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Checklist on Establishing Post-2020 Emission Pathways
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## Abbreviations

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<th>Full Form</th>
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<tr>
<td>CCC</td>
<td>Committee on Climate Change</td>
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<td>CGE</td>
<td>Computable General Equilibrium</td>
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<td>CoP</td>
<td>Conference of the Parties</td>
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<tr>
<td>ETS</td>
<td>Emissions trading scheme</td>
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<td>GDP</td>
<td>Gross domestic product</td>
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<td>GNI</td>
<td>Gross national income</td>
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<td>GVA</td>
<td>Gross value added</td>
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<td>GWP</td>
<td>Global warming potential</td>
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<td>IMF</td>
<td>International Monetary Fund</td>
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<td>INDC</td>
<td>Intended nationally determined contributions</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<tr>
<td>LULUCF</td>
<td>Land use, land-use change and forestry</td>
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<tr>
<td>MACC</td>
<td>Marginal abatement cost curve</td>
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<tr>
<td>NAMA</td>
<td>Nationally Appropriate Mitigation Actions</td>
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<tr>
<td>NPV</td>
<td>Net Present Value</td>
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<tr>
<td>RD&amp;D</td>
<td>Research, development and deployment</td>
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<td>SAM</td>
<td>Social Accounting Matrices</td>
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<td>SMAP</td>
<td>Sectoral Mitigation Action Plans</td>
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<td>TAMT</td>
<td>Transport Activity Measurement Toolkit</td>
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<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
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Executive Summary

This “checklist” is designed to support countries in the development and presentation of medium- and long-term emission pathways. The development of these pathways is crucial to allow countries to plan their international commitments in a manner consistent with future economic development, and to construct a suitable package of policies and measures that build synergies between the two, in many cases including the use of carbon pricing instruments. This work is expected to be of particular use to countries devising their intended nationally determined contributions (INDCs) to submit to the United Nations Framework Convention on Climate Change (UNFCCC).

A wide range of tools and analytical techniques support the development of long-run emission pathways—but the questions they are best suited to answer, and their relationship to one another, are not always clear. To address the challenge, the paper sets out a framework of four components, as set out below.

For the first three (analytical) components, the paper addresses a common set of issues including the questions that might be considered and options for how the answers to these questions might be presented; key tools and analytical techniques that can help address these questions; the data sources that might be used to populate these tools and models; and how practitioners may wish to account for the inevitable uncertainty in their analysis. The fourth component provides suggestions on different options for the presentation of the resulting technical analysis. Recognizing the heterogeneity of national methodologies, the paper does not recommend a single approach, model or tool; rather it provides examples that are widely used and accepted and aims to promote consistency in how national approaches are described and explained. The checklist is intended to bridge the gap between policy makers and technical experts. It is also intended to help technical experts to draw on good practice in constructing scenarios, to help communicate analysis to policy makers, and to facilitate transparency.

Figure 1. The Checklist Examines Key Methodological Options across Four Components

- **Country context**: Sectoral patterns of emissions, the socio-economic significance of these patterns and their drivers to help communicate country context internationally
- **Baseline pathways**: Plausible pathways for activity and associated emissions in the status quo
- **Alternative emissions pathways**: Identification of emission mitigation options and/or policies and their costs and benefits to develop emission mitigation pathways
- **Results presentation**: Suggestions on what and how to present results
Component 1 identifies how countries might analyze and report historical information on emissions and the socio-economic significance of the sectors responsible for those emissions. This information is important in setting the context for any forward-looking analysis and can help to identify drivers of historical trends, likely opportunities to reduce emissions (growth) and some of the constraints that may be faced in undertaking further emission reduction activity. Much of this analysis can be undertaken in a relatively straightforward fashion, using national sources to explain trends in emissions and the output, employment and other key variables of the sectors responsible for those emissions. National data can be supplemented by international sources where relevant. It may be valuable to augment graphical and tabular descriptions of the historical patterns of emissions with statistical techniques, such as the Kaya Identity and the ASIF decomposition, that provide a more robust understanding of historical emission trends.

Component 2 addresses how analysts might develop pathways of the future economic development for their country, and the emissions that this might generate, in the absence of any additional policy effort beyond that already in place or committed to. It identifies four broad options that countries may want to adopt in the development of such “baseline pathways”:

- A relatively simple approach where economic activity and the emissions intensity are projected on the basis of historical trends to yield a projection of future emissions based on trend extrapolation.
- An augmented version of the first option whereby factors are taken into account that would be expected to lead to future development trends differing from those seen in the recent past.
- The results from analysis of past emissions drivers (such as the Kaya Identity and the ASIF decomposition) can be used to identify the relationship between emissions and these drivers. Forward-looking projections of these key drivers can then be used to develop a baseline pathway.
- A bottom-up analysis in which, making use of national projections of economic development, analysts develop an understanding of the possible future development of activity drivers (for example, electricity generation demand, vehicle use, waste generation) and multiply these with possible future emissions factors.

These approaches increase in the level of sophistication, with the first approach generally not being attractive unless data constraints are acute. The fourth approach is likely to lead to the most robust results, although it will also require the most time and resources.

Different approaches may be used for different sectors, depending on data availability and analytical capacities.

In most cases, some policy instruments that reduce emissions relative to a “no policy” scenario already exist. A clear description of the extent to which these policies are included in the baseline pathway will promote understanding and transparency of both the baseline and the alternative emissions pathways. When incorporating the impact of existing policies, formal commitments may only have been made for part of the period being analyzed. In these cases, it may be necessary to make assumptions regarding longer-term policy settings.
All projections are uncertain, and pathways can depend strongly on external factors like global economic activity. Good practice suggests mapping out the sources and potential extent of uncertainty over future emissions outcomes. This may be done by producing a range of alternative baseline scenarios and/or through exploration of sensitivity to variations in selected assumptions.

**Component 3** considers different ways in which countries might develop alternative emission pathways with lower emissions than in the baseline pathway. It presents three main approaches (labeled subcomponents due to the wealth of different tools and techniques available under each):

A. Countries might collect data and identify the technical and behavioral emission reduction opportunities that are available within the country—for example, the opportunity to switch from coal-fired to gas-fired power generation—and then filter and aggregate these to develop one or more packages. These emission reduction opportunities can be used in large-scale optimization models (such as MARKAL); top-down Computable General Equilibrium (CGE) models; and bottom-up sectoral analyses building on, for instance, technology roadmaps. These approaches allow for an assessment of the magnitude of abatement that different options provide, their costs and, often, the associated investment and financing needs. Typically, the process of identifying emission reduction opportunities would be followed by the creation of one or more packages of opportunities, making use of both information on the cost and availability of the different emission reduction opportunities, as well as a wider range of social, institutional and political factors.

B. Countries might identify one or a series of policy instruments, such as a carbon price, that they wish to consider pursuing and, as desired, undertake technical analysis to better understand possible costs and impacts, including, as relevant, the extent to which the policy instrument supports a previously announced policy goal. The shortlisting of possible policies—which might include carbon pricing measures—can be developed by an understanding of which policies may be most effective at overcoming barriers to achieving emission reductions as well as a range of further political, institutional and social factors. An understanding of the likely impacts of one or a set of policies can be informed by a number of modeling techniques including bottom-up sector-specific modeling, financial marginal abatement cost curves, top-down macroeconomic modeling (either CGE or macroeconometric models) and distributional analyses.

C. Countries may choose to combine subcomponents A and B, iterating between the two types of analysis so as to develop an understanding of both the emission reductions opportunities that the country might pursue (subcomponent A), the policies that will deliver these opportunities, taking into account barriers to implementation (subcomponent B) and include assessment of policy impacts. Such iterative process helps identify policies that would ensure not only that abatement opportunities deliver desired emission outcomes, but also that they do it at the least cost and leverage other desired social and economic outcomes. In addition, the iterative process of matching policy instruments with abatement options can also be informed by the analysis of impacts on other important issues, such as incidence of costs, output and employment impacts among sectors and income groups. Direct incidence of impacts can be simulated with bottom-up or sector-wide models, while final incidence requires economy-wide macroeconomic models.
Additional considerations include local co-benefits, such as impact of policies on local air pollution, health and innovation. All this informs the choice of the level of ambition of mitigation opportunities, the choice of policy instruments and their design (including the design of complementary policies to mitigate the unwanted side effects and strengthen side benefits).

The iterative approach (C) represents good practice but will require more time and resources than if approach A or B were undertaken in isolation.

Regardless of the approach taken, there will be considerable uncertainty surrounding future emission pathways, and their costs and impact. To help reduce this uncertainty, countries may wish to make use of more than one tool/analytical approach and also to test the results derived from any one tool or analytical approach with a range of input assumptions, possibly using Monte Carlo analysis. This can help countries understand the key factors that are likely to determine the feasibility of any given pathway, and to construct a pathway that is more robust to future changes in the external environment.

It may also be desirable to establish a number of alternative emission scenarios which vary according to their level of emission reduction ambition. This can help identify how costs and impacts might vary at differing levels of ambition and to clarify the constraints that need to be overcome to adopt a more ambitious pathway.

Component 4 presents suggestions on how countries may wish to present the technical analysis of the previous three components. As a minimum, countries would ordinarily present the key results from the technical analysis including:

- **Time frame**: the horizon over which the pathway has been developed.
- **The type of pathway**: whether the analysis relates to absolute emissions, emissions expressed relative to some normalization variable (such as emissions per capita or emissions per unit of gross domestic product [GDP]), or some variable linked to emissions, such as renewable energy capacity.
- **Scope**: which sectors are covered by the pathway and, in the case that the pathway(s) specifying emissions has (have) been developed, the percentage of the emissions of the country covered by the pathways, the geographic coverage, and the gases covered.
- **Expected trajectory of key variables**: how the variables of interest are expected to develop over the time frame of the pathway. This may be expressed either relative to some historical reference year or relative to what that variable would be considered to be in the baseline pathway (in which case it provision of the assumptions underpinning the baseline pathway would also be valuable). It may also be helpful to express these both in absolute terms and using index values to facilitate easy understanding and transparency.
- **Assumptions and methodological approaches**: this may include the approach taken to calculating the global warming potential (GWP) of non CO₂ greenhouse gases (GHGs) and the treatment of emissions from land use, land-use change and forestry.

Countries may also choose to present information on the detailed assumptions underpinning the analysis. The benefit of this is that it provides a basis for identifying sources of risks to implementation and reviewing
progress against the pathway, making it easier to identify quickly when performance is deviating from that assumed in the pathway and to take corrective action accordingly. Indeed, the assumptions underpinning the development of the pathway could be used to formulate a tracking framework.

Finally, countries may wish to present information on some of the challenges they anticipate in implementing the pathway. This can help create greater confidence among the international community that the emission reduction scenario is credible, robust and achievable, having given due consideration to both the benefits and costs associated with the scenario. It can also provide the foundation for a credible and detailed formulation of the ways in which the international community may be able to support the achievement of a particular alternative emission pathway.
Introduction

I.1 Background

As countries consider their mid- and long-term mitigation pathways, an important task for them is to analyze the pathways of their economies and related emissions over the next few decades, as well as the communication of such analysis and its results. This exercise can help identify the scale, scope and pace of alternative emission pathways and their costs (financing needs, but more importantly, the impact on the government budget, on output, and on employment), so that a suitable package of policies and measures can be constructed, in many cases including the use of carbon-pricing instruments. There are various methodologies and tools that can support this process, augmented by a diversity of options and practice, and growing international understanding of what constitutes good practice. Bringing that good practice to the attention of the PMR countries and beyond, and helping them to ramp up their technical abilities, will strengthen and advance their work in increasing their mitigation ambition and developing a package of effective and cost-efficient instruments to achieve that ambition.

The “checklist” outlined in this document aims to facilitate transparency and comparability of analytical approaches, technical methodologies and processes that countries may use to construct and present their post-2020 mitigation pathways. Recognizing the heterogeneity of national methodologies, the checklist aims to enhance understanding of the approaches and principles so as to both make it easier for countries to assign technical experts to harness certain modeling tools, as well as to foster understanding between policy makers and technical experts. It also aims so serve as an input on possible communication approaches. Rather than recommending a single model or tool, it provides examples of models widely used and accepted and aims to promote consistency in how national approaches are described and explained.

It is envisaged that this work may be particularly useful in helping countries develop and explain intended Nationally Determined Contributions (INDCs). In preparation for a new international climate agreement to be reached at the 21st Conference of the Parties (CoP) to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris in December 2015, countries have agreed to provide information that outlines what actions they intend to take, which are known as INDCs. Furthermore, at the 20th meeting at the CoP, parties agreed that:

the information to be provided by Parties communicating their intended nationally determined contributions, in order to facilitate clarity, transparency and understanding, may include, as appropriate, inter alia, quantifiable information on the reference point (including, as appropriate, a base year), time frames and/or periods for implementation, scope and coverage, planning processes, assumptions and methodological approaches including those for estimating and accounting for anthropogenic greenhouse gas emissions and, as appropriate, removals and how the Party considers that its intended nationally determined contribution is fair and ambitious, in light of its national circumstances, and how it contributes towards achieving the objective of the Convention as set out in its Article 2
The checklist is intended to provide policymakers and technical practitioners with a summary of the tools and analytical approaches that might be used to develop and present much of this information. In this way, it differs substantively from a number of other recent reports focusing on INDCs, which tend to focus more on the analysis submission of INDCs and less on the analysis and tools that countries might use in support of this work. This balance is reversed in this paper, although it does also briefly identify specific information governments may wish to include in their formal INDC submission to the UNFCCC.¹

I.2 Audience

This checklist aims to inform—and act as a bridge between—policymakers and practitioners working on post-2020 emission scenarios and INDCs. This can include government agencies and other groups deciding upon, and carrying out, the analysis, including think tanks, academic institutions and consultancies. The checklist also highlights how the results obtained can be presented internally, for example to decision makers, and externally, for example as part of documentation of technical analysis or an INDC submission.

I.3 Outline

The framework for the checklist consists of four components:

1. **The country context**: discusses options for analyzing and presenting emissions profiles, historical emissions trends and their drivers.
2. **Establishing an economics baseline and associated emission pathways**: sets out different options for understanding the future underlying economic structure of the economy, as well as the possible impacts on emissions, in the absence of any additional policy, taking into account external market drivers, current policies and technological development.
3. **Alternative emission pathways**: identifies different ways to analyze and present options for reducing emissions relative to this baseline. This component consists of three subcomponents: tools and analytical techniques that identify the technical emission reduction opportunities; approaches that can be used to identify different policy measures (including carbon price instruments) and their possible impacts; and interaction between these approaches.
4. **Results presentation**: provides suggestions on how the results of the analysis can be presented.

¹The aspects of the Lima Call for Climate Action that states that Parties should demonstrate how it consider “how the Party considers that its intended nationally determined contribution is fair and ambitious, in light of its national circumstances, and how it contributes towards achieving the objective of the Convention.” The tools and methodologies in relation to these objectives are not considered in this checklist. While the information that should be included in the submission of an INDC is still under negotiation (section K of Lima Agreements) there have been a number of suggestions made from a scientific perspective about which information will be needed to enable understanding of INDCs and contribute to the global 2 degree objective. See, for example, World Resources Institute (WRI). 2014. “Ex-Ante Clarification, Transparency, and Understanding of Intended Nationally Determined Mitigation Contributions”; Oeko-Institut. 2014. “Up-Front Information for Emission Reduction Contributions in the 2015 Agreement under the UNFCCC.”
For each of the first three analytical components, the checklist discusses the following methodological issues:

- the key issues to help facilitate transparency and comparability of analytical approaches, methodologies and processes across countries constructing and presenting their post-2020 mitigation pathways;
- the sectoral and economy-wide models and analytical tools that can be used to address these issues; their functions, features and structural assumptions; how different models and tools might be linked; and any differences in approach needed where analysis is sector-specific rather than economy-wide;
- the sources of data and assumptions that might be used for calibrating such models and analytical tools, including parameters related to global and external trends;
- the extent of uncertainty and options available to deal with uncertainty; and
- the output variables that may be reported, the methods of their aggregation, and their presentation.

Each of these components also includes one or more summary tables that might be used as a guide in preparing information about aspects of a country’s INDC or other long-run emission scenario analysis, and about the underlying technical analysis.

The presentation component summarizes the results obtained throughout the components and provides suggestions on how to present results internally and externally. It also contains a brief overview explicitly focused on a formal INDC submission.
The checklist uses a range of key terms in a consistent manner, with definition set out in box 1 below.

**Box 1. Terminology Used throughout This Checklist**

- *Baseline pathway*: a plausible outlook for the future of a country or sector, in terms of activity levels and emissions, assuming no extra policies to reduce emissions beyond policies already in place or committed.
- *Emission reduction opportunity*: a behavioral change or investment that can be undertaken in order to reduce the emissions associated with a particular activity relative to the baseline.
- *Policy instrument*: action or initiative, such as a carbon price or regulations, introduced by a public sector entity to encourage individuals and firms to take up emission reduction opportunities.
- *Policy goal*: the outcome expected as a result of the introduction of a policy instrument. This may include, for example, emission reductions, energy efficiency improvements, and renewable energy generation.
- *Emission mitigation pathway*: the outcome from possible future emission reduction opportunities that lead to a change (reduction) in emissions relative to the baseline.
Component 1: Country Context

1.1 Key Questions Covered by This Component

The purpose of this component is to outline the options for analyzing and presenting historical trends in economic activity and emissions. These set the context in which future emission pathways can be analyzed.\(^1\) This component provides suggestions on how to address and present information on questions such as:

- What is the breakdown of emissions by sector and over time and, within these sectors, what are the main emission-intensive activities? How do economy and sector emission profiles compare to other relevant countries?
- What is the socio-economic importance of these sectors, using metrics such as share of:
  - value-added in the gross domestic product (GDP)?
  - exports in total country export revenues?
  - total employment in the economy?
  - the net fiscal revenue of the government?
- What have been the main drivers of change in energy use and emissions, including key commitments and policies?

Addressing questions such as these provides an overall sense of the emission reduction opportunities available within a country and where they are most likely to be concentrated.

1.2 Key Data Sources

To inform forward-looking analysis, it will generally be useful to provide data for economic and emissions trends over a period of a decade. The data should also ideally cover all of the sectors responsible for emissions—with the Intergovernmental Panel on Climate Change (IPCC) classification of energy, transport, industrial processes, agriculture, waste and land use, land-use change and forestry (LULUCF) providing a typical breakdown. All greenhouse gases (GHG) should also ideally be covered.

In terms of emissions data, it may be possible to draw extensively on the National GHG inventory prepared as part of the National Communications.\(^2\) However, these data sources will sometimes be incomplete with respect to sectoral coverage and/or data may not provide a complete time series.

When sectoral coverage is incomplete, it will be important to ensure that sectors accounting for the largest share of GHG emissions are included. Where this data is not available new estimations may be required, typically by applying suitable emissions factors to nationally monitored activity levels in energy use or

\(^{1}\)This component largely deals with options for presenting historical data. Given this, it adopts a slightly different structure to the subsequent components to reflect the greater importance surrounding data sources in this component.

\(^{2}\)http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php.
industrial production. IPCC guidelines and procedures for emissions accounting, as well as United Nations Framework Convention on Climate Change guidance on the preparation of national emissions inventories, may be of use in such estimations.

Emissions data collected by international organizations (such as the International Energy Agency (IEA), which provides information on CO$_2$ emissions from fuel combustion, or the European Commission/Netherlands Environment Assessment Agency EDGAR database (Emissions Database for Global Atmospheric Research)) might also help fill gaps, although possible methodological discrepancies between different data sources should be noted. These sources may be particularly relevant in constructing longer time series.

Key assumptions used in aggregating the emissions data should ideally be noted, for example emission factors used in the computation of CO$_2$ equivalents for non-CO$_2$ emissions. Guidance can again be found in relevant IPCC documents.

Historical socio-economic data—for example, on population, sectoral gross value added (GVA) and employment—can be sourced from both national accounts prepared by central statistics offices and/or central banks, supplemented with international data sources from organizations such as the International Monetary Fund (IMF) or the World Bank. These might be presented (as appropriate) in both national currency units as well as in US dollars. The exchange rate used in converting to US dollars should be identified.

### 1.3 Tools and Analytical Approaches

Information on the sectoral pattern of emissions (including international comparisons) and the socio-economic significance of these sectors can be compiled without the use of specialized tools or analytical approaches, and standard decomposition analysis can be added to provide additional insight and comparability.

One option for the presentation of the analysis of drivers of emissions is to provide a commentary of how patterns of development and technological change may have led to changes in emissions across sectors. For example, countries might explain how a rapid increase in emissions was due to expansion of particular industries such as mining or gas extraction, or where a reduction in emissions may be the result of a reduction in deforestation. This type of commentary could also highlight the emergence of new technologies across sectors, such as LED lighting or methane capture in agriculture. The role that historic commitments and policies have helped to shape emissions and the emergence of key technologies can also provide valuable context for stakeholders.

The advantage of this type of approach is that it is relatively straightforward and can quickly allow the reader to understand the most salient issues. However, the disadvantage is that the analysis may be either partial or subjective as it is difficult to rely solely on qualitative techniques to untangle the impact of a

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3 See also component 2 in section 3.
range of drivers within a complex economy. This approach does not provide a firm basis for the future development of pathways, described in subsequent components.

It is also possible to use analytical techniques to gain a more robust understanding of the key drivers of historical emission trends, either at the economy-wide or sectoral level. Understanding drivers of historical trends, along with changes over time and possible turning points in these drivers, can provide valuable information to inform future projections. Applying such standardized, quantitative analysis also allows direct comparison with emission drivers in other countries.

Tools that support such analysis include the Kaya Identity and the ASIF decomposition.

1.3.1 Kaya Identity
The Kaya Identity breaks down changes in emissions from energy use into changes in the following underlying drivers:

- population;
- GDP per capita;
- energy intensity of GDP; and
- carbon intensity of energy use.

Given its focus on emissions from energy use, its value will be greatest for countries where emissions from these sources are dominant. Key advantages of the Kaya Identity are its relative simplicity and direct comparability between countries.

However, the energy intensity of the GDP component in the Kaya Identity captures changes in both energy efficiency and in the structure of the economy (for example, the shift away from energy-intensive manufacturing towards a more service-based economy). The Kaya decomposition is therefore best accompanied by information about the rate of economic structural change.

Box 2 discusses analysis presented by the IEA using the Kaya Identity.

1.3.2 ASIF Decomposition
The Kaya Identity might be augmented to explicitly take account of changes in the structure of the economy using the Activity, Structure, Intensity and Fuel (ASIF) decomposition. The ASIF decomposition can account for changes in the following components:

- activity: economic activity, such as GDP growth (which can be further decomposed into population growth and per capita GDP growth);
- structure: structure of the economy, such as shares of industry and services;

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6 Details are found in appendix A. Note that the Kaya identity can be used only to decompose changes in emissions from energy use.
7 Details are provided in appendix A.
Box 2. Global CO₂ Emissions from Energy Examined Using the Kaya Identity

The IEA publication “CO₂ emissions from fuel combustion” uses the Kaya Identity to help explain global, regional and country-specific trends in CO₂ emissions from energy use. This analysis is presented at around five-yearly intervals from the 1970s, with annual data from 2009.

The results of the IEA’s global analysis are presented in figure B2.1. It shows that, globally, these emissions have grown by 50 per cent since 1990, driven largely by population growth and gross domestic product (GDP) per capita growth. Energy intensity improvements have led to a small reduction in emissions, while the CO₂ intensity of energy use has remained almost unchanged. Further analysis, for example using the ASIF framework, could shed light on changes in energy intensity of GDP.

Figure B2.1. Using the Kaya Identity on Global CO₂ Emissions from Energy Use Shows that the Emission Increases Have Been Driven by Growth in GDP per Capita and Population Growth


- **intensity**: energy intensity of the economy, capturing energy efficiency improvements; and
- **carbon content of fuel**: capturing the fuel mix, electrification rate and carbon content of electricity.

The historical analysis of these components might facilitate more granular or accurate projections of future emissions (based on projections of the ASIF components) than is possible from the Kaya Identity, although it requires somewhat greater analytical input.

1.4 Options for Dealing with Uncertainty

Given that this component addresses historical data, key uncertainties are likely to relate to the quality of the recorded data, rather than uncertainty over future developments.
An assessment of the quality of historical data might be based around four principles:

**Completeness** requires that all key sources of emissions are accounted for. This might be assessed by considering:
- Have all fuels been covered?
- Has CO₂ from non-energy combustion sources been analyzed?
- Have all GHGs, including non-CO₂ GHGs, been covered in the analysis?

**Comparability** requires that data can be compared between different groupings of emissions and that emissions have been appropriately allocated to different sectors. This might be considered by asking:
- Are the boundaries surrounding the allocation of emissions to different sectors clearly defined?

**Consistency** requires that the same methods have been used, where appropriate, to different groupings of emissions. This might be assessed by considering questions such as:
- Are all emissions being reported in the same unit?
- Have the same factors for assessing the CO₂ equivalence of different GHGs across different sectors been used and has this been reported?
- What sources are being used for calculating the emissions of different activities and are these choices robust and documented?
- Are the emissions in different sectors being presented over the same time frames?

**Accuracy** requires that assumptions about the calculation of emissions are valid and unlikely to be biased. This might be considered by addressing questions such as:
- What is the process for collating information on emissions? Do those providing information about emissions have an incentive to over- or understate emissions?
- In the event that sampling techniques and estimates are used (for example, for non-point sources of emissions), are these techniques robust?

### 1.5 Options for Presenting Outputs

There are a number of ways in which the data and analysis associated with this component might be presented.

Trends in emissions over time might be presented in tabulated and/or graphical form. These might also be scaled by variables such as population, GDP or other metrics. Tables and graphs can also help to describe the socio-economic significance of the different sectors of the economy. Where graphs are used, it will usually be desirable to also provide key data in tabular form or give key numbers in accompanying text.

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An accompanying narrative explaining the key drivers behind the patterns of emissions in terms of, for instance, economic growth, structural change in the economy, population increases and existing policy impact, can also be valuable. This narrative might also include a discussion of innovations, key actors and the environment in which key innovations have arisen. The narrative might also be supplemented with details from the statistical analyses exploring drivers of emissions change in more detail (Kaya decomposition, ASIF decomposition), at the national level and possibly for key sectors.

### 1.6 Summary Checklist

**Table 1. Summary Checklist for Component 1**

<table>
<thead>
<tr>
<th>Key questions to consider</th>
<th>Analytical techniques available and key observations where relevant</th>
<th>Key observations about techniques</th>
<th>Data options/sources</th>
<th>Output options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the breakdown of emissions by sector and over time?</td>
<td>Quantitative description of data and comparison with other relevant countries.</td>
<td>Historical emissions data may need to be checked for completeness, comparability, consistency and accuracy.</td>
<td>Emissions from national GHG inventories and international databases such as IEA, EDGAR.</td>
<td>Tabular/graphical presentation of trends with accompanying commentary and relevant comparisons</td>
</tr>
<tr>
<td>2. What is the socio-economic significance of those sectors?</td>
<td>Quantitative description of data taking account of variables such as employment, GDP, export earnings.</td>
<td>Can help in providing economic context for the evaluation of emission reduction opportunities, and the application of policy instruments.</td>
<td>National accounts data from central statistics offices, central banks or international organizations such as the IMF and World Bank.</td>
<td>Tabular/graphical presentation of trends with accompanying commentary.</td>
</tr>
<tr>
<td>3. What are the key drivers of the trends in emissions?</td>
<td>1. Qualitative assessment of drivers.</td>
<td>Can provide useful summary but risk of subjectivity and incompleteness in assessment. Does not particularly support future pathways development.</td>
<td>National accounts data to understand economic patterns; expert review of trends in particular sectors.</td>
<td>Commentary including tabular/graphical presentation of key drivers and statistical results where these are calculated.</td>
</tr>
<tr>
<td></td>
<td>2. Kaya decomposition</td>
<td>Simple, powerful tool but does not capture structural change. Only relevant for energy CO₂ emissions.</td>
<td>Emissions from national GHG inventories and international databases such as IEA, EDGAR.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. ASIF decomposition</td>
<td>More complicated than Kaya decomposition but accounts for structural change.</td>
<td>National accounts data from central statistics offices.</td>
<td></td>
</tr>
</tbody>
</table>
Component 2: Establishing Baseline Economic and Emission Pathways

This component considers the options that are available, and the issues that might be addressed, when undertaking and presenting analysis around the possible future emission pathways for the country, and individual sectors within the economy, in the absence of any additional policy effort. As noted in box 1, this checklist describes such pathways as “baseline pathways.”

2.1 Key Issues to Be Addressed

The key questions that the discussion in this component can help to address include the following:

- What are the key drivers for the future growth of emissions in a country?
- Taking account of these drivers, what are plausible pathways of economy-wide and sectoral emissions in the period to 2020, and to 2025 and 2030, without dedicated additional policy effort?
- What are the key uncertainties surrounding future economic activity and emissions and how might this be taken into account in devising baseline pathways?

A key consideration in producing and communicating baseline pathways is the extent to which existing and planned policies are factored into the analysis. On the one hand, a baseline that assumes the absence of any policies that dampen emissions growth would over-estimate baseline greenhouse gas (GHG) emissions growth in most countries, as policies that have this effect are typically already in place—for example, policy measures to improve energy efficiency or to minimize local pollution. On the other hand, factoring in the impact of existing or planned policies may require a wide range of further assumptions—in relation to both the policy settings in the longer term and on the impact that the policies will have on emissions—that may be difficult to substantiate.

The development of one or more baseline pathway therefore ideally requires a carefully designed conceptual basis and detailed explanation of the approach taken and assumptions made, in particular in relation to the extent to which, and how, existing or planned policies are factored into the analysis.

2.2 Tools and Analytical Approaches

A number of analytical approaches can derive future pathways of economic activity which, in turn can be used to derive pathways of future emissions. These vary in the level of sophistication and complexity and different approaches may be used in different sectors depending on data and resource availability, and taking into account the relative importance of different sectors.

2.2.1 Trend Extrapolation

The most basic approach would be a straightforward extrapolation of the existing trend. For instance, if gross domestic product (GDP) growth in the recent past has been 4 per cent per year, and the emissions intensity of the economy has reduced by an average of 1 percent per year, this approach would assume
continued growth at these rates. Multiplying extrapolated GDP in a given year by the extrapolated emissions intensity of the economy would give an extrapolation of emissions—in this case an increase in emissions of 3 per cent per year. However, the assumption that the economy will continue to grow at the same rate as in the recent past over the next 10–15 years is unlikely to be valid (due to changes in, for instance, population structure and productivity improvements). Similarly, assuming that the historical rate of change of emissions intensity of GDP would prevail in future, under baseline policy settings, is also likely to be inaccurate as the extent of structural and technological change as well as the impact of existing policies may change over time.

For many variables, trend extrapolation is therefore not the most appropriate tool and more suitable approaches exist. However, in some circumstances, notably where there are good reasons to expect little deviation in trends or where data limitations are acute, it may be a suitable approach. If baseline projections are produced sector by sector, it might be applied for some sectors where other approaches are not readily applied.

2.2.2 Augmented Extrapolation
Extrapolation can be augmented with an expectation of how GDP growth rates and/or the rate of change in carbon intensity of the economy might change in the future.

This evidence could be gathered either from the country in question or from appropriate comparators. For instance, as described below, planning projections may already incorporate expectations of future economic growth; while changes in economy-wide carbon intensity can be identified by looking at how this variable has changed as relevant economies have grown in the recent past. By capturing expectations in future changes in GDP and emissions intensity improvements (which might result either from structural or technological change or due to current policies), this approach is likely to give a more robust view of future emissions than the simple extrapolation approaches described above.

However, it still relies on assumptions that the economy will exhibit growth patterns similar to those observed historically. This may not be appropriate—especially in many developing and middle-income countries subject to rapid structural change. It also provides very little opportunity to identify where emission reduction opportunities might be found.

2.2.3 Decomposition Projection
This approach would draw on the results of the decomposition analyses described in component 1. These analyses explain the historical trends in emissions in terms of a small number of key drivers (population, economic growth, energy intensity, structural change). With these relationships established it would be possible to derive projections on how these drivers are expected to change in future and to use these to project an emission pathway.

The projections for future drivers could be obtained from sources external to the analysis (for instance, population, GDP or structural change expectations could come from domestic or international projections), while other variables (such as carbon intensity of energy use) might be assumed to change at the same rate as historically. By expanding the number of emission drivers, this approach is likely to
be more robust than the two options above. Nonetheless, it is still a top-down approach and so lacks a sector-by-sector examination that might reveal why future trends in emissions may differ significantly from those observed historically. It is also of limited use in identifying where there may be emission reduction opportunities.

2.2.4 Detailed Bottom-Up Analysis
A fourth analytical approach would be to undertake a detailed bottom-up analysis of emission drivers and then emissions. This approach could be applied either to the economy as a whole or to one of a series of emissions-intensive sectors to help inform and provide more detail to support any of the analyses described above. It would involve a number of steps, as shown in figure 3 and described further below.

2.2.4.1 National Economic Projections
This approach starts with a projection of future national-level economic activity. These projections might be developed in a way that is consistent with the overall expected development pathway of the economy and the policies in place to deliver that: for example, if a country has expressed ambitions to

![Figure 3. A Four-Stage Process Might be Used to Generate a Detailed Bottom-Up Analysis of Emission Drivers and Emissions](image)

Note: As discussed below, some sectors and sub-sectors, notably forestry and land-use change, demand a slightly different approach.
reach upper-middle-income status by a certain date, the projections should be consistent with this. More specifically, these projections should incorporate expectations of:

- population growth and planned/expected rates of urbanization;
- labor force participation;
- structural composition of the economy;
- investment; and
- productivity growth.

Countries may consider whether they have this information already available as part of existing national planning activities. Alternative tools that can be used to help develop such projections include long-term integrated planning tools and are available from commercial sources.

As part of this analysis, analysts may consider placing their country’s development within broader global trends. For instance, global resource prices, global growth and trade, developments in energy and industrial technologies and the extent of climate ambition by other countries could all have a material impact on the future development prospects of the economy. Countries can draw on projections of these variables from international organizations such as the IEA or the International Monetary Fund (IMF).

### 2.2.4.2 Sector, Sub-Sector and Activity-Level Projections

The aggregate economic activity projections can then be used to generate sector, sub-sector and activity-level projections that are consistent with the overall development pathway for the economy. This provides a detailed understanding of the demands or needs of the economy which might then be fulfilled in either an emissions-intensive or low-emissions fashion.

The appropriate level of disaggregation of economic activity will depend on both country circumstances and the extent to which there are structural differences in drivers of emissions in each sector, but might include the following:

- In the energy sector, projections of prices and demand for different energy carriers (electricity, heat, and solid, liquid and gaseous fuels), taking into account the future growth of different sectors of the economy and factoring in, where appropriate, expected rates of change in energy efficiency and changes in energy-conversion technologies.

- In transport, a split into different modes of transport—for example, rail road and air—and then further differentiated by type, such as motorcycles, diesel vehicles, petrol vehicles and natural gas vehicles, taking into account expected income growth and how this may translate into demand for travel for different purposes (leisure, work), and factoring in, where appropriate, expected changes in fuel efficiency.

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1 The activity level/emission factor approach is not relevant in relation to forestry and land-use change emissions and so this sector is not listed here. A separate discussion on these emissions is provided below.
• In **agriculture**, disaggregation to the level of different agriculture practices will likely be required—for example, cattle farming, rice production and fertilizer use in broad-acre farming—taking into account expected household income growth and associated changes in dietary patterns.

• **Industrial process** activity projections may be required at the level of the sector responsible for the emissions, for example, chemicals and cement manufacture or coal-mining.

• In the **waste** sector, estimates of the overall volume of waste and different waste disposal methods (for example, solid waste disposal and incineration) will be required, based on economic growth, population growth and likely waste diversion rates.

Different methods exist to produce activity projections in different sectors, and typically existing projections would be used to construct baseline pathways. There are also tools and techniques available from international organizations such as the World Bank's Transport Activity Measurement Toolkit (TAMT) in the transport sector. To facilitate discussion within and outside each country, it will typically be useful to indicate what projections have been used and where they derive from—for example whether produced by government, industry associations or independent agencies. It may be helpful to consider the consistency between different projections if compiled from a range of sources.

In addition, as with the national projections, these sectoral, sub-sector and activity-level projections are likely to be influenced by international developments and market interactions. For example, levels of agricultural production may depend on global patterns of trade and consumption of different agricultural commodities, or the level of coal-mining activity will depend on the ambition of emission reduction activities in other countries. It will therefore be important for consistent assumptions on this global context to be incorporated into these drivers.

### 2.2.4.3 Energy Intensity and Emissions Factors

With baseline expectations of future economic activity developed, energy intensity and emission factors can be applied to these activity-level estimates to derive emission projections.

The projections should ideally take into account expected changes over time in emissions factors, including the continued impact of existing policies as described further below. It could also be valuable to consider international trends that might influence emission factors—for example, global trends in renewable energy costs which, if declining, could lead to increased penetration of renewable energy technologies, even in the baseline pathway.

In some sectors more detailed sectoral modeling can be used to assess how emission factors might change, especially in response to existing policy drivers. MARKAL modeling tools, described in more detail in component 3 (see section 4), may be particularly useful in relation to future emissions factors in the energy sector.

### 2.2.4.4 Summation

By multiplying activity levels with emission factors at the activity level, and aggregating across activities, a sectoral-level depiction of future emissions can be generated. Summing across different sectors allows an aggregate economy-wide assessment of possible future emissions to be established.
2.2.4.5 Approach for LULUCF Emissions

Projections of emissions from the land use, land-use change and forestry (LULUCF) sector may demand a slightly different approach. In these cases, the most appropriate starting point is likely to be a quantitative examination of historical trends as well as a qualitative assessment of the drivers of those trends. An assessment can then be made of whether the drivers of emissions in this sector are likely to lead to an increase or decrease in emissions, or indeed negative net emissions if sequestration outweighs gross emissions. This can draw on the economic analysis identified above to identify some of the key drivers for forestry, agriculture and livestock production such as food demand, likely future trade patterns, along with information about the effect of existing policy settings and biophysical conditions (influencing yield projections). Example key questions to address might be what types and magnitude of agricultural production are expected in the future, to what extent agricultural intensification is expected, how much land may be needed to be converted from forests to agricultural land, and how much land of different type and quality is available for reforestation. These types of qualitative and quantitative assessment will normally rely on national models and databases, and can also be informed by modeling analysis making use of tools such as the World Bank’s land use, land-use change and forestry module or IIASA’s GLOBIOM model\(^2\) as well as remote sensing data.

2.2.5 Analysis of the Effect of Existing Policies and Policy Interactions

As described in the introduction to this section, the development of baseline pathways often take into account the impact of existing and committed or planned policies. This can make such baselines distinct from a “no policy” scenario, as is sometimes used in economic analysis, for example as a counterfactual scenario in CGE modeling.

Taking into account existing and planned policies helps identify the effect of policy effort already under way, and is often important in avoiding over-estimating emissions growth in the baseline pathway. It is also possible that existing policies will inflate emissions growth compared with the absence of policy—for example, where there are fossil fuel subsidies. Including such emissions-increasing policies in the baseline facilitates subsequent analysis of the effect of adjusting or removing these policies to achieve a reduction in emissions or emissions growth.

Countries may find it helpful to begin by identifying the key planned and expected policies influencing activity levels across the different sectors in order to integrate them into their projections. A taxonomy that may be helpful is outlined in table 2.

Policy mapping tools may be used to generate a visual mapping of a policy landscape. These tools aim to provide a holistic perspective of the key policies affecting an outcome variable and the interactions between them.

Once the policies are understood, there are two broad options that countries might take to incorporate them into the analysis. Under either option, it may be necessary to make assumptions about future policy settings and their effects (see also box 3). For example, a subsidy scheme may be in place with an end date  

\(^2\)http://www.globiom.org.
Table 2. A Taxonomy for Considering Existing Policy Instruments That May Affect Baseline Emission Pathways

<table>
<thead>
<tr>
<th>Classification</th>
<th>Example policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic instruments</td>
<td>Instruments of price and quantity controls, including carbon-pricing instruments, tradable certificates, minimum prices, market reforms</td>
</tr>
<tr>
<td>Fiscal instruments</td>
<td>Subsidies and public infrastructure expenditures, special loans, tax deductions, public procurement and investments; also subsidies for activities that increase emissions, for example fossil fuel and fertilizer subsidies</td>
</tr>
<tr>
<td>Voluntary instruments</td>
<td>Voluntary and/or negotiated agreements between industries and governments, agreements among industries and/or enterprises</td>
</tr>
<tr>
<td>Regulation</td>
<td>Legal obligations and standards, technology or product bans or limitations, technical standards, and specifications</td>
</tr>
<tr>
<td>Information</td>
<td>Information, motivation, and technical assistance, reporting obligations, other measures to reduce structural barriers</td>
</tr>
<tr>
<td>Education</td>
<td>Framing and supporting education and training</td>
</tr>
<tr>
<td>Research, development and deployment</td>
<td>Public support of research, development and deployment (RD&amp;D), basic and applied research, support of demonstration projects, lead-market development</td>
</tr>
<tr>
<td>Others</td>
<td>Indicative targets, planning, removal of barriers, etc.</td>
</tr>
</tbody>
</table>

Box 3. The Baseline Pathway (Reference Case Scenario) for the EU’s 2030 Analysis

The European Commission’s 2030 impact assessment used a suite of modeling tools to identify the likely emissions without further policy intervention. This was necessary given the range of existing policies that needed to be taken into account. In modeling these policies, it was necessary to make assumptions about how these policies might evolve. Key aspects included:

- the continued provision of a carbon price through the EU ETS (where the cap was assumed to tighten at the same rate as it had in the period 2013–20);
- an assumption that subsidies for renewables would persist but decline after 2020;
- energy efficiency targets relating to existing energy efficiency policies would be met and maintained.

For consistency, the modeling assumed that other countries would meet their Copenhagen Accord commitments but not achieve further emission reductions. It adopted fossil fuel pricing assumptions considered consistent with this assumption.

The resulting analysis showed that, without additional policy effort, EU emissions (excluding land use, land-use change and forestry) would be 24 per cent below 1990 levels in 2020, 32 per cent in 2030 and 44 per cent in 2050. Thus the pre-existing policy effort, together with underlying trends, is expected to take the EU part of the way to its 2050 emissions goal of an 80 per cent reduction compared with the 1990 baseline.
before the end of the projection period, or regulations for energy efficiency may increase in stringency over time, but for which parameters have not yet been decided for the projection period. In such cases, assumptions made will usually be labeled as technical assumptions that do not imply that governments presume specific future policy settings.

The first option, most appropriate when the existing policy landscape is comparatively simple, is to incorporate existing policies within some of the steps reported above. Most notably, in the detailed bottom-up analysis, the impact of existing policies could be considered in two places: they may influence the split between different types of activity (for example, policies encouraging transport modal shift may lead to a reduction in the expected demand for car travel); and they may alter the emission factors applied to any activity driver projection (for example, fuel efficiency standards might reduce emissions per vehicle-kilometer travelled). Existing policies can also affect relative costs between low carbon opportunities and their carbon intensive alternatives, and therefore change the patterns of investment decisions over time (for example renewable support schemes can shift some investments away from fossil-fuel generation that would not occur if historical trends were simply extrapolated).

In the more aggregate assessments (in other words, approaches 1–3 above) this analysis could be used to inform either the expected future emissions intensity of the economy (approaches 1 and 2) or the expected future pathway of key emissions drivers such as emissions intensity of energy use (approach 3). However, even in these more aggregate assessments it will generally be desirable to identify the assumed effects of the policies, along with uncertainties about these effects, where this information is available.

Under this option, it will also be valuable to consider the impact of policy interactions. Sometimes a suite of policies will have different impacts compared with the sum of the impact undertaken in isolation. For example, energy efficiency awareness may be more effective if energy prices are also anticipated to rise; on the other hand, feed-in tariffs for low-carbon electricity supply are likely to have little or no impact on aggregate emissions where an emissions trading scheme (ETS) exists (or is planned) with a fixed cap on overall emissions. Combining policy mapping tools with existing experience and literature can help to identify these types of interactions. Extensive research and guidance exists on the question of policy interaction. Quantitative simulations of interactions between different policies can be most realistically done with the financial models of specific markets or bottom-up marginal cost curves but designed consistently from financial perspective.

The alternative option, more appropriate when the existing policy landscape is more complicated, is to use a number of the tools and analytical approaches described in component 3, making “reasonable”

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assumptions about how current policies may persist into the future. This was the approach used, for instance, by the European Commission when developing the baseline pathway for its 2030 emissions analysis, as described in box 3. If these modeling tools are well specified and calibrated then concerns over policy interaction should already be incorporated.

Sometimes choices need to be made as to which existing policies are included in the baseline, and which are part of the emission reduction scenarios. For example there may be policies that are approved and legally binding, but not yet fully implemented. Other example included policies that envisage future changes in the level of stringency (e.g. tightening of energy performance standards, lowering emission caps or increasing rate of emission taxes). There is no one universal rule where to draw a line between baseline and emission reduction scenarios, but it is useful to make these choices transparent and justified in the INDCs.

2.3 Sources of Data

All except the most basic analytical approach outlined above rely on some forward projections of national economic activity. National economic projections at the aggregate, sectoral and sub-sectoral level are sometimes already available from domestic sources such as central banks, departments of finance and planning departments. On occasion, further disaggregation of this data may be needed to drill down to activity levels to which it is meaningful to apply emissions factors. The precise data required for this analysis will depend on the sector but will typically include estimates of how consumer and firm behavior and demand will change as income levels rise (which may be derived from existing econometric analyses in the country in question or from analyses from comparable countries).

The bottom-up approach outlined above identified the value of embedding national, sectoral, sub-sectoral and even activity-level projections in a regional and global economic context. Some of the most useful sources for such analysis include:

- IMF/World Bank global projections—including, for instance, World Bank projections on commodity markets5;
- IEA projections for energy demand and supply and CO₂ emissions and their market and policy drivers, as in the World Energy Outlook, for example6;
- OECD long-term scenarios to 20607;
- projections from other governments—for instance, the US Department of Agriculture provides estimates of GDP, population, real exchange rates, and other variables for 190 countries and 34 regions,8 as well as demand and price forecasts for major agricultural commodities.9

7 http://www.oecd.org/eco/outlook/lookingto2060.htm#WKP.
The analytical approaches outlined above would assess emissions intensities in different ways. The more basic approaches would rely on national emissions intensities that could be calculated based on information already collected through national GHG emission inventories or international organizations such as the IEA (for emissions from energy use), World Resources Institute\textsuperscript{10} or EDGAR.\textsuperscript{11}

The bottom-up approach relies on emissions factors at the activity level that can be substantially informed by the compendium of work compiled by the IPCC. The Emissions Factors Database (EFDB)\textsuperscript{12} may be a particularly useful source of information. Typically, this will need to be augmented with nationally specific data, although this can often be calculated directly from the information already collected with national GHG inventories.

Importantly, the expected future trends in emission factors given the current policy mix can also be taken into account in the bottom-up approach. This might be achieved by analyzing the recent changes in emission factors as well as an (appropriate) international comparison of them. Information from international sources such as the IEA’s Energy Technology Perspectives, as well as specific technology roadmaps, might also help inform the plausible future pathway of emission factors.

2.4 Dealing with Uncertainty

Generating economic projections of emissions to 2030 and possibly beyond is profoundly uncertain. Therefore, there can be significant value in generating a range of pathways for future economic activity and emissions levels. This can take the form of illustrative alternative scenarios that result in lower or higher emission trajectories, using a plausible range of alternative parameters.

This can help stakeholders, both domestic and external, understand the key influences on possible future emissions within a country, and ideally gain a sense of a plausible range of emissions outcomes. This in turn can help to place projected emission reduction pathways in context.

A series of questions can help guide the development and/or interpretation of these different pathways:

- Are there coherent “narratives” behind the different national pathways and are the assumptions underpinning these pathways consistent with their narratives? The provision of a narrative can often make the interpretation of the pathways easier and provide a sense-check that might lead to the elimination of inappropriate pathways. In the simple approaches, the pathways might simply differ according to GDP growth and/or degree of improvements in emissions intensity. In the more detailed approaches narratives may flow through all of the assumptions: for instance, a low-growth pathway might be associated with slower structural change from agriculture to manufacturing and less demand for new power capacity.

\textsuperscript{10}http://www.wri.org/resources/data-sets/cait-country-greenhouse-gas-emissions-data.
\textsuperscript{11}http://edgar.jrc.ec.europa.eu.
\textsuperscript{12}http://www.ipcc-nggip.iges.or.jp/EFDB/main.php.
• Are assumptions on global factors coherent with national developments and narratives? For instance, countries highly reliant on exports of natural resources might tie their different national pathways to corresponding pathways for worldwide economic activity. Similarly, the extent of mitigation action being undertaken globally could have a significant impact on the terms of trade for countries depending on their existing economic structure and comparative advantage. If there are certain scenarios where there appears to be an inconsistency between national and international data points then this might point to the need for further refinement, or elimination, of such scenarios.

• Are assumptions on global factors coherent with the assessment of supranational organizations and other countries? Coherence with external projections can add credibility to the analysis as well as point to additional pathways to investigate—for example, under lower growth or higher resource prices.

• Is it clear what impact these pathways have on the overall expected level of emissions and what are the key drivers of these results? Understanding the expected sensitivity of emissions to key economic variables can significantly aid interpretation of emission pathways.

• Are the interactions between and within current and planned policies incorporated, both as enhancing or diminishing their impacts? Certain policy combinations can create benefits larger or smaller than the sum of their parts, and understanding the interactions—also under different assumptions—can lead to a more sophisticated emission pathway.

As well as generating different scenarios (where multiple input variables change between scenarios), countries may also wish to undertake sensitivity analysis. This considers the effect of varying a single input and estimating its impact on the baseline pathway, such as the impact on emissions of higher or lower economic growth. This can be valuable in understanding the key drivers of emissions and hence useful in considering which variables might be tracked in order to monitor and update emission pathways (see component 4 in section 5). This can be facilitated by using Monte Carlo analysis—where key input variables are assumed to take a random distribution and repeated sampling from that distribution is used to examine how sensitive the output may be to fluctuations in the input.

2.5 Output Data Reported

There are a number of ways of presenting the results derived from the baseline analysis:

• in terms of emissions or in terms of some variable linked to emissions (for example, renewable energy capacity);

• and, in the case of emissions, whether it is expressed in absolute terms or relative to some other unit (per capita, per unit of GDP);

• for the entire economy or for certain key sub-sectors of the economy, such as the energy sector;

• for all GHG emissions or only for certain key gases (most notably CO₂);

• on an annual basis or at less frequent intervals, such as every five years.

It is also valuable to report the key economic assumptions associated with the derivation of the baseline (depending on the analytical approach used), alternative scenarios, and also the results of any sensitivity analysis (as described in dealing with uncertainty section).
### 2.6 Summary Checklist for Component 2

**Table 3. Summary Checklist for Component 2**

<table>
<thead>
<tr>
<th>Questions to consider</th>
<th>Analytical techniques available</th>
<th>Key observations about techniques</th>
<th>Data options/sources</th>
<th>Output options</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the key drivers for the future growth of emissions? What are plausible pathways of economy-wide and sectoral emissions?</td>
<td>Trend extrapolation—economic growth rate and trends in emission intensity assumed to continue as in the recent past and multiplied together.</td>
<td>Simplistic. Likely to be appropriate only when good reason to think little structural change in economy over next 10–15 years.</td>
<td>Historical trends in economic growth from national or international organizations. Emissions from national GHG inventory or international databases.</td>
<td>Regardless of approach taken, there are a number of output presentation options: emissions or variable linked to emissions nationwide or sectoral CO₂ or all GHGs annual or less frequently. Possible to report underlying economic analysis supporting emission projections. Possible to report the role a current or planned carbon price plays. Possible to report different baseline pathways, possibly constructed around coherent narratives of potential future development pathways.</td>
</tr>
<tr>
<td></td>
<td>Augmented trend extrapolation—as above but adjusted to take account of expectations of future economic growth and changes in emissions intensity.</td>
<td>Preferable to trend extrapolation but still subject to significant error. Does not identify where emission reduction options are available.</td>
<td>Projections of economic growth. Historical relationship between growth and emissions.</td>
<td></td>
</tr>
<tr>
<td>Use of decomposition analysis—combine historical analysis of emission drivers with forward-looking projections for these drivers.</td>
<td>Likely to provide more accurate projections than (augmented) trend extrapolation, but will not help identify where future emission reduction options are.</td>
<td>Decomposition analysis as in component 1 Future trends of drivers either from national accounts and plans or international sources.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom-up assessment. Identify sector, sub-sector and activity drivers to generate activity projections and apply emission factors. Draw on policy mapping techniques (as appropriate) to map impact of current/planned policies.</td>
<td>Requires high levels of information about possible future activities in the economy. Likely to generate the most accurate results. Can be done for only some sectors, to help augment economy-wide analysis as under techniques 1–3.</td>
<td>National planning exercises for sector and sub-sector. Tailored nationally specific information for activity-level projections. IPCC can provide emission factor information augmented by international comparison or modeling analyses (for example, MARKAL model). Can also be informed by global/regional projections as provided by OECD, IMF, USDA, etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis of effects of existing policies including policy interactions based on quantitative and qualitative analysis in sectors where policies are in place.</td>
<td>Useful to identify effects of policies already under way and to avoid over-estimation. Can inform the analysis in any of the approaches under techniques 2–4.</td>
<td>National stock-takes of policies and any associated policy appraisals or impact assessment. Publications by international organizations to help explore policy interactions.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: Vivid Economics.*
Component 3: Constructing Alternative Emission Pathways

3.1 Key Questions that This Component Addresses

The objective of this component is to highlight the options available to identify, analyze and present deviations in emissions relative to the baseline established in component 2. In particular, it seeks to provide guidance and options in relation to the following questions:

- What emission reduction opportunities are available in the country as a whole and/or within a particular sector, and what might be the costs and benefits of realizing these emission reduction opportunities?
- How might different packages of emission reduction opportunities be combined to establish one or more alternative emission pathways?
- What sectoral and economy-wide policies, including carbon pricing, might be considered appropriate as a means of reducing emissions relative to the baseline?
- What might be the economic and social impact of different policies?
- How can issues of policy interaction be explored to ensure that the ultimate policy suite is coherent?

3.2 Tools and Analytical Approaches

There are three broad approaches (subcomponents) that countries might take in relation to the development of alternative emission pathways.

A. Countries may identify the technical emission reduction opportunities—in other words, technologies or practices that allow for a reduction in emissions such as improvements in vehicle fuel efficiency or greater penetration of renewable power generation—that are available within the country along with the cost and investment needs of these opportunities. These can then be filtered and aggregated to develop one or more packages of emission mitigation.

B. Countries may identify one or a series of policy options, such as fossil fuel subsidy removal or a carbon price, that they wish to pursue and, as desired, undertake technical analysis to better understand its/their possible costs and impacts.

C. Countries may choose to combine subcomponents A and B, iterating between the two types of analysis so as to develop an understanding of both the emission reduction opportunities that the country might pursue and the policies that will deliver these opportunities (see figure 5).

Crucially, these three approaches highlight the difference between a technical emission reduction opportunity (the focus of subcomponent A) and a policy measure (the focus in subcomponent B), as shown in figure 4. A technical emission reduction opportunity is a (change in) activity or behavior that can lead to a reduction in emissions, whereas a policy is an effort by a public body to bring about a change of behavior by individuals, firms or the public sector to realize some or all of the technical emission reduction opportunity. For example, a technical emission reduction opportunity identified
in subcomponent A might involve generating 50 GW of wind power capacity, while different policies that might be considered in subcomponent B might include carbon prices, feed-in tariffs or command and control instruments. The approach under subcomponent C would be to confirm whether there was an alignment between the technical emission reduction opportunities and a particular suite of policies.
Another useful distinction is between policy objectives and policy instruments. The former represent the aspiration about the result, while latter are the measures that are needed to deliver this result. For example, certain penetration targets and the levels of energy performance standards for buildings or installations represent policy objectives, although involves specific instrument design. Nonetheless, implementation of these standards will require additional policy instruments, such as penalties for non-compliance embedded in the building codes and permitting regulations as well as fiscal incentives that would encourage investments in advanced thermal insulation of buildings.

The choice between these subcomponents will depend on individual country circumstances. Technical mitigation option analysis (subcomponent A) will often be a natural starting point for many countries. By identifying a range of opportunities, and drawing on a range of evidence to identify those opportunities—including, for instance, country-specific technology roadmaps—it is an approach that can give confidence that any targets are likely to be practical and achievable in a given country context. It may also be a sensible approach where emission reduction opportunities are within the direct influence of government and so policies to incentivize the private sector are less important.

In contrast, some countries may wish to pursue a policy-led approach (subcomponent B). This may be particularly attractive when an aspirational (political) target exists and there is a desire to determine whether this target is feasible and the best way to achieve it. It may also be optimal when changing private sector behavior is expected to be very important, or where countries have already undertaken technical analysis of emission reduction opportunities and mapped the already ongoing or planned activities with mitigation potential in the country.

An iterative approach of technical analysis and policy assessment, subcomponent C (see figure 5), will provide the richest insights and provide the most robust analysis. Best practice would suggest that this iterative approach is desirable to the extent that it is feasible in practice, recognizing that it is also the most data-intensive and time-consuming. Box 4 describes how Colombia is adopting an approach that combines both analysis of emission reduction opportunities and the policies that can deliver them.

Some of the specific tools that may be used within each of the three subcomponents are presented below.

3.2.1 Subcomponent A: Analysis of Emission Reduction Opportunities

There are three broad categories of approach that countries may take to identify and evaluate emission reduction opportunities:

- optimization models;
- bottom-up assessments; and
- top-down modeling (CGE modeling).

Summary information for each approach is provided below, with further detail—including the advantages and disadvantages of different approaches and when they may be most appropriately used—provided in appendix B. In addition, countries may wish to consider how to combine results from different approaches (and how this analysis can be presented), as well as how to move from the technical assessment of emission reduction opportunities to one or more packages of emission reduction opportunities.
3.2.1.1 Optimization Models

Optimization models are most prevalent in the energy sector. The most salient examples are models such as MARKAL or TIMES, which have been developed by the IEA Energy Technology Systems Analysis Program. These models determine how a country can meet its energy demand in the least-cost fashion over a certain time horizon, while incorporating country- or policy-specific constraints. The key outputs these models provide are:

- energy flows in the economy and by sector;
- energy commodity prices;
- greenhouse gas (GHG) emissions;
- capacity and shares of different technologies delivering energy to sectors;
- energy costs;
- investment needs (and hence financing requirements);
- marginal emission abatement costs; and
- the pace at which the energy system can reduce emissions and how.

Modeling tools that can serve the same purpose also exist for other sectors, although many of these have thus far been developed with a focus on developed countries.\(^1\)

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Box 4. Over the Course of a Number of Years, Colombia Is Adopting an Approach which Combines both Analysis of Emission Reduction Opportunities with Policies That Might Realize These Opportunities

Colombia is in the process of developing Sectoral Mitigation Action Plans (SMAPs). These will consist of both prioritized mitigation options by sector and the policies, plans and measures that will allow this abatement to be achieved.

The sectoral mitigation analysis involved using sectoral models to identify mitigation options in each of the key sectors of the economy (agriculture, electricity, coal, oil and gas; transport; residential; industry and waste). These have then been prioritized taking account of the size and cost of the different opportunities, as well as the co-benefits they could bring, and with the explicit engagement of different ministries.

With PMR support, the role of different policy instruments in delivering different emission reduction opportunities is now being explored. This includes an examination of the possible role carbon prices might play, using a CGE model.

The intention is that the fully specified SMAPs will include both prioritized mitigation opportunities and a suite of policies that will facilitate their attainment.

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\(^1\) For example, the PARIS-TREMOVE model used by the EU for generating emissions projections and identifying abatement opportunities from the transport sector, or the Forestry and Agricultural Sector Optimization Model—Greenhouse Gas Version (FASOM-GHG), which assesses the land allocation of competing activities in forestry and agriculture based on public policy as well as environmental changes in the US.
3.2.1.2 Bottom-Up Modeling

A complementary or alternative approach is bottom-up engineering analysis to identify the emission reduction opportunities available in different sectors, including the public sector. This involves gathering data about specific technical opportunities to reduce emissions, such as shifting from coal- to gas-fired electricity, replacing industrial boilers or motors, replacing road with rail transport, moving to species of trees in plantations that store greater levels of carbon, etc. The difference in the life-cycle costs between a particular emission reduction opportunity and its most likely alternative can be computed and expressed on a per tonne of CO₂ basis, along with an estimate of the magnitude of emission reduction resulting from that opportunity. Supplementary information on the investment and financing needs associated with these opportunities can also be collected. Assessments may either be focused on particular sectors of interest or at an economy-wide level.

Typically these assessments are based on an expert-driven process of identification and prioritization of low-carbon opportunities, taking into account the current pattern of emissions. Existing technology roadmaps and sector development plans—highlighting sector-specific technology opportunities—can provide valuable information. In addition, there are also diagnostic tools that could this process more systematic. For instance, the World Bank’s TRACE tool—which covers six municipal sectors: passenger transport, municipal buildings, water and waste water, public lighting, solid waste, and power and heat—including modules that compare performance indicators among peer cities and that identify which sectors that offer the greatest potential with respect to energy cost savings. Evidence from existing mitigation activities, including Nationally Appropriate Mitigation Actions (NAMAs), may also be valuable.

There are a number of issues to consider when undertaking and presenting such bottom-up analyses:

- What is the alternative to each emission reduction opportunity?
- How have the future costs of both the emission reduction opportunity and the alternative been calculated? Best practice typically emphasizes the benefits of analyzing and presenting ranges of potential costs rather than using a single point estimate.
- What discount rate has been used in relation to the future costs and benefits of a particular emission reduction opportunity? Analysis focusing on which emission reduction opportunities a country might pursue would be expected to use a social discount rate, which is lower than that used when undertaking analysis to determine what emission reduction opportunity the private sector might adopt (see further below).
- Does the assessment of possible penetration of the technology take into account the maximum potential take-up, or has it been adjusted downwards to take account of what is considered to be the “achievable” potential (given, for instance, consumer inertia on adopting new technologies)?
- How and to what extent have institutional barriers, transaction costs and non-monetary costs been taken into account in the cost estimate? (These can be particularly important in relation to energy efficiency emission reduction opportunities, for example.)
- Whether and to what extent quantifiable (but non-monetizable) benefits are taken into account in the cost estimate? Many emission reduction opportunities generate benefits other than reduced emissions—for instance, public transport schemes might reduce air pollution or congestion. It is possible for these to be treated as offsetting the costs of the emission reduction opportunity.
There are two key graphical techniques that might be used to present this type of bottom-up analysis, illustrated in figure 6.

- **Economic marginal abatement cost curve (MACC).** This presents emission reduction potentials in one dimension and unit cost of energy saving/emission reduction in the other dimension at a particular point in time. This can be a powerful and effective tool for presenting key information.

- **Wedge curve.** This extends MACC presentations by explicitly capturing emission reduction potential over time as a result of different abatement opportunities. This type of presentation can be helpful in illustrating emission reduction opportunities that may represent a relatively small and/or costly amount of abatement at a particular point in time (as might be observed on a MACC) but which are fundamental to achieving low-cost emission reductions over the longer term.

### 3.2.1.3 Top-Down (CGE) Modeling

Economy-wide modeling, typically using CGE models, can also be used to identify abatement potential and costs. CGE models set up a coherent economy-wide framework and allow economic decision-making to be the outcome of decentralized optimization by producers and consumers. They simulate the functioning of a market economy, including markets for commodities, labor for capital, and impact on macroeconomic variables including GDP, gross national income (GNI), investment, trade, terms of trade and so forth.

Where both top-down (CGE) and bottom-up modeling techniques are used, the results from bottom-up analyses can be used to calibrate the parameters in top-down models, which can then be used for economy-wide assessments, taking into account interactions between different sectors and policies. By linking bottom-up (and/or optimization) models to top-down models in this way, the best aspects of each modeling approach can be combined.
3.2.1.4 Combining Results from Different Modeling Approaches
As illustrated above, a range of approaches can be used to identify abatement opportunities and costs. Comparing the results across these approaches will enable an assessment of their consistency. Key questions that can be usefully considered in such an exercise include:

- Do different types of analysis point to broadly the same mitigation opportunities?
- To the extent that they do not, what are the reasons for these differences? Are these reasons driven by fundamental differences in the modeling structure or because they use different assumptions on values that are uncertain (for example, the future costs of different emission reduction opportunities)?
- Have opportunities to use the results from one type of analysis to inform the assumptions of other modeling approaches been exploited?
- Is there further research that can be undertaken that would help to narrow the differences between the results and that could provide a stronger understanding of the scope for future emission reductions?

3.2.1.5 Construction of Different Pathways
An understanding of the emission reduction opportunities available in different sectors of the economy can be used to build up a series of pathways to assess future emission reduction potential. In developing these pathways it is important to note that while the technical analysis (using the approaches described above) will provide valuable evidence to inform one or more pathways, a wider range of issues, often involving political judgment, will also need to be considered.

A typical approach to deriving such pathways would be to use qualitative multi-criteria analysis to judge the desirability of different emission reduction opportunities. The (qualitative) scores achieved by the different emission reduction options can inform the selection of one or more packages, with packages varying according to emission reduction ambition among other factors. This approach can be facilitated by the development of a template where consistent information is collected about each emission reduction opportunity, for example, expected mitigation, cost, likely co-benefits, possible barriers. An example of how Costa Rica intends to use such a template in order to help compare different opportunities and hence construct pathways is provided in box 5 below.

Where this type of approach is taken, some of the key questions that may be considered include:

- What are the criteria that have been used to judge the desirability of different emission reduction opportunities? As well as the quantity and cost of emission reduction, other important factors may include:
  - impact on vulnerable members of society (for example, measures such as energy efficiency which both reduce emissions and promote energy security among vulnerable households may be particularly favored);
  - consistency with other macroeconomic or development objectives (for example, the development of bioenergy may be tempered if there are concerns that this would jeopardize food security, while the development of clean cookstoves may be advantageous in both reducing
emissions and improving health outcomes, while afforestation may both reduce emissions and have adaptation co-benefits);

- political feasibility (for example, some industrial sector emission reduction opportunities may be considered too politically difficult to introduce unless there is a degree of coordination with other countries that have similar opportunities);

- administrative ease of introduction (for example, some emission reduction opportunities may be within the remit of state or regional governments with priorities that differ from those of national government).

• Have the dynamic impacts of different emission reduction opportunities been taken into account? As discussed above, a “naïve” interpretation of bottom-up analysis may lead to emission reduction opportunities that are high-cost at a particular point in time being ignored, even though they are crucial in achieving longer-term emission reductions.

• Is it valuable to create (and present) more than one package of emission reduction opportunities? While this will entail additional resources, it can help in identifying how costs (or other key parameters of interest) might change at differing levels of ambition. It can also help in identifying some of the key constraints—for instance, technology costs, action by other countries, resistance toward governance reform—that could allow a more ambitious package to be implemented.

• Is there a role for a narrative to support the alternative emission pathways? In many cases a broader narrative discussion can provide credibility to the pathway by explaining how it is consistent with both the broader development goals of the country and its existing skills base and comparative advantage.
3.2.2 Subcomponent B: Policy-Based Approach

In subcomponent B, countries identify key policies, including carbon pricing and, taking account of their expected impact, develop one or a series of alternative emission reduction pathways. Figure 7 identifies one way in which this approach might be developed.

When considering a policy-based approach, it can be helpful to distinguish a policy measure from a policy goal: the policy measure being the precise way in which a stated policy goal is expected to be achieved. For example, policymakers might decide that a policy goal would be to improve energy efficiency by a certain percentage or to attain a certain proportion of renewable power production. There are then a host of policy options (energy efficiency standards, feed-in tariffs, carbon prices) that can be used in isolation or in combination in order to reach a given policy goal.

Figure 7. The Identification of Policy Options Is Based on Feedback between Steps 1 and 3

3.2.2.1 Step 1: Identification of Possible Policy Measures

There is a broad range of policy measures that can help to achieve emission reduction pathways. Some of the key options are outlined in box 6.

Before undertaking detailed analysis, and as a first step, countries may wish to identify qualitatively why and how particular policy measures are more or less appropriate for their context. There are a number of factors—economic, social and political—that countries may wish to consider when undertaking this type of analysis.

Effectiveness at Addressing Market Failures. There is a wealth of evidence on when and where different policy measures may be most appropriate at promoting emission reductions. At a high level, this points to identifying the market failures that are currently preventing emission reductions from being undertaken. Of greatest significance is often the inappropriate price signals, which means
that consumers and producers do not take into account the full social cost of their actions—with the weight of economic evidence pointing to carbon pricing being the most efficient way of addressing this market failure.\(^2\) Furthermore, market failures that can also be important include insufficient information, which means that consumers and producers are not aware of the opportunities to reduce emissions that may be in their own interest; and an inability to access finance to undertake investment that will lead to emission reductions. Countries may therefore wish to identify which are the market failures that currently prevent emission reductions being undertaken and how well different potential policies match to these market failures. This analysis will be particularly important in cases where countries have already committed to a particular policy goal and are keen to understand which (combination of) policy measures are likely to be most effective at supporting the realization of that goal.

*Understanding of and Coherence with Existing Institutions and Regulations.* It may be possible to extend or adjust existing policy measures in order to better support emission reduction objectives—for instance, existing agricultural support and extension policies might be easily adjusted to encourage carbon sequestration in soil. In other cases, particular policy measures may be inappropriate given the institutional context—for example, emissions trading schemes (ETSs) may be inappropriate when there is a small number of large emitters within a country.

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**Consistency with Other Development and Policy Objectives.** Many policy measures that support the delivery of emission reductions can also support other policy goals. For instance, reducing or removing energy subsidies, possibly followed by the introduction of carbon pricing, in countries that are reliant on fossil fuels for a large proportion of their energy needs will improve energy security as well as deliver emission reductions.

**International Experience.** Countries may wish to draw on the experience of other countries that have faced similar challenges, and examine the policy responses that they have adopted. International forum such as the PMR, the European Climate Forum and the Global Climate Change Alliance support this cross-fertilization of ideas. Furthermore, the introduction of policies in one country can sometimes increase the effectiveness of the same policies in a second country; for instance, the linking of ETSs of different countries can result in the most cost-effective opportunities to reduce emissions being highlighted, as well as boosting market liquidity.

**Political Feasibility.** Some policy measures may be more or less attractive in a given political context. The removal of fossil fuel energy subsidies may be easier when global energy prices are at historically low levels, for example.

### 3.2.2.2 Step 2: Analysis of Costs and Impacts of Policies

Once one policy or a small set of policy measures have been identified, countries may wish to undertake more detailed analysis of the likely impact in order to decide whether to proceed with the policy and, if so, to appropriately tailor its detailed design. This might involve understanding issues such as the expected impact in terms of emission reductions, costs, consumer prices and producer profit, public finances, and employment. Countries may then wish to report this analysis to domestic and international stakeholders.

A number of tools are available for this type of analysis, and these are more or less appropriate for different types of policy.

Broadly speaking, there are three main types of modeling technique:

- **bottom-up/sector-specific modeling;**
- **top-down macroeconomic models.** These can be further disaggregated into CGE and macroeconometric models; and
- **tools focused on assessing distributional impacts of policies.**

Each of these is briefly discussed below, with more detail, including advantages and disadvantages and the circumstances in which each might be used, in appendix B.

**Bottom-Up/Sector-Specific Modeling.** Bottom up/sector-specific modeling seeks to understand how a particular policy measure might influence behavior within that sector. It usually relies on a model that aims to understand how a policy measure may influence a sector, taking into account the competitive interactions between firms in that sector. This might either be based on a particular understanding of how firms interact within a market (for example, models of lowest-cost dispatch in the electricity sector), or more generally applicable models of competitive firm interaction based on economic theory.
**Top-Down Modeling.** Top-down models are the most useful tools in generating a comprehensive economy-wide understanding of different types of policy measure. For example, they can assess what might happen to GDP or unemployment from the introduction of a policy measure. This makes them particularly useful for assessing policies that are targeting large parts of an economy such as carbon pricing.

Top-down models may be further disaggregated into CGE and macroeconometric models. As described above, CGE models set up a coherent economy-wide framework and allow economic decision-making to be the outcome of decentralized optimization by producers and consumers. As such, they can also provide a detailed look at how changes in economic conditions brought about by a policy are mediated through prices and markets while assuring that all economy-wide constraints are respected.

Some CGE models in use for policy analysis allow modeling of specific detail or additional economic aspects, for example:

- detailed impacts in specific industries, such as shifts between electricity generation technologies and impacts on upstream industries (fuel supply, construction, etc.) and downstream industries and consumers;
- inclusion of specific sources of emissions and reduction opportunities not commonly modeled in top-down approaches, such as forestry and agricultural emissions;
- the geographic impact of policies, through the use of regional CGE models where one country is disaggregated into a number of regions (such as states or provinces, or geographical areas) while also possibly taking account of the international impact of policies;
- the trade impacts of policies using models such as the modeling framework provided by the Global Trade Analysis Project (GTAP);
- distributional effects of climate change policies, such as the impact on incomes and the prices of the basket of goods consumed by different groups.

An alternative approach relies on macroeconometric modeling. This uses an estimate of the historical relationship between economic variables to predict what might happen to different parts of the economy when one or more of those variables are influenced by policy.

**Distributional Analysis.** The effect of climate change mitigation policy measures on different groups in society, particularly different income groups, is often of interest in policy and political decisions. Distributional policy analysis can be used to help assess the desirability of policy options. It can also be used as a basis for setting policy parameters to meet desired distributional outcomes. For example, Australia’s carbon-pricing mechanism was accompanied by changes in income tax rates and government transfers that were calibrated to provide disproportionate benefits to lower-income earners, and were estimated to leave a majority of households financially better off even after price increases arising from the carbon price.

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3 The Applied Dynamic Analysis of the Global Economy (ADAGE) is a good example of this sort of model.
Distributional effects can be analyzed quantitatively through detailed household expenditure and cost models. Alternatively, distributional analysis can be undertaken by way of approximations, for example, by comparing the relative importance of energy costs in household incomes at the bottom, middle and top of the income distribution.

3.2.2.3 Step 3: Policy Interaction
Countries may also undertake and present analysis concerning policy interaction and overlap to ensure that the entire suite of policy measures is complementary. A typical approach to this type of analysis, possibly using the same policy mapping tools described under component 2, involves identifying sectors or emissions where there is more than one policy influence. An example from the transport sector might be fuel taxes or subsidies, charges on vehicle ownership or operation, road-user charges, subsidies to car manufacturers, and car import tariffs. In these cases, the drivers through which the policy measures are expected to lead to a change in emissions can then be clearly identified, thereby allowing the identification of possible overlap and tension. In undertaking this sort of exercise, a comparison with international experience may be useful, as can existing research that explicitly analyzes likely cases of policy overlap and whether they may be complementary or in tension.4

3.2.3 Subcomponent C: Iteration between Technical and Policy Measures
As described above, the most robust approach to developing alternative emission pathways would be to combine the assessment of technical emission reduction opportunities with an assessment of the policy measures that are expected to deliver those emission reductions. By combining both sets of analysis, and iterating between the two, greater confidence can be achieved that the technical emission reduction opportunities can actually be delivered through a suite of policy measures, and that policy measures can be better targeted at optimal emission reduction opportunities.

This type of approach could draw upon some or all of the analytical approaches described above. A particularly useful approach is to make use of Financial MACCs. These quantify the expected effect of planned policy instruments on the implementation of abatement measures and resulting emission trajectories. They adjust traditional economic MACCs by simulating the behavior of investors under market conditions. They are useful tools to quantify how different policy instruments can affect the relative costs of alternative emission reduction opportunities and counterfactual carbon-intensive choices. Therefore they can be used to predict emissions under various policy scenarios. Further details on the advantages and disadvantages of this approach are provided in appendix B while figure 8 provides an example of the output from this sort of analysis.

3.3 Sources of Data

3.3.1 Subcomponent A

The data for optimization models, such as MARKAL and TIMES, is often available in national accounts or in IEA regional studies. This includes current data on primary energy use by source, electricity generation by source, energy use by activity and sector, heating use by sector and activity and, if desired, data on transport energy use, which can be sourced from national databases. A full list of data requirements can be found in the MARKAL and TIMES documentation.

Bottom-up analyses typically require bespoke studies, or are even an output of the optimization models. The typical data that needs to be collected includes:

- emission intensities of existing technology and lower-emission alternative;
- maximum penetration rate of both existing technology and emission-mitigation alternative;
- costs of different technologies, split between capital and operating costs as relevant;
- expected speed at which new technologies might enter the market.

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5 http://www.iea.org/statistics/.
Studies of this sort have become increasingly common in recent years and in some cases it may be possible to use them. If relevant data for a country or sector is unavailable, estimates from other countries or sectors in the region might be useful, with adjustments made for country-specific factors as appropriate.

Top-down CGE models rely on Social Accounting Matrices (SAM)\(^7\) and elasticity estimates, as described below.

**3.3.2 Subcomponent B**

In terms of policy identification (step 1), a range of sources are available which can be tested in a particular policy context. These include the IEA Policies and Measures database, while the World Bank’s decision-making toolkit, TRACE, has an intervention selection module which functions like a “playbook” of tried-and-tested energy efficiency measures, and helps select locally appropriate energy efficiency interventions.

In terms of assessing costs and impacts of potential policy measures (step 2), partial equilibrium models typically rely on economic theory and estimate the impacts on a specific sector. The data for such models can be found in national statistics and relevant national and international industry publications that cover most, if not all, emissions-intensive sectors.

CGE models are sometimes already in place and form part of the process to create national account projections. Where they are not readily available, their creation relies on two key pieces of data: SAMs and estimates of various elasticities. The former traces the flow of economic transactions within an economy—for example, the amount that one sector purchases from another, or the amount that households purchase from overseas. Data for SAMs comes from input–output tables, national income statistics and household surveys including labor statistics. Although SAMs provide a static depiction of flows within an economy, elasticities provide an estimate of how these relationships might change in response to a (policy) shock. These might be estimated econometrically using historical data. However, it may be easier and more transparent to rely on existing available work.

Macroeconometric models are relatively bespoke and may often need to be developed. The models themselves require robust, detailed and historical data to generate a sensible estimation. Estimation techniques are standardized and there is a broad understanding of best practice based on modeling analyses presented in peer-review articles.\(^8\)

Full-scale distributional models require large amounts of household-level data on incomes, taxation and expenditures, often acquired by governments through census exercises. For less sophisticated distributional analysis, data can be procured through selected surveys or through other data that may be available as part of national statistical collections.

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3.3.3 Subcomponent C

Using financial MACCs to tailor and design policy measures will make use of the same data as needed for the initial assessment of the emission reduction options, as described under subcomponent A. These then need to be adjusted by using a higher discount rate to reflect the risks faced by the private sector and the adjustment of prices to account for the impact of taxes and subsidies (which should be stripped out of social analysis).

3.4 Dealing with Uncertainty

Examining whether it might be possible to achieve emission reductions and/or the impacts of policy measures to achieve these reductions is an inherently uncertain exercise. Countries formulating their future development strategy will want to try and reduce this uncertainty if possible, so that they can have greater confidence that a particular alternative emission pathway is indeed desirable to pursue.

There are two sets of questions to consider. The first concerns how variable or robust the results generated from any one analytical tool are to a range of input emissions. For instance, when undertaking a bottom-up analysis of emission reduction opportunities, countries may want to know whether the ranking of emission reduction opportunities changes significantly with assumed fossil fuel prices or, if looking at the impact of a carbon pricing policy, whether a CGE analysis gives notably different impacts if different GDP growth rate assumptions are used. For some cases, Monte Carlo techniques—where key variables are assumed to take a random distribution and repeated sampling from that distribution is used to examine the possible impacts depending on the value that the variable takes—can be helpful (as also identified in component 2).

The second set of questions addresses whether different analytical tools yield the same results in terms of emission reduction opportunities or likely policy impacts. To the extent that they do not, there are a number of further questions that it can be helpful to address:

- What are the reasons for these differences? Are these reasons driven by fundamental differences in the modeling structure or the use of different assumptions on values that are uncertain (for example, the future costs of different emission reduction opportunities)?
- Can a “best estimate” of the variables of interest be identified for specific sectors and the overall economy, based on an understanding of the relative strengths and weaknesses of the models?
- Is there further research that can be undertaken that would help to narrow the differences between the results, and that could provide a greater understanding of the scope for future emission reductions?
- Do other assessments of the emission reduction opportunities available, or the impact of similar policies—undertaken either historically or in similar jurisdictions—demonstrate similar results?

3.5 Output

The main outputs of an analysis of alternative mitigation pathways are one, or a series of, emission reduction pathways and costs.
As with the baseline emissions (discussed in component 2) there are a number of ways in which the results derived from the pathway analysis might be presented:

- in terms of emissions or some variable linked to emissions (for example, renewable energy capacity)
- and, in the case of emissions, whether this is expressed in absolute terms or normalized relative to some other unit (per capita, per unit of GDP). It may also be expressed in terms of a deviation from the baseline pathway;
- for the entire economy or for certain key sub-sectors of the economy (such as the energy sector);
- for all GHG emissions or only for certain key gases (most notably CO₂);
- on an annual basis or at less frequent intervals, such as every five years.

In the interests of transparency, the emission mitigation pathways should be presented using the same format as the baseline pathway.

In the event that countries pursue subcomponents B and/or C, this could be accompanied by a quantitative and qualitative description of the policy measures that are important in driving the alternative emission pathways, the emission reductions they are expected to deliver, the impacts that may result (positive and negative), and the key assumptions underpinning this analysis. It may also be helpful to set out a discussion of how the policies were decided.

### 3.6 Checklist Summary

The following tables summarize the approaches to identifying and assessing emission reduction opportunities (subcomponent A), policy options (subcomponent B) and their combination (Subcomponent C). The table for Subcomponent C is very short as it only considers the approaches that explicitly combine analysis of emission reduction opportunities and policies. In practice countries adopting subcomponent C would also need to draw heavily on the tools and analytical approaches discussed in relation to subcomponents A and B.
<table>
<thead>
<tr>
<th>Key questions to consider</th>
<th>Analytical techniques available</th>
<th>Key observations about techniques</th>
<th>Data options/sources</th>
<th>Output options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What emission reduction options are available in the country as a whole and/or within a particular sector, and what might be the costs and benefits of realizing these emission reduction options?</td>
<td>1. Optimization models like MARKAL and TIMES</td>
<td>Comprehensive approaches that identify dynamically optimal emission mitigation strategies and interlinkages between different options. However, detailed data requirements and assumptions often difficult to scrutinize.</td>
<td>Depend on particular modeling option but MARKAL models require energy use by source, electricity generation by source, energy use by activity and sector, heating use by sector and activity and, if desired, data on transport energy use.</td>
<td>One or a series of emission mitigation pathways based on either: emissions or variable linked to emissions – nationwide or sectoral – CO₂ or all GHGs – annual or less frequently. Should ideally be presented on same basis as baseline pathway(s). Can also be expressed on both absolute or relative basis. Presentation of multiple pathways helps to identify the sensitivity of economic development/growth to different levels of ambition.</td>
</tr>
<tr>
<td>2. How might different packages of emission reduction options be combined to establish emission mitigation pathways?</td>
<td>2. Bottom-up modeling techniques to identify opportunities (as appropriate and supported by diagnostic tools and software packages like MACTool or TRACE)</td>
<td>Flexible approach that can be applied in more contexts. May risk missing synergies between emission reduction opportunities. Risk of misinterpretation of results unless clarity over issues such as assumed speed of diffusion; discount rates; extent to which institutional barriers have been taken into account.</td>
<td>Typically requires bespoke studies collecting data on emission intensities of different options, likely penetration rates, and costs of different technologies. May be possible to make use of existing studies with ad hoc adjustments.</td>
<td></td>
</tr>
<tr>
<td>3. Top-down models (such as CGE models)</td>
<td>Takes into account interaction between different sectors and policies. Can be linked to results from bottom-up models. Can model the impact of a national and/or sectoral and/or activity-based carbon price.</td>
<td>Requires detailed input/output database with energy use and emissions, and information about substitution factors, embedded in a suitable economic modeling framework.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Comparison and combination of modeling pathways</td>
<td>Can identify areas where there is confidence or uncertainty over emission reduction options. Can help identify a “most likely” reduction pathway.</td>
<td>Readily done if different modeling approaches are used.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Summary Checklist for Subcomponent A of Component 3: Analysis of Emission Reduction Opportunities
### Table 5. Summary Checklist for Subcomponent B of Component 3: Policy-Based Approach

<table>
<thead>
<tr>
<th>Key questions to consider</th>
<th>Analytical techniques available</th>
<th>Key observations about techniques</th>
<th>Data options/sources</th>
<th>Output options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What are the different policy measures that might be considered?</td>
<td>Qualitative multi-criteria analysis possible</td>
<td>May wish to consider issues such as: – whether market failure will be addressed – consistency with existing policies – international experience – political feasibility.</td>
<td>International databases such as IEA Policies and Measures database. Other tools such as TRACE.</td>
<td>One or a series of emission mitigation pathways based on: – emissions or variable linked to emissions, or – nationwide or sectoral, or – CO₂ or all GHGs, or – annual or less frequently. Should ideally be presented on same basis as baseline pathway(s). Can also be expressed on both absolute or relative basis. Associated commentary on how the policies relate to these scenarios, their expected costs and impacts and, possibly, the process through which the policies were selected.</td>
</tr>
<tr>
<td>2. What might be the costs and other impacts of different policy measures?</td>
<td>1. Bottom up—partial equilibrium modeling</td>
<td>Most suitable when policy measure is restricted to small number of sectors or there is a desire to understand detailed sectoral impacts. Does not provide information on macroeconomic aggregates.</td>
<td>Sector-specific data from national accounts and national and international industry publications.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Bottom up—partial equilibrium modeling</td>
<td>Most suitable when policy measure is restricted to small number of sectors or there is a desire to understand detailed sectoral impacts. Does not provide information on macroeconomic aggregates.</td>
<td>Sector-specific data from national accounts and national and international industry publications.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Top-down—CGE modeling</td>
<td>Most suitable when aiming to understanding long-term impact of broad-based policy on key variables, especially for carbon prices.</td>
<td>Input–output tables to provide SAMs. Elasticity estimates from existing models or econometric estimation.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Top down—macroeconometric modeling</td>
<td>Most suitable when aiming to understand impact of broad-based policy on key variables in the short-medium term. Data availability is a key challenge and may not be appropriate for long-term analysis.</td>
<td>Long time series on cross-sectoral economic activity.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Household expenditure and cost models</td>
<td>Can provide detailed assessment on distributional impact on policies but data-intensive.</td>
<td>Data to populate models often needs to be collected through censuses.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Ad-hoc distributional analysis</td>
<td>Relatively simple techniques based on assessment of profile of spending by different members in society.</td>
<td>Household expenditure survey data.</td>
<td></td>
</tr>
<tr>
<td>3. How can issues of policy interaction be explored?</td>
<td>Policy mapping tools to identify where there are multiple policy influences. Qualitative analysis of risks of distortion. International experience.</td>
<td>Work from international institutions and academics can help identify likely overlaps.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 6. Summary Checklist for Subcomponent C of Component 3: Iteration between Analysis of Emission Reduction Opportunities and Policy Analysis

<table>
<thead>
<tr>
<th>Key questions to consider</th>
<th>Analytical techniques available</th>
<th>Key observations about techniques</th>
<th>Data options/sources</th>
<th>Output options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do proposed policies provide enough incentive to support uptake of emission reduction opportunity?</td>
<td>Bottom-up—adjusted MACC type analysis</td>
<td>Most suitable for tailoring the financial strength of policies. Does not provide information on macroeconomic aggregates; difficult to capture non-financial barriers that policy may be intended to address.</td>
<td>As per the data collected in subcomponent A but with adjustments made to discount rate and treatment of taxes and subsidies</td>
<td>One or a series of emission mitigation pathways based on: – emissions or variable linked to emissions, or – nationwide or sectoral, or – CO₂ or all GHGs, or – annual or less frequently. Should ideally be presented on same basis as baseline pathway(s). Can also be expressed on both absolute or relative basis. Associated commentary on how the policies relate to these scenarios, their expected costs and impacts and, possibly, the process through which the policies were selected.</td>
</tr>
</tbody>
</table>

*Note:* Table only focuses on tools at the intersection between analysis of emission reduction opportunities and policy analysis. In practice countries following subcomponent C would also need to make use of many of the tools and analytical approaches described in tables 4 and 5.
Component 4: Results Presentation

The objective of this component is to highlight key options on how the technical results of the preceding components of the checklist can be presented. In particular, it considers the options regarding the level of detail in the final results reporting.

There is a menu of options for countries to consider when presenting their analysis. While all countries would be expected to provide the key results from their technical analysis, there are also opportunities to present detailed information around the assumptions underpinning the analysis, as well as some of the findings on possible impacts, which leads naturally to a discussion on possible barriers and constraints. Some of the options are presented in figure 9.

4.1 Key Results

The high-level approach would focus on the outcome of the underlying technical analysis, although it may not elaborate on that analysis in significant detail. This is the sort of information that governments might choose to include in their actual submissions to the United Nations Framework Convention on Climate Change, in the context of the guidance from the Lima decision. Some of the key information that might be provided in this category includes the following:

- **time frame**: the horizon over which the pathway has been developed;
- **type of pathway**: whether the analysis relates to absolute emissions, emissions expressed relative to some normalization variable (such as emissions per capita or emissions per unit of gross domestic product [GDP]), or some variable linked to emissions, such as renewable energy capacity;
- **scope**: which sectors are covered by the pathway and, where the pathway specifies emissions, the gases that are covered, the percentage of the emissions of the country covered by the pathways, the geographic coverage;
- **expected trajectory of key variables**: how the variables of interest are expected to develop over the time frame of the pathway. This may be expressed relative to either some historical reference year, or to what a particular variable would be considered to be in the baseline pathway (in which case an explanation of the baseline would also be valuable). It may also be helpful to express these both in absolute terms and using index values to facilitate understanding;
- **assumptions and methodological approaches**: including the approach taken to calculating the global warming potential (GWP) of non CO$_2$ greenhouse gases (GHGs) and the treatment of emissions from land use, land-use change and forestry.

Note that, as described in the Introduction, the Lima decision also includes reference to information to be included in the INDC which is not covered in this Checklist, such as how the INDC is “fair and ambitious, in light of its national circumstances, and how it contributes towards achieving the objective of the Convention as set out in its Article 2.”
4.2 Detailed Assumptions

While the high-level information discussed above may provide information on some of the key assumptions underpinning an emissions reduction pathway (for example, on the GWP assumed of different gases or of the BAU emissions assumed if the pathway is presented as a reduction from BAU) countries may also wish to present more detail about how they intend to deliver a particular emission reduction pathway and a detailed description of the assumptions on which this is based.

For instance, if their emission reduction pathways have been based on an assessment of emission reduction opportunities, they may wish to provide information on:

- the costs assumed for the emission reduction opportunity and the alternative (including, for instance, assumptions on global resource prices such as oil);
• the expected speed of penetration of new technologies; and
• overall rates of economic growth and how changes in economic growth rates are likely to influence emissions.

If countries have instead based their emission reduction pathways on a particular suite of policies, they may wish to provide information on:

• the sectors and activities expected to deliver the bulk of the emission reduction opportunities;
• how policies are expected to change the activity levels and emissions intensities in these sectors (and the assumptions/evidence on which this has been based); and
• how changes in economic growth rates and other macroeconomic variables might change the activity levels and hence emissions.

Providing such information can serve a number of purposes. From a country perspective, it can provide a means of tracking progress against assumptions, and hence make it easier to identify and justify adjustments (up or down) in the event that the future does not develop as anticipated. As stressed in component 3, projecting emission pathways to 2030 (or beyond) is subject to significant uncertainties concerning, for instance, the speed of technological developments, developments in international resource prices, or actions by international trading partners. These may make it either more or less difficult to achieve a particular alternative emission pathway, or require that the emission reductions envisaged within a particular pathway need to be achieved using alternative policies or technology options. By identifying and articulating the assumptions upon which an alternative emission reduction pathway will be realized, the need to make such adjustments can both be identified more quickly and explained more easily. Indeed, it may be possible to use the explanation of these assumptions to develop a tracking framework that countries update on a regular basis—annually, for example. The example of the UK, a particularly detailed case, is presented in box 8.

The provision of such information can also foster transparency in international assessments and comparisons, as it helps other countries or organizations assessing INDCs understand the basis of national-level analysis that has informed national decisions. For the same reasons, the provision of information on the process that will be implemented in relation to the monitoring, reporting and verification of emissions, including under international MRV processes, might also be valuable.

### 4.3 Expected Impacts and Possible Barriers

A second further aspect of technical information which countries may wish to present internationally relates to the possible expected impacts, both nationally and by sector, of the expected emission reductions.

This might cover the expected positive impacts of the delivery of emission reductions and/or certain policies—for example, where delivery of emission reductions promotes development objectives.

However, it can also focus on where there could be negative impacts on individual sectors or activities—for instance, if emission reductions can be achieved only by significant changes in the practices and activity levels of carbon-intensive activities, leading to the need to manage transitions and/or to
mobilize additional investment. This can help identify where there are barriers in the political decision-making process that might make achieving particular emission reductions more challenging, and in the consideration of how to address these barriers. Countries may also wish to report institutional and technical barriers that may need to be overcome to achieve progress against an emission reduction pathway.

This discussion of political and technical barriers might be further informed by commentary on the reasons why particular technical and/or policy options were selected for analysis.

Box 8. Tracking Progress against the UK’s Carbon Budgets

The UK’s Committee on Climate Change (CCC) engages in detailed tracking of progress against the UK’s “carbon budgets.” Some of the key elements covered in this framework include:

- comparison of national emissions against anticipated emissions;
- comparison of progress in individual sectors;
- assessment of whether technologies are developing in terms of cost/impact as expected;
- comparison of performance against international peers;
- assessment of whether, given developments, the country is on track in the medium term to meet its emission reduction objectives.

The comparison of national emissions with the target provides a succinct summary of efforts so far and whether progress is in line with expectations. Additional information might also be provided, such as changes in economic growth or the structure of the economy, which might not have been anticipated when the emission reduction pathway was formulated.

Sectoral progress can be undertaken in a similar way and help to identify sectors either exceeding or falling short of that expected in the emission reduction pathway. This can be helpful in understanding the reasons behind national level performance and can help policymakers consider their responses.

Assessment about whether individual technologies are performing in line with expectations provides further detail to help identify the need for any policy responses. This can be particularly useful when progress along the emission reduction pathway relies on relatively immature (for that country) technology. For instance, the UK’s tracking framework reports on operational offshore wind capacity, capacity under construction, and capacity at various stages of seeking planning approvals.

Progress relative to international peers can help identify whether, in the event that there are deviations from the expected pathway, this has been as a result of domestic or international factors.

Finally, a forward-looking assessment of whether, taking into account the most recent developments, the country remains on course to meet its ambitions expressed in a particular alternative emission scenario, can help policymakers determine whether and how they may wish to take additional policy action and/or reformulate their objectives.

One advantage of providing this additional information is that it can offer greater confidence to the international community that the emission reduction scenario is credible, robust and achievable, with countries having given due consideration to both the benefits and costs associated with the scenario. It can also provide the foundation for a credible and detailed formulation of the ways in which the international community may be able to support the achievement of a particular alternative emission reduction pathway.
Appendix A

Kaya Identity

\[ C = P \times \frac{G}{P} \times \frac{E}{G} \times \frac{C}{E} \]  \hspace{1cm} (1)

where:
- \( C \) is \( \text{CO}_2 \) emissions from human sources;
- \( P \) is population growth;
- \( G \) is GDP;
- \( E \) is energy consumption.

Emission projections can be generated by using projections of underlying variables. The Kaya Identity does not account for structural change as can be seen in equation (1). The ASIF decomposition improves on this.

ASIF Decomposition

\[ C = A \times S_k \times I_{k,j} \times F_{k,j} \]  \hspace{1cm} (2)

where:
- \( C \) are the emissions of a certain sector or economy;
- \( A \) represents a measure of activity, such as electricity generation or passenger-kilometers for sectors or GDP growth for economies;
- \( S \) are the shares of \( k \) different modes in the sector or economy, such as shares of different passenger car technologies for the transport sector or sectoral shares for economies;
- \( I \) is the intensity, fuel or energy, of each mode \( k \) using a specific energy source \( j \), such as the fuel efficiency of diesel and petrol cars or the energy consumption of services and heavy and light industry; and
- \( F \) is the carbon content of each fuel or energy source \( j \) used in mode \( k \).

The ASIF decomposition allows the capturing of changes in the structure of sectors or the economy, changes in energy efficiency as well as changes in the carbon content of fuels or energy sources. These dynamics improve projections generated by a Kaya Identity, but also require projections of the aforementioned factors instead of the ubiquities projections required for the Kaya Identity.

The decomposition can use several techniques, with Laspeyres and Logarithmic Mean Divisia I (LMDI). An overview of these is provided by the IEA.\(^1\)

\(^{1}\)http://www.iea.org/media/training/presentations/Day_3_Session_12_Indicators_Decomposition_Methods.pdf.
Appendix B

This appendix provides more detail about the pros and cons of the different tools and analytical approaches identified in component 3.

Subcomponent A

Subcomponent A introduced three approaches that can be used to identify emission reduction opportunities:

- optimization models;
- bottom-up assessments; and
- top-down modeling (CGE modeling).

The key advantage of optimization models is that they are designed so that links between different parts of a sector can be captured. For instance, a MARKAL analysis might identify the use of wind energy to generate electricity to power electric vehicles, which might be missed by separate analysis of the power and transport sectors. They also explicitly allow for inter-temporal optimization, such that opportunities which might not appear to be very cost-effective in immediately reducing emissions in themselves are identified as important as they facilitate lower-cost emission reduction opportunities in the longer term. These considerations are easy to miss in bottom-up analyses.

However, populating such models is typically very data-intensive, which can mean that they are not available for use in many developing countries. Even when sufficient data is available, a key challenge with the use of these types of models is the extent of transparency regarding the assumptions and optimization procedures within the models, and hence the ease with which stakeholders can inspect and scrutinize their outputs. Given these limitations, the key benefits from using such models is often not in the specific results that they provide but in the strategic insights derived from understanding how they respond to different sets of assumptions—for example what sorts of technologies remain cost-effective regardless of future assumptions.

In comparison with optimization models, the significant advantage of bottom-up analysis is its ability to be applied to a variety of contexts and its relatively light data requirements. There is also now an increasing body of evidence that can be drawn upon (both to understand different methodologies and also as potential sources of empirical information). On the other hand, by looking at each emission reduction opportunity individually, this type of analysis typically fails to look at the interactions between different opportunities that could either significantly increase or decrease the costs of action—for instance, promoting electric vehicles and green electricity together would reduce GHG emissions to a greater extent than the sum of the two isolated abatement measures. Furthermore, and importantly, in the absence of careful explanation of key methodological approaches, such as those set out above, it is easy for the results of this type of analysis to be misinterpreted (for example, it may not be clear that the analysis has
not been adjusted for institutional barriers and transaction costs, and that it therefore gives an unrealistic assessment of abatement potential).

**CGE modeling** can address an important shortcoming of bottom-up analysis identified above, namely that, as interactions between different emission reduction opportunities are missed, the resulting estimates of emission reduction potential and costs may be inaccurate. On the other hand, top-down models do not have the detailed data that populates bottom-up analyses, instead relying on broad-brush characterizations of technologies and mitigation costs in entire economic sectors. CGE models are further constrained in their representation of consumer and business behavior; for example, they typically do not allow for the possibility of “negative cost abatement potential” which comes about due to market failures or real-world behavioral characteristics.

**Subcomponent B**

Subcomponent B introduced three main categories of modeling tools/analytical approaches that can be used to identify the costs and impacts of different policies:

- bottom-up/sector-specific modeling;
- top-down macroeconomic models. These can be further disaggregated into CGE and macroeconometric models; and
- tools focused on assessing distributional impacts of policies.

The advantage of **bottom-up (sector-specific) models** is that they allow for a detailed understanding of how a particular policy will influence the sector, which can be valuable both when a policy is being contemplated in only one sector (and hence would typically be difficult to pick up in macroeconomic models), or where a broader-based policy is being contemplated but there is a need for a detailed understanding of its likely impacts in key sectors of importance. This means, for instance, that this modeling approach can be particularly useful when exploring whether a particular policy may have a detrimental impact on sector competitiveness. A further advantage of these types of model is that their relatively narrow focus means that they are often flexible enough to model a number of different types of policy, such as carbon pricing, policies reducing the carbon intensity of key inputs, and tradable certificate regimes. However, the narrow focus on one sector means that they are unable to capture interactions between sectors and hence report macroeconomic impacts (for example, on variables such as gross domestic product (GDP) and employment) that can often be of most interest to policymakers.

Both **CGE and macroeconometric models** can be used to understand the economy-wide impacts of different policies and hence overcome the key disadvantage of bottom-up models. Both approaches require significant data—with macroeconometric approaches being particularly demanding in this regard. CGE models may be considered theoretically superior and particularly useful for long-term analysis where the assumptions used, for instance that all markets clear (including labor markets—no unemployment), are more reasonable. Macroeconometric models may be preferred for shorter-term analysis, for example where there is clear evidence that (labor) markets do not clear.
**Detailed household expenditure and cost models** allow a detailed representation of policy effects on net incomes and expenditures of different income groups and different types of households and individuals (for example, families versus singles, older versus younger people), and may also be regionally disaggregated. Such models can also be linked to CGE models. Distributional models require large amounts of household-level data on incomes, taxation and expenditures.

**Subcomponent C**

Subcomponent C shows that one analytical tool to explore whether policies are well targeted at particular emission reduction opportunities is to adjust the bottom-up analysis identified under subcomponent A and compare the resulting costs with a measure of the strength of the financial incentive provided by a particular policy. The advantage of this type of analytical approach is that it can provide a relatively quick and easy assessment, using data that may have already been collected as part of work in earlier subcomponents, of whether a particular policy is likely to offer sufficient financial incentive to ensure take-up of an emission reduction opportunity. It can therefore be used to quickly tailor policy design. However, this type of analysis will not easily capture whether there are non-financial barriers that can prevent individuals or firms from taking up emission reduction opportunities. It also offers only a relatively narrow assessment of whether it is financially attractive to pursue a particular emission reduction opportunity, rather than some of the wider economic impacts that may result from the introduction of a particular policy—for example, impact on different firms, consumer process or macroeconomic aggregates such as GDP and employment.