW of small hydro) • Cumulative capacity of solar 1,048 MW as of July 2016 (SolarPower Europe, 2016) • By end of June 2015, 1,860 MW of procured capacity had already started operations (960 MW solar PV, 790 MW onshore wind, 100 MW CSP, 10 MW hydro) (del Río, 2015)

Abbreviations: CSP, concentrated solar power; PPA, power purchase agreement

TABLE **C.3**

Example tax incentive policies

Country	Main design characteristics	Main barriers and challenges	Achieved impact
Argentina (IRENA, 2015c) Law 25.019 Art. 3 enacted September 1998 for solar and wind (Government of Argentina, 1998); Law 26.190 Art. 9 enacted December 2006 (Government of Argentina, 2006), including decree 562/2009 (including wind, solar, geothermal, tidal, hydraulic, biomass, landfill gas, purification gas and biogas); Law 27.191 Arts 3 & 4 enacted October 2015 (amendment to law 26.190) (Government of Argentina, 2015) Law 26.334 01/2008 for biofuels	• Available technologies are wind, solar, geothermal, tidal, small hydro, biomass, landfill gas, purification gas and biogas (Climatescope, 2015a) At national level: • **Accelerated income tax depreciation** • **VAT rebate:** 15-year VAT deferral from capital investments in wind and solar equipment (from enactment of Law 25.019) At provincial/local level (KPMG, 2012; IRENA, 2015c): • **Real estate tax exemption** • **Stamp tax exemption** • **Turnover tax exemption/ deferral** • **Tax stability**	• **Market barriers:** Subsidies for consumption of fossil fuels. Tax breaks for companies investing in oil and gas. Tax incentives to promote exploration (Pickard, 2015) • **Institutional and administrative barrier:** Public investment in fossil fuel power stations (Pickard, 2015) • **Market barrier:** Availability of substantial amounts of natural gas and hydropower makes other sources uncompetitive (UNEP, 2011) • **Financial barrier:** Lack of support from financial institutions	• No ex-post impact study available
Colombia Law 1715 (Government of Colombia, 2014) and its decree 2143 (Government of Colombia, 2015) published November 2015 and effective February 2016 Law 1716 (2014) Art. 11 to 14	Four explicit fiscal incentives described in Laws 1716 and 1715 (decree 2143): • 50% tax break on investment over 5 years • VAT exemption for equipment and machinery (local or foreign) associated with the project • Accelerated depreciation of assets • Exemption from import duty • Tax exemptions for biofuels: some biofuel plants are labelled tax-free zones (IRENA, 2015b)	• **Market barriers:** Subsidies for fossil fuels, although reduced over time, are still present (UPME, 2015b). Oligopolies for conventional energy production (UPME, 2015a). Slightly higher investment costs for renewable technology than for conventional • **Techno-economic barrier:** Lack of technical requirements to connect and operate wind parks and small solar PV projects (UPME, 2015a) • **Infrastructure barrier:** Lack of transmission lines in areas with the greatest potential for wind energy generation	• No ex-post impact study available

TABLE **C.3**, continued

Example tax incentive policies

Country	Main design characteristics	Main barriers and challenges	Achieved impact
Colombia, continued		• **Public acceptance and environmental barrier:** Competition with historical heritage interests in the area • **Lack of awareness and skilled personnel:** Insufficient skilled workers, and lack of training and education	
Indonesia Implemented by Government Regulation No. 1/2007 (amended by GR No. 62/2008 and GR No. 52/2011), Ministry of Finance Regulation No. 21/2010 and Regulation No. 130/2011 (Damuri and Atje, 2012; PwC, 2013)	• **Import duty and VAT exemption:** Import duty exemption on machinery and capital for development of power plants. Exemption from VAT on importation of taxable goods • **Income tax reduction:** Reduction and various facilities for income tax on energy development projects, including net income reduction, accelerated depreciation, dividends reduced for foreign investors and compensation for losses • **Accelerated depreciation and amortization:** This allows investments to be depreciated within 2–10 years, depending on type of asset. This incentive would reduce the income tax paid by investors and is expected to encourage expansion of investment (Government Regulation No. 1/2007) • **Income tax reduction for foreign investors:** Allows them to pay a rate of only 10% on dividends they receive • Income tax holidays/ reductions under "Pioneer Industries Facility": **corporate income tax (CIT) exemption** for 5–10 years, 50% reduction of CIT for 2 years after end of exemption period	• **Market barriers:** The tariff for electricity set by the government is lower than the costs of production (indirect subsidy on conventional energy production). Unequal tax burdens between conventional and renewable energy sources (WWF, 2014) • **Institutional and administrative barriers:** Multilayer government approval procedures (IEA, 2015b). Difficult licensing acquisition • **Regulatory and policy uncertainty barrier:** Unclear regulations	• No company in the RE sector has qualified as a pioneer to receive additional tax exemptions (tax holidays of 5–10 years) as of April 2015 (Ministry of Finance Indonesia, 2015) • No further ex-post impact study found

TABLE **C.3,** continued

Example tax incentive policies

Country	Main design characteristics	Main barriers and challenges	Achieved impact
Panama For all renewables: Law 45 (2004) Arts 9 and 10. For wind installations: Law 44 (2011) Art. 22. For wind installations: Law 37 (2013) Art. 20 and its reform (2016) (Government of Panama, 2013, 2016)	• Available technologies are solar, wind, hydro, small hydro and geothermal • Incentives for the construction, operation and maintenance are valid for up to 20 years for solar and 10 years for other renewable energies For projects up to 0.5 MW (Climatescope, 2015b): • **Import tax exemptions** • **VAT exemptions** • **Income tax credit** equivalent to up to 100% of direct investment for 10 years For projects up to 10 MW (Climatescope, 2015b): • Exemption from **import, transmission** and **distribution taxes** • **Income tax credit** equivalent to up to 50% of direct investment For projects up to 20 MW: • Exemption from transmission taxes (on the first 10 MW for 10 years)	• **Infrastructure barrier:** Lack of transmission lines in areas with the greatest potential for wind energy generation • **Financial barrier:** Absence of adequate funding opportunities and financing products for RE • **Market barrier:** Price structure that disadvantages renewables • **Lack of awareness and skilled personnel:** Insufficient skilled workers, and lack of training and education • **Public acceptance and environmental barrier:** Competition with protected status in some potential areas	• No ex-post impact study available

TABLE **C.3**, continued

Example tax incentive policies

Country	Main design characteristics	Main barriers and challenges	Achieved impact
United States (California) 26 USC § 25D and § 48 established in 2005 (for solar), extended in 2008 and in 2015 (California Energy Commission, 2015) 26 USC § 45 established in 1992 and subsequently amended numerous times (NC Clean Energy Technology Center, 2016b) 26 USC § 136 (1992) Cal Rev & Tax Code § 73 (2012) (NC Clean Energy Technology Center, 2016a)	• **Federal ITC:** 30% for solar, fuel cells and small wind; 10% for geothermal, microturbines, and combined heat and power • **Federal renewable electricity PTC:** Available technologies are geothermal, wind, biomass, hydroelectric, municipal solid waste, landfill gas, tidal, wave, ocean thermal • **Non-taxable energy conservation subsidies:** Applicable to residential solar thermal and PV systems • **Section 73 of the California Revenue and Taxation code:** Property tax exclusion of certain solar energy systems installed between January 1999 and December 2016	• **Institutional and administrative barrier:** State incentive programmes can have complex eligibility requirements (California Energy Commission, 2015) • **Regulatory and policy uncertainty barriers:** Financial incentive legislation for RE has been volatile. Typically, extensions for tax credits are only given for 1–3 years; barriers in environmental permitting due to strict requirements for large-scale RE technologies (U.S. EPA, 2016) • **Infrastructure barrier:** Constraints in existing transmission infrastructure (California Energy Commission, 2011).	• Residential and commercial solar ITC has helped annual solar installation grow by more than 1,600% since 2006 – a compound annual growth rate of 76% (SEIA, 2016) • In years following PTC expiration, wind installations drop by about 80% (Spengler, 2011)

Abbreviations: ITC, investment tax credit; PTC, production tax credit; VAT, value-added tax; USC, United States Code

TABLE **C.4**

Case studies of renewable energy policies in the literature

Study	Author, year	Case study countries	Type of policy	Link
Renewable Energy Auctions in Developing Countries	IRENA, 2013	Brazil, China, Morocco, Peru, South Africa	In-depth description of country case studies, including design characteristics and achieved auction outcomes for all case studies	www.irena.org/DocumentDownloads/Publications/IRENA_Renewable_energy_auctions_in_developing_countries.pdf A continuation of this study is available at: https://irena.org/publications/2019/Jun/Renewable-energy-auctions-Status-and-trends-beyond-price
Renewable Energy in Latin America 2015: an Overview of Policies	IRENA, 2015b	20 countries in Central and South America	Overview of all implemented policies in the fields of national policy, fiscal incentives and grid access, especially Table 1 (plus IRENA in-depth country profiles); no/limited information on achieved outputs linked to specific policies	www.irena.org/DocumentDownloads/Publications/IRENA_RE_Latin_America_Policies_2015.pdf
Powering Africa through Feed-in Tariffs	Heinrich Böll Stiftung and World Future Council, 2013	13 countries in Africa ("pioneers" and "late movers")	Country profiles for each country with design characteristics and (short) impact assessment	https://ke.boell.org/sites/default/files/2013-03-powering-africa_through-feed-in-tariffs.pdf
Evaluation of feed-in tariff-schemes in African countries	Meyer-Renschhausen, 2013	4 countries in Africa	Overview of FiT design choices; no information on achieved outputs/impacts	www.erc.uct.ac.za/sites/default/files/image_tool/images/119/jesa/24-1jesa-meyer.pdf
Performance and Impact of the Feed-in Tariff Scheme: Review of Evidence	UK Department of Energy and Climate Change, 2015	Country case study for the UK	In-depth description of FiT policy and impact/output assessment	www.gov.uk/government/uploads/system/uploads/attachment_data/file/456181/FIT_Evidence_Review.pdf
Comparison of Feed-in Tariffs and Tenders to Remunerate Solar Power Generation	Grau, 2014	Country case studies for Germany and France	Overview of FiT and tender policies in both countries	www.diw.de/documents/publikationen/73/diw_01.c.437464.de/dp1363.pdf
Ontario's Feed-in Tariff Program: Two-Year Review Report	Ontario Ministry of Energy, 2012	Case study for Ontario (province in Canada)	Overview of FiT design and impact plus policy recommendation	www.chfour.ca/uploads/1/4/1/9/14199462/fit-review-report-en.pdf
A Policymaker's Guide to Feed-in Tariff Policy Design	NREL, 2010	Information overview for 5 countries	Information on FiT tariff payment levels for Germany, Spain, Ontario, Switzerland, Minnesota (USA)	www.nrel.gov/docs/fy10osti/44849.pdf

Abbreviation: FiT, feed-in tariff

Appendix D: Overview of the Clean Development Mechanism combined margin approach

The combined margin approach used in the CDM has gained wide technical and political acceptance over the years. The combined margin is calculated in the CDM Tool to Calculate Emission Factor for an Electricity System using the following formula:

$$EF_{grid,CM,y} = EF_{grid,OM,y} \times W_{OM,y} + EF_{grid,BM,y} \times W_{BM,y}$$

where

$EF_{grid,CM,y}$ = combined margin emission factor for a defined time frame *y* (tCO_2e/MWh)

$EF_{grid,OM,y}$ = operating margin emission factor for a defined time frame *y* (tCO_2e/MWh)

$EF_{grid,BM,y}$ = build margin emission factor for a defined time frame *y* (tCO_2e/MWh)

$W_{OM,y}$ = weighting of operating margin emission factor (%)

$W_{BM,y}$ = weighting of build margin emission factor (%)

The main steps of the CDM tool are summarized as follows:

Step 1: Determine the operating margin ($EF_{grid,OM,y}$). Operating margin provides the GHG impact due to displacement of power generated from existing grid-connected power plants by the introduction of new capacity. The CDM tool provides four calculation approaches for estimating the operating margin, outlined in Table D.1. The appropriate approach should be selected based on the composition of the generation mix, particularly the extent of use of low-cost/must-run plants in the grid.[64]

TABLE **D.1**

Overview of options for calculating operating margin

Input parameter	Description
Simple operating margin	The emission factor is calculated as the power generation weighted average of all power units supplying to the grid, except for low-cost/must-run plants.
Simple adjusted operating margin	If low-cost/must-run power plants generate a significant share of electricity (>50%) and daily load (average load > average lowest recorded hourly load over a year), these must be included in the simple operating margin calculation. In such cases, first the generation-weighted average emissions rate is estimated separately for power plants that fall in the low-cost/must-run category and for the rest. Next, these two are weighted based on the number of hours when low-cost/must-run power units are on the margin in a year.
Average operating margin	The average operating margin emission factor is a simple average of all power plants that contribute to the grid, including low-cost/must-run plants.
Dispatch data analysis operating margin	The operating margin is calculated using the electricity displaced hourly by the project and the emission factor of the grid power units that are at the top of the dispatch order in that hour (whose power is replaced by the project).

Source: UNFCCC (2015).

64 Low-cost/must-run resources are power plants with low marginal generation costs, or power plants that are dispatched independently of the daily or seasonal load of the grid (e.g. hydro, geothermal, wind, low-cost biomass, nuclear, solar generation) (UNFCCC, 2015).

Step 2: Calculate the build margin ($EF_{grid,BM,y}$). Build margin refers to the GHG impacts of future capacity expansion. The CDM recommends using historical data from the most recently built power plants as a proxy for determining the make-up of future power units in the energy system.

$$EF_{grid,BM,y} = \frac{\sum m\ EG_{m,y} \times EF_{EL,m,y}}{\sum m\ EG_{m,y}}$$

where

$EF_{grid,BM,y}$	=	build margin emission factor (tCO_2e/MWh)
$EG_{m,y}$	=	electricity generated and delivered to the grid in a defined time frame y (MWh)
$EF_{EL,m,y}$	=	CO_2 emission factor for power plants m in a defined time frame y (tCO_2e/MWh)
m	=	all power plants serving the grid in defined time frame y except low-cost/must-run power units
y	=	defined time frame (most recent historical year for which electricity data are available)

Step 3: Determine combined margin emission factor. The combined margin is calculated as a weighted average of the operating margin and build margin:

- The sum of the weighting factors for operating margin ($W_{OM,y}$) and build margin ($W_{BM,y}$) must be equal to 1.
- They must reflect the age of currently operational plants and expected future capacity additions.
- Common default values used in the CDM, are as follows
  - » wind and solar – operating margin, 0.75; build margin, 0.25
  - » other RE technologies – operating margin, 0.5; build margin, 0.5.

Selecting alternative weights for operating and build margin

The CDM tool provides for some adjustments to the default weighting of operating and build margin. Users should consider the technology focus of the policy, the national electricity generation mix and load characteristics when determining whether the weightings should be adjusted. The CDM tool provides further guidance on adjusting weights.

Appendix E: Stakeholder participation during the assessment process

This appendix provides an overview of the ways that stakeholder participation can enhance the process of assessment of GHG impacts of renewable energy policies. Table E.1 provides a summary of the steps in the assessment process where stakeholder participation is recommended and why it is important, explaining where relevant guidance can be found in the ICAT *Stakeholder Participation Guide*.

TABLE **E.1**

Steps where stakeholder participation is recommended in the impact assessment

Chapter/step in this document	Why stakeholder participation is important at this step	Relevant chapters in *Stakeholder Participation Guide*
Chapter 2 – Objectives of assessing the GHG impacts of RE policies	Ensure that the objectives of the assessment respond to the needs and interests of stakeholders	Chapter 5 – Identifying and understanding stakeholders
Chapter 4 – Using the methodology Section 4.2.5 – Planning stakeholder participation	Build understanding, participation and support for the policy or action among stakeholders Ensure conformity with national and international laws and norms, as well as donor requirements related to stakeholder participation Identify and plan how to engage stakeholder groups who may be affected, or may influence the policy or action Coordinate participation at multiple steps of this assessment with participation in other stages of the policy design and implementation cycle, and other assessments	Chapter 4 – Planning effective stakeholder participation Chapter 5 – Identifying and understanding stakeholders Chapter 6 – Establishing multi-stakeholder bodies Chapter 9 – Establishing grievance redress mechanisms
Chapter 6 – Identifying impacts: how RE policies reduce GHG emissions	Enhance completeness of the list of GHG impacts with stakeholder insights Improve and validate causal chain with stakeholder insights on cause–effect relationships between the policy, behaviour change and expected impacts	Chapter 5 – Identifying and understanding stakeholders Chapter 8 – Designing and conducting consultations
Chapter 7 – Estimating RE addition of the policy ex-ante	Improve identification of barriers and evaluation of their severity with stakeholder insights	Chapter 8 – Designing and conducting consultations
Chapter 10 – Monitoring performance over time	Ensure that monitoring frequency addresses the needs of decision makers and other stakeholders	Chapter 8 – Designing and conducting consultations
Chapter 11 – Reporting	Raise awareness of benefits and other impacts to build support for the policy or action Inform decision makers and other stakeholders about impacts to facilitate adaptive management Increase accountability and transparency, and thereby credibility and acceptance of the assessment	Chapter 7 – Providing information to stakeholders

Appendix F: Selecting the scope of the methodology

The scope of this methodology was selected using a set of criteria developed with the Technical Working Group:

- role of the subsector in countries’ NDCs
- GHG emissions reduction potential
- extent to which policies for the subsector exist in countries and are being implemented to directly promote renewable electricity generation
- current and future emissions levels/share of subsector emissions
- potential lock-in/transformation
- gaps in available guidance
- investment needs under a 1.5–2°C temperature goal.

Abbreviations and acronyms

CDM Clean Development Mechanism

CH_4 methane

CO_2 carbon dioxide

CO_2e carbon dioxide equivalent

GDP gross domestic product

GHG greenhouse gas

GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH

GWh gigawatt-hour

ICAT Initiative for Climate Action Transparency

IEA International Energy Agency

IPCC Intergovernmental Panel on Climate Change

IRENA International Renewable Energy Agency

IRR internal rate of return

kWh kilowatt-hour

LCOE levelized cost of electricity

MRV monitoring, reporting and verification

$MtCO_2e$ mega-tonnes of carbon dioxide equivalent

MW megawatt

MWh megawatt-hour

NDC nationally determined contribution

PV photovoltaic

RE renewable energy

SDG Sustainable Development Goal

tCO_2e tonnes of carbon dioxide equivalent

UNFCCC United Nations Framework Convention on Climate Change

VRE variable renewable energy

WACC weighted average cost of capital

Glossary

Activities	The administrative activities involved in implementing a policy (undertaken by the authority or entity that implements the policy), 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 transformational impacts of a policy
Barrier	Any obstacle to developing and deploying an 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 a policy leads to impacts through a series of interlinked logical and sequential stages of cause-and-effect relationships
Electricity grid (grid)	A network consisting of wires, switches and transformers to transmit electricity from power sources to power users. A large network is layered from low-voltage (110–240 V) distribution, over 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.
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	A carefully considered, well-documented qualitative or quantitative judgment made in the absence of unequivocal observational evidence by a person or persons who have a demonstrable expertise in the given field[65]
Feed-in tariff	The price per unit of electricity that a utility or 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 the assessment in terms of the range of GHG impacts included in the assessment
GHG impacts	Changes in GHG emissions by sources that result from a policy
Grid access	The acceptance of power producers to deliver to the electricity grid

[65] IPCC (2006).

Impact assessment	Estimation of changes in GHG emissions or removals resulting from a policy, either ex-ante or ex-post
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
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
Inputs	Resources that go into implementing a 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 behaviour, technology, processes or practices that result from a policy, which lead to GHG impacts
Jurisdiction	The geographic area within which an entity's (such as a government's) authority is exercised
Key performance indicator (indicator)	A metric that indicates the performance of a policy
Levelized cost of electricity (LCOE)	The unique cost price of the outputs (US cent/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 a policy and its impacts
Monitoring period	The time over which a 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 unfavourable 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 PV system). The net energy produced or consumed is purchased from, or sold to, respectively, the power producer.
Non-policy drivers	Conditions other than RE policies, such as socioeconomic factors and market forces, that are expected to affect the emissions sources included in the GHG assessment boundary
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. They include both policies that have the same or complementary goals (such as national and subnational energy efficiency standards for appliances) and 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 technologies, processes or practices; and public or private sector financing and investment
Policy implementation period	The time period during which a policy is in effect
Policy scenario	A scenario that represents the events or conditions most likely to occur in the presence of a policy (or package of RE policies) being assessed. The policy scenario is the same as the baseline scenario except that it includes the policy (or package of policies) being assessed.
Positive impacts	Impacts that are perceived as favourable from the perspectives of decision makers and stakeholders
Power purchase agreement (PPA)	A contract between an electricity (power) producer and an electricity consumer (or distributor). Historically, PPAs have been 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 (National Renewable Energy Laboratory definition).
RE addition	The additional installation of RE capacity or electricity generation from renewable sources realized via a 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. It 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 requires utilities to procure a certain percentage or flat amount of renewable electricity or power, based on their total generation. Utilities can procure the RE via direct ownership or the purchase of RE credits (National Renewable Energy Laboratory definition).
Short-term impacts	Impacts that are nearer in time, based on the amount of time between implementation of a policy and its impacts
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 PV panels and converted directly into electricity
Stakeholders	People, organizations, communities or individuals who are affected by, and/or who have influence or power over, a 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 a 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

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