

# The Clean Energy Technology Assessment Methodology

*A methodology for assessing renewable  
energy and energy efficiency technology  
markets*

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## INTERNATIONAL ENERGY AGENCY

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The Global Environment Facility is a partnership for international cooperation where 183 countries work together with international institutions, civil society organisations and the private sector, to address global environmental issues. Since its establishment in 1991, the GEF has provided 13.5 billion United States dollars (USD) in grants and leveraged USD 65 billion in co-financing for 3 900 projects in more than 165 developing countries.

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<sup>1</sup> Under FINTECC, the Early Transition Countries (ETC) are: Armenia, Azerbaijan, Belarus, Georgia, Kyrgyz Republic, Moldova, Mongolia, Tajikistan, Turkmenistan and Uzbekistan. The IEA-EBRD collaboration also considers Kazakhstan as a reference country within this grouping.

<sup>2</sup> For the EBRD, and for the purposes of the IEA-EBRD collaboration, SEMED refers to: Egypt, Jordan, Morocco and Tunisia.

<sup>3</sup> In the framework of FINTECC, "climate technologies" concern technologies that can assist climate change mitigation and/or climate change adaptation. The IEA collaboration with the EBRD focuses on energy efficiency technologies (EETs) and renewable energy technologies (RETs). In parallel, the EBRD is collaborating with the Food and Agriculture Organization on climate technologies with a focus on the agriculture, food and water sector.

## Introduction

Renewable energy technologies (RETs) and energy efficiency technologies (EETs), referred to from this point on as “clean energy technologies”<sup>4</sup> have many benefits, which have been well documented. Clean energy technologies can improve energy access, energy security and economic productivity, and have a host of other co-benefits. With around two thirds of greenhouse gas emissions being related to energy, shifting to renewable, low-carbon energy sources and using energy efficiently is vital to mitigating anthropogenic climate change.

Despite the strong case for clean energy technologies, some countries have been slow to deploy them, even where there are plentiful renewable energy resources and energy efficiency opportunities. Such is the case in certain Southern and Eastern Mediterranean (SEMED) countries and Early Transition Countries (ETCs) of the Black Sea-Caspian region. While there are myriad reasons for the relatively low deployment of clean energy technologies in these countries, broadly speaking, analysis has shown that policies to directly support clean energy technologies, and the wider “enabling environment” in which these policies operate, are under-developed (IEA, 2015a).

A necessary precondition for assessment of clean energy technologies is that a country must first establish its overall energy system objectives, which often take into account the broader economic, social, and environmental goals of a country. Such objectives should guide how clean energy technologies are assessed and prioritised for deployment and monitoring. Regardless of the objectives a country might have for deploying clean energy technologies, increasing their deployment will depend on implementing effective policies and attracting public and private finance. Equally important is to ensure that barriers to implementing effective policies and attracting finance are removed, including information barriers that currently exist in both regions.

### The need for a methodology to monitor clean energy technologies

Both policy makers and investors require a range of information to make informed decisions, yet, in many SEMED countries and ETCs, access to information is poor. Policy makers and investors interested in stimulating the uptake of clean energy technologies to meet a diverse range of objectives require information such as:

- Which technologies are appropriate for deployment, given existing and projected supply and demand side conditions within a country;
- Existing levels of market penetration and opportunities for future technology deployment; and
- If significant impediments to clean energy technology deployment exist in the country.

The quality of information on clean energy technologies in the SEMED and ETC regions varies by country and it generally leaves room for improvement. Existing information tends to be

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<sup>4</sup> The methodology described in this paper is focused on assessing renewable energy technologies (RETs) and demand-side energy efficiency technologies. It excludes analysis of other technologies that can be used to reduce carbon emissions on the supply side such as nuclear energy or carbon capture and storage, and technologies to increase the energy efficiency of energy production, transmission and distribution.

inconsistent in the way it is reported and analysed, making international benchmarking difficult. Moreover, in the absence of monitoring systems to measure technology deployment, information in these regions often relies on one-off studies or surveys and can soon become out-of-date, failing to take into account changing conditions. Without clear, up-to-date, internationally comparable information on clean energy technology market conditions, investors are unable to make investment decisions on funding particular technologies, while national policy makers have difficulty designing targeted support policies and measuring their efforts against international best practices.

The methodology presented in this paper is a tool for assessing clean energy technology market conditions in the ETC and SEMED regions and seeks to bridge an information gap that currently exists.

## The Clean Energy Technology Assessment Methodology (CETAM)

CETAM is designed to provide clear, transparent information about clean energy technology markets. While it has been developed for application in the SEMED and ETC regions, it is generally applicable in most countries. Its primary goal is to assist development agencies such as the EBRD and others identify the most promising technologies for policy support and investment. It is based on previous IEA work on indicators and technology assessments and builds on other evaluation frameworks as appropriate.

The methodology takes into account potential challenges related to data availability and consistency within the ETC and SEMED regions. For example, to assess EETs, it adopts a “top down” approach by examining national-level energy consumption data to determine priority sectors and end uses, and expert judgement to assess market penetration of “best available technologies.” This approach is based on the idea that detailed “bottom-up” information on technology deployment tends to be unavailable in many of the countries in these regions.

The primary users of CETAM will be the EBRD, which will use it to inform assessments of clean energy technology investment opportunities in the SEMED and ETC regions, and policy makers in the two regions, who could use it to track progress toward achieving clean energy technology deployment targets and inform policy formulation. Moreover, applying the methodology produces a set of “granular” information that could be used generally by:

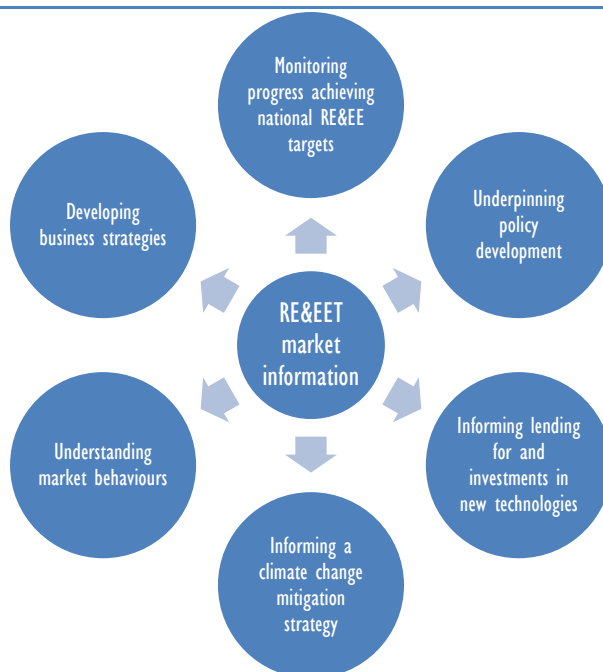
- technology manufacturers and distributors when assessing markets for their products;
- lenders, seeking reassurance that there will be sufficient potential uptake of technologies for which they provide finance; and
- investors seeking information on opportunities for investing in specific technologies.

The methodology focuses on the energy supply sector, and industrial, buildings, and transport demand sectors and is complemented by work being carried out by FAO in conjunction with EBRD on the regionally important agro-industry sector. The methodology’s outputs include:

- An assessment of priority clean energy technologies that meet a given country’s specific objectives;
- Metrics for measuring the market penetration and impact of the above technologies on energy supply and demand;
- A high-level qualitative assessment of the enabling environment for priority clean energy technologies.

The methodology's outputs can be used for a number of purposes (Figure 1). For example, information on the market penetration, deployment potential and enabling environment for priority clean energy technologies, could be used by governments to inform a technology-specific energy strategy but equally by businesses, seeking new markets for clean energy technologies.

Figure 1 • Potential uses for clean energy technology market information



## Comparisons to other methodologies

A number of methodologies exist for assessing and prioritising clean energy technologies and policies. Indeed, the IEA itself uses a range of tailored methodologies within its various publications, which have contributed to the development of CETAM<sup>5</sup>.

Methodologies have been developed for a number of different purposes and it is useful to note the differences between the various methodologies in existence. Some have been explicitly designed with climate change and sustainable development aims in mind. For example, the UNDP and UNFCCC's Technology Needs Assessment for Climate Change (TNA) is designed to "identify, evaluate and prioritize technological means for both mitigation and adaptation, in order to achieve sustainable development ends" (UNDP, 2010). Its outputs are a list of high-level climate change technologies that developing countries should prioritise for development.

While many methodologies focus broadly on "clean energy", "sustainable energy" or "low-carbon technologies", their scope varies significantly depending on their specific purpose. For example, the International Renewable Energy Agency's (IRENA) Renewables Readiness Assessment (RRA)

<sup>5</sup> Of particular relevance to the development of CETAM have been methodologies developed for the following publications: the Energy Technology Perspectives series, the Tracking Clean Energy Progress series, the Technology Roadmap series, Energy Efficiency Indicators: Fundamentals on Statistics and Essentials for Policy Making (IEA, 2014b), the Energy Efficiency Market Report series, the Medium-Term Renewable Energy Market Report series, Deploying Renewables 2011: Best and Future Policy Practice (IEA, 2011a), and Renewable Energy: Markets and Prospects by Region (2011b).

methodology is used to assess renewable energy only. At the other end of the scale are methodologies that adopt a wide scope such as the UNDP/UNFCCC's TNA, which examines both mitigation and adaptation technologies across all sectors of an economy (UNDP, 2010).

Other methodologies focus particularly on the supporting policies, availability of finance, or other factors that provide an “enabling environment” for technology deployment. For example, the World Bank’s Readiness for Investment in Sustainable Energy (RISE) methodology is designed to “assess the legal and regulatory environment for investment in sustainable energy—energy (electricity) access, renewable energy and energy efficiency” (World Bank, 2014a). Its primary outputs are ratings (expressed as an index) of a country’s support for sustainable energy.

The UN’s Sustainable Energy for All Initiative includes a high-level methodology for tracking progress towards its three strategic goals for 2030 – of universal energy access, doubling the share of renewables in the global energy mix and doubling the rate of improvement of energy efficiency.

**Table 1 • Comparison of existing methodologies related to “clean energy technology”**

	Outputs	Scope	Purpose
	Tech. penetration levels Future tech. priorities assessment Tech. cost assessment Policy and enabling env. Assessment		
World Bank RISE		Sustainable energy (renewable energy, energy efficiency, energy access)	Measuring support for sustainable energy
UNDP TNA		Climate change mitigation and adaptation technologies	Measuring needs for technology transfer in developing and emerging economies
World Bank CIRI		RETs and EETs	Measure enabling environment for low carbon technology investment
E&Y RECAI			Assessing the “attractiveness” for investment in renewable energy
IRENA RRA		RETs	Assist countries identify renewable energy technologies for deployment in the short-medium term
CETAM		RETs and EETs	Assessing clean energy technology markets including priority technologies, their market penetration and the enabling environment.

\* For RETs, the methodology can produce a set of “likely costs” (explained below). For EETs, costs are assessed qualitatively during the prioritisation step.

Sources: Ernst & Young (2015), *Renewable Energy Country Attractiveness Index (RECAI): Methodology*, [www.ey.com/GL/en/Industries/Power---Utilities/Renewable-Energy-Country-Attractiveness-Index---Methodology](http://www.ey.com/GL/en/Industries/Power---Utilities/Renewable-Energy-Country-Attractiveness-Index---Methodology), IRENA (2013), *Renewables Readiness Assessment: Design to Action*, UNDP (2010), United Nations Development Programme (UNDP) (2010), *Handbook for Conducting Technology Needs Assessment for Climate Change*, World Bank (2014a), *RISE: Readiness for Investment in Sustainable Energy - A Tool for Policymakers*, World Bank (2012), *Assessing the Investment Climate for Climate Investments: A Comparative Clean Energy Framework for South Asia in a Global Context*.

Table 1 provides a comparison between CETAM and some of the methodologies mentioned above. While there are some cross-overs, the main difference is that CETAM examines both RETs and EETs and includes steps to monitor technology *penetration* levels.

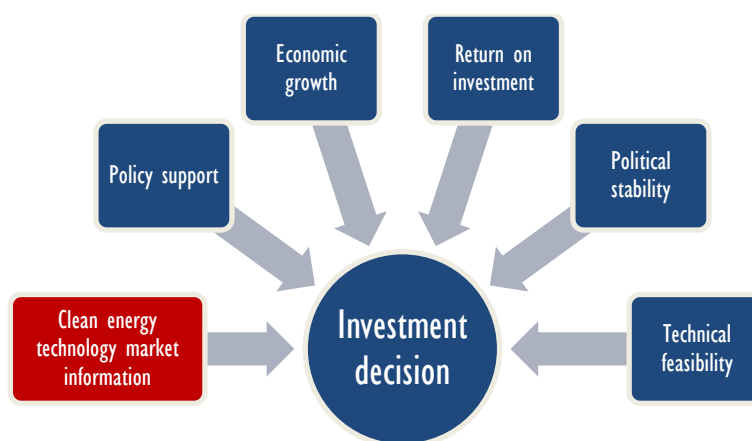
## Caveats to its use

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While CETAM's outputs can be used to inform investment decisions it is not designed to assess all of the factors that underpin investment decisions. As shown in Figure 2, any given investment decision depends on a range of factors.

The methodology is not a tool for assessing market "readiness" or "attractiveness", both of which require analysis of a much broader range of factors and ultimately a level of subjectivity because different investors will each have a different propensity to risk.

Figure 2 • Main factors that affect decisions to invest in clean energy technologies



## Overview of the methodology

CETAM follows three overall steps:

- 1) Prioritisation
- 2) Metric formulation
- 3) Monitoring.

Within these steps there are various sub-steps that differ depending on whether it is being used to assess RET or EET market conditions.

### 1. Prioritisation

It is difficult and resource-intensive to assess market conditions for all clean energy technologies within a given country. In some cases it is also unnecessary; a hot climate country may not need to monitor the penetration of space heating technologies for example. Therefore, this step involves prioritising which clean energy technologies should be measured and monitored, given local circumstances and policy objectives. For energy efficiency, prioritisation begins by selecting priority energy-using *sectors and subsectors*, whereas for renewable energy prioritisation tends

to begin by examining renewable *resources*, although demand is also an important consideration (as shown in Figure 3). For both RETs and EETs, the prioritisation phase involves assessing technologies against a range of criteria (Refer to Figures 8 and 22).

## 2. Metric formulation

In this step, decisions are made on how to measure penetration of the technologies identified in step 1. Key considerations at this step include the form of the metrics, options of constructing them, and the data necessary to calculate the metrics over time and in consistent fashion. At the end of this step, metrics will be established for each priority technology.

## 3. Monitoring

The third step involves establishing systems and procedures to monitor technology penetration over time, using the metrics established in Step 2. Decisions to be made at this step include the length of time between data collection processes, systems and processes needed to interpret indicators and trends (including potential modelling capacity), and how information is communicated. In addition to monitoring trends in energy efficiency and in renewable energy technology penetration, it is useful also to monitor the key features of the enabling environment, such as policy settings, institutional arrangements, and energy prices, which will play an important role in determining future trends in technology deployment levels.

**Figure 3 • Flow chart showing key steps of the methodology**

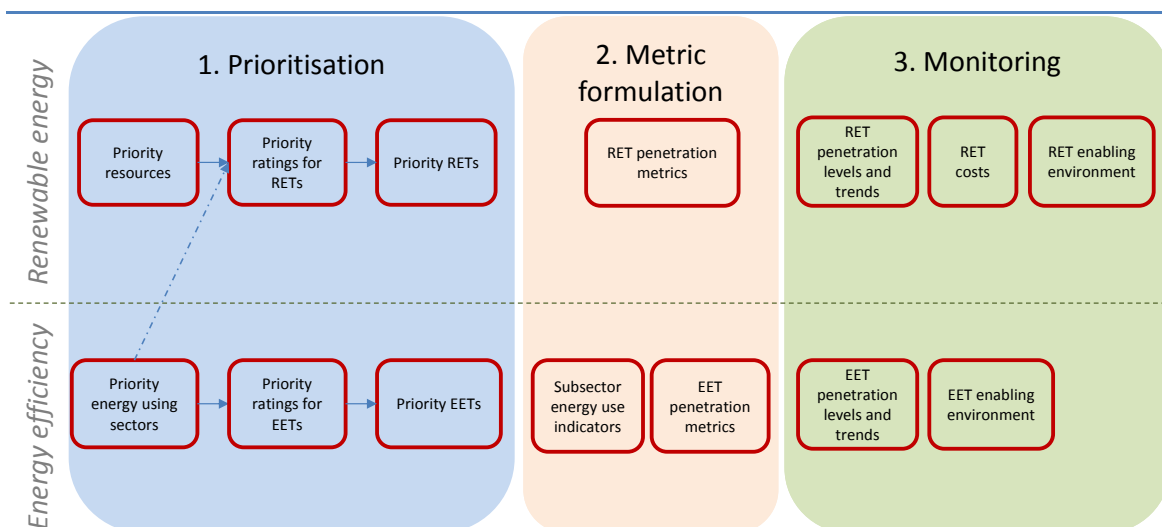


Figure 3 illustrates the three key steps of the methodology and the outputs at each step. The overall process is the same for assessing renewable energy and energy efficiency technologies although the sub-steps differ, reflecting the different challenges and issues faced in assessing supply-side compared to demand-side technologies. Certain differences in assessing RETs versus EETs are not represented in Figure 3 but are worth discussing in greater detail.

On the demand side, there are many different energy end uses across many different subsectors, each of which may have multiple EET options. Therefore, for assessing EETs, the methodology involves significant work at the prioritisation step, to establish a shortlist of priority technologies for monitoring from the wealth of options available across all end use sectors.

Establishing metrics for EETs is also complicated as for each EET, decisions must be made to determine which metrics most accurately capture the impact of the technology on energy use, when it exists as part of a wider system. For example, the energy savings associated with

replacing an inefficient motor with an efficient motor in a manufacturing process will depend on how it interacts with the other equipment in the process and the way that equipment is used. In contrast, for RETs, the impact of a technology on the energy system is easily expressed in terms of units of capacity added or units of energy generated.

Monitoring RET deployment and costs is also more straightforward because the number of commercialised technologies is more limited so data collection should be more straightforward, at least for utility-scale technologies (in theory). Conversely, accurately monitoring deployment of EETs may involve detailed audits or surveys of potentially thousands of individual firms or households to gather data, which is a very resource intensive process.

The enabling environment tends to be vastly different for each EET, particularly as EETs are perceived and used differently by different end users. For example, social factors such as how households perceive the appearance of energy efficient appliances can have a much bigger impact on the success of EET deployment compared to RETs, although similar issues may exist for small-scale RETs. This makes monitoring the enabling environment an arduous process for EETs as there is no “one size fits all” approach.

The remainder of this paper is structured as follows: The next chapter discusses the current IEA knowledge of general energy statistics in the SEMED and ETC regions. These statistics are an important element of the data needed to use the methodology. It shows that while all fifteen countries publish supply and demand data, in both regions there are still some data deficiencies (mainly on the demand-side) – at least in the data that is available to the IEA.

This is followed by two chapters with detailed explanations of how to apply the methodology to assess RETs and EETs. Each of these chapters broadly follows the structure in which the steps of the methodology take place: 1) prioritisation, 2) metric formulation, and 3) monitoring.

The IEA has produced a step-by-step guide to using the methodology as a companion to this paper (Annex 1).

## Energy data collection in the ETC and SEMED regions: The IEA perspective

Assessing technology market penetration requires a range of data: from high-level national energy supply and demand data for use at the prioritisation stage, to more “granular”<sup>6</sup> data on specific energy generating and consuming technologies.

Undertaking a thorough analysis of all data sources required for conducting technology market penetration assessments in the ETCs and SEMED countries would necessitate long-term, in-country analyses, which is beyond the scope of this study<sup>7</sup>. However, the IEA compiles national-level supply and demand data from all fifteen countries for its energy balances of non-OECD countries, which are essential for assessing technology markets. Energy supply data by fuel are a useful high-level indicator of current RET market penetration and energy demand data by sector are a minimum requirement for the first step in calculating EET market penetration

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<sup>6</sup> The “granularity” of data refers to the size in which the data fields are sub-divided. For example, electricity generation data sub-divided into only fossil fuel generation and renewable generation is not particularly granular and would instead be referred to as “course”. The granularity of generation data increases when it can be sub-divided into fuel type (e.g. gas, coal, hydropower, solar, etc.). More granular still would be data sub-divided into technology type (e.g. photovoltaic or thermal for solar) and plant size (e.g. 1-10 kW, 10 kW-1 MW, 1 MW-10 MW, over 10 MW).

<sup>7</sup> Pilot studies in Belarus, Kazakhstan and Morocco will be undertaken in 2015-16 which will further assess available data sources and collection mechanisms in these countries.

(prioritisation). By examining IEA supply and demand data for these countries, it is possible to make some broad observations about the state of data availability in the two regions.

Most of the countries report their energy supply and demand data on a yearly basis and of the fifteen countries in this study, eight report to the IEA using questionnaires that the IEA has developed in partnership with Eurostat and the United Nations Economic Commission for Europe (UNECE) (Tables 2 and 3). There are five questionnaires for collecting energy supply and demand data from countries: Coal, oil, gas, renewables and waste, and electricity and heat.

While use of the IEA's questionnaires does not guarantee that data is of a high quality, provided the country completing the questionnaire clearly understands what is required for each question, it is a good way to at least ensure data is reported in a form that is internationally comparable<sup>8</sup>. In 2016, the IEA is introducing a Russian language guidance document alongside its questionnaires, which should help to ensure Russian-speaking countries fully understand each component of the questionnaires and may help improve the quality of reporting from the ETCs.

Of the countries that currently do not report their data through IEA questionnaires, the IEA assembles national supply and demand data through other means. Some countries send their data to the IEA in other formats (for example, Morocco), while others, such as Mongolia, make their data publicly accessible, which the IEA then aligns with its database using its own data publishing methodology. Finally, for some countries (for example, Uzbekistan), the IEA only has access to secondary data sources on supply and demand.

## Supply data

In general, IEA energy supply data for both regions tend to be higher quality than energy demand data, primarily because it is easier for countries to collect supply data from the limited number of energy suppliers, in contrast to the far wider number of diverse energy consumers. The IEA is generally confident in the quality of supply data provided by countries through its surveys and even those that do not report directly to the IEA still tend to publish annual energy supply data in a format that is consistent with IEA definitions. Countries for which the IEA would like to have more accurate information about the compilation of energy supply data include Armenia, Turkmenistan and Uzbekistan (ETCs) and Egypt in the SEMED region.

The most relevant energy supply data for use with CETAM is renewable energy data. For many of the ETCs and SEMED countries, currently available data on renewable energy generation is mainly limited to hydropower – a reflection of what is actually installed in these countries. Some countries that report to the IEA directly are also able to provide details on total hydropower installed capacity and generation with the data organised by plant size: less than 1MW, 1 to 10MW, or over 10MW.

The IEA also collects data on non-hydro renewable electricity capacity and generation but as yet, this is not reported by plant size. Solar thermal heat produced and consumed directly is reported according to the sector in which it is consumed. For example, in 2013, Jordan reported that it had generated 6071 TJ of solar thermal heat, of which 5024 TJ was generated and consumed in the residential sector and 1047 TJ generated and consumed in the commercial and public services sector.

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<sup>8</sup> The IEA has been actively involved in formulating the UN International Recommendations on Energy Statistics which will seek to improve the harmonisation of international energy statistics.

## Demand data

Demand data in all the countries under this study tends to be lower quality than supply data, primarily because it is harder to collect, especially for sectors with a large number of energy consumers. Within countries, demand data is generally compiled using a combination of sources including electricity and gas meters (where they exist), sales data, and surveys. As with energy supply data, the IEA collects consumption data from countries through its five questionnaires (for countries that use them), national statistics publications and secondary sources. Of the 15 countries under this study, the most comprehensive energy demand datasets tend to be from those that complete the IEA questionnaires. In some cases, the IEA has to apply default assumptions to estimate energy demand.

It is difficult for countries to compile accurate demand data without systems to exchange information between energy consumers, suppliers and statistics agencies amongst others. Many of the countries under this study are still in the process of establishing the necessary institutional frameworks to gather good quality demand data.

Where data collection systems are well established, countries report energy demand by source (e.g. coal products, oil products, electricity, etc.) and sector (for example, industry, transport, etc.). In addition, subsectoral demand data is collected. For example, industrial energy demand data can be sub-divided into subsectors such as iron and steel, food and tobacco, and non-metallic minerals (amongst others). Likewise transport demand data is reported by mode (road, rail, etc.). An example of the disaggregation level across energy sources and sectors of the data collected by the IEA is provided at Annex 3. This dataset is particularly useful for prioritising which sectors and subsectors to focus on when assessing the market penetration of EETs (explained more in later sections of this paper).

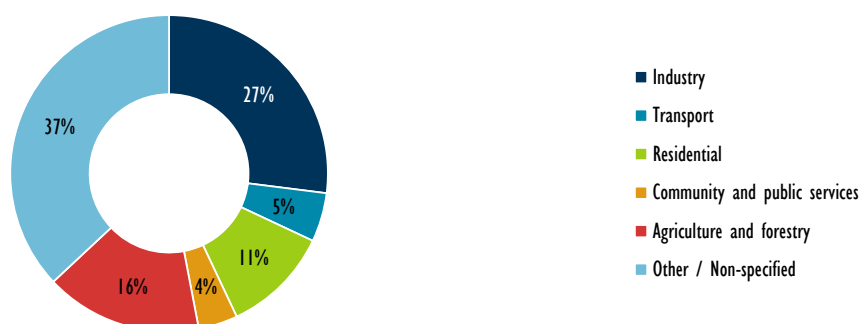
Energy demand data in both regions has recently improved, thanks in part to progress made through the INOGATE program in the ETCs, and MEDSTAT program in the SEMED region. Examples of countries with improved consumption data include Morocco and Tunisia (SEMED) and Belarus and Azerbaijan (ETCs). Countries for which the IEA wishes to improve its understanding of energy demand data or increase the granularity of reported data, include Armenia, Mongolia, Kyrgyzstan Tajikistan, Turkmenistan, Uzbekistan (ETCs), Egypt and Jordan (SEMED).

The issue of demand-side data granularity in both regions is worth discussing in greater detail. As sectoral demand data is necessary for the first step in assessing EET market penetration, it is important that ETCs and SEMED countries are able to provide a breakdown of total energy demand by sector and subsector. While most of the fifteen countries do provide details of sectoral energy demand, some have a large proportion of energy demand that is classified as “other/non-specified” (IEA, 2015c). For example, Figure 4 shows that the largest proportion of Tajikistan’s energy demand (37%) is currently classified as “other/non-specified”. The problem is more pronounced at the subsectoral level. Figure 5 shows the IEA’s best available information on industrial energy use in Jordan, with 61% of industrial energy demand classified as “other/non-specified”.

While domestic analysts in these countries may have better access to information and could potentially explain the non-specified sources of demand, such incomplete datasets pose problems for analysts and potential technology investors who rely on transparent, international data sources. Notably, it would be difficult to conduct an EET market assessment without explaining the non-specified portion of demand, which is necessary to identify priority sectors and subsectors.

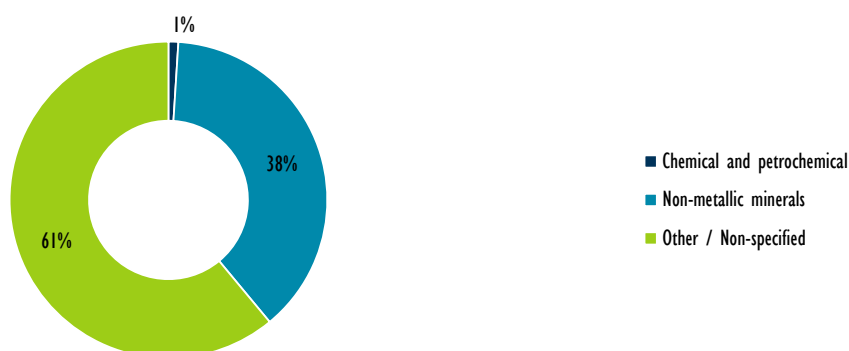
IEA experience gained through conducting pilot studies in Belarus, Kazakhstan and Morocco suggests that in many cases the portion of energy consumed classified as non-specified is in fact accounted for, and is simply not categorised due to misunderstandings about category definitions. This suggests the quality of demand data could be improved quite easily in these regions if resources were dedicated to working with each of the countries to explain data reporting categories in depth.

**Figure 4 • Energy demand by sector in Tajikistan (2013)**



Sources: IEA (2015c), *Energy balances of non-OECD countries*, (2015 Edition).

**Figure 5 • Industrial energy demand by subsector in Jordan (2013)**



Sources: IEA (2015c), *Energy balances of non-OECD countries*, (2015 Edition).

## Overview of relevant agencies and opportunities for strengthening data collection methods

In most of the ETCs, centralised statistical agencies are responsible for the collection of energy data. These agencies tend to work with other government agencies and non-government organisations to gather energy data. For example, the National Statistics Office of Georgia (Geostat) collects energy data by collaborating with the Ministry of Energy, Georgian State Electric System, the Georgian Electricity System Commercial Operator, and the Georgian Oil and Gas Corporation, amongst others. Table 2 shows the key agency in each ETC responsible for energy data collection and whether that country completes the IEA's annual energy questionnaires.

**Table 2 • Official sources of energy data in ETCs**

Country	Main Sources of official data	IEA/Eurostat/UNECE questionnaires completed for 2013?	Direct contact between IEA EDC and government?
Armenia	National Statistical Service	Yes but renewables questionnaire not completed. Electricity questionnaire data used for renewables data.	Yes
Azerbaijan	State Committee of Statistics and Ministry of Economics	Yes	Yes
Belarus	National Statistical Committee of Belarus, Ministry of Energy	Yes	Yes
Georgia	National Statistics Office of Georgia (Geostat) / Energy Efficiency Centre Georgia	Yes	Yes
Kazakhstan	Committee on Statistics of the Republic of Kazakhstan	Yes	Yes
Kyrgyzstan	National Statistical Committee of Kyrgyzstan	Yes	Yes
Moldova	National Bureau of Statistics of the Republic of Moldova	Yes	Yes
Mongolia	National Statistical Office of Mongolia	No	Yes
Tajikistan	National Statistics Agency's Office of Industry and Investment in Construction (supply data) and Office of Trade and Services (export, import and consumption data).	No	No
Turkmenistan	State Statistical Committee	No	No
Uzbekistan	State Statistics Committee	No	No

In the SEMED countries, energy ministries tend to be the main contact points for obtaining energy data, noting that Egypt has recently shifted responsibility for energy data collection to the Central Agency for Public Mobilization and Statistics (Table 3). Tunisia is currently the only SEMED country that has completed the IEA questionnaires but Jordan and Morocco's data tends to be reported in a form that is consistent with IEA definitions. Egypt is the only SEMED country for which the IEA has difficulties obtaining data.

**Table 3 • Official sources of energy data in SEMED countries**

Country	Main Sources of official data	IEA/Eurostat/UNECE questionnaires completed for 2013?	Direct contact between IEA EDC and government?
Egypt	Central Agency for Public Mobilization and Statistics	No	Yes
Jordan	Ministry of Energy and Mineral Resources	No	Yes
Morocco	Ministère de l'Énergie, des Mines, de l'environnement et de l'eau	No	Yes
Tunisia	Observatoire National de l'Énergie, Agence Nationale pour la Maîtrise de l'Énergie	Yes	Yes

In both regions there are ongoing challenges to ensure that:

- supply and demand data are consistent with each other
- data is reported regularly
- data meets international reporting standards and is internationally comparable.

Institutional arrangements within Government are part of the solution, and it is noted that many countries in the study are making good progress improving their institutional frameworks for data collection. That said, in stakeholder consultation sessions for this project with representatives from ETCs and SEMED countries, some participants raised overlapping responsibility for data collection as an institutional barrier to improving data quality.

In addition, it should be noted that organisations outside of national ministries and statistics agencies will be important sources of *technology-level* data, which are necessary for assessing technology market penetration. For example, sales data on particular equipment may be obtained from retailers, manufacturers, or industry associations. However, acquiring such data will require good coordination and establishing safeguards to protect confidentiality where data are considered commercially valuable.

## Potential users of CETAM in both regions

The methodology presented in this paper can be used to produce datasets on energy technology market penetration, which will be particularly useful for policy makers and regulators in both regions. Tables 4 and 5 provide some initial suggestions of government and non-government organisations that could benefit from using the methodology in both regions.

**Table 4 • Organisations in ETCs that could use CETAM**

Country	Organisations
Armenia	Ministry of Nature Protection, Ministry of Energy and Natural Resources, Energy Saving and Renewable Energy Fund (R2E2).
Azerbaijan	State Agency on Alternative and Renewable Energy Resources (SAARES), Ministry of Industry and Energy.
Belarus	Ministry of Energy, Department of Energy of the State Standardisation Committee (including all seven regional Energy Efficiency Departments that sit within its jurisdiction).
Georgia	Ministry of energy, Ministry of Environment and National Resources Protection, National Energy and Water Supply Regulatory Commission, Georgian Energy Development Fund, Energy Efficiency Centre, Sustainable Development and Policy Centre.
Kazakhstan	Ministry of Energy, Samruk-Kazyna (sovereign wealth fund), The National Fund (state-run fund), Council for Sustainable Development, Committee on Renewable Energy Sources.
Kyrgyzstan	Ministry of Energy and Industry, Scientific Technical Centre for Energy, Centre on the Problems of Using Renewable Energy Resources, Directorate for Small and Medium-size Power Facilities, State Agency for Environmental Protection and Forestry, Coordinating Commission on Climate Change.
Moldova	Ministry of Economy, Ministry of Regional Development and Construction, Energy Efficiency Agency, Ministry of Environment, Energy Efficiency Fund, Moldovan Sustainable Energy Financing Facility.
Mongolia	Ministry of Energy, Mongolia Energy Development Centre.
Tajikistan	Ministry of Energy and Water Resources, Ministry of Trade and Economic Development.
Turkmenistan	Ministry of Energy.
Uzbekistan	Ministry of Economy, Ministry of Agriculture and Water Resources, UzbekEnergO, Fund for Reconstruction and Development of Uzbekistan.

**Table 5 • Organisations in SEMED countries that could use CETAM**

Country	Organisations
Egypt	Ministry of Economic Development, Ministry of Water Resources, Environmental Affairs Agency,
Jordan	Ministry for Energy and Mineral Resources, Royal Scientific Society.
Morocco	Ministère de l'Énergie, des Mines de l'environnement et de l'eau (MEMEE), ADEREE, MASEN, IRESEN, SIE, Energy Development Fund, Moroccan Federation of Energy, or the Moroccan Association of Wind and Solar Energy (AMISOLE).
Tunisia	Agence Nationale de Maitrise de l'Énergie, Observatoire National de l'Énergie, Ministère de l'Industrie, de l'Énergie et des Mines

## Capacity building and training for data collection

To improve the quality of data, statisticians from SEMED countries and ETCs could benefit from training in data collection, analysis and dissemination.

Statisticians would benefit from training on data collection methodologies for each energy source (gas, coal, oil, or renewables), tools for tracking energy pathways, advice for avoiding common errors, and systems for tracking energy prices. Training in maintaining databases, identifying outliers, and making accurate estimations in the absence of data would be useful in these countries, particularly in contexts where the quality of data is poor. On the data analysis side, important topics include checks and consistency, database structure, identifying statistical differences using spreadsheets other data management software, and dealing with differences between supply side and consumption data. Ministries and statistics centres may also require support to upgrade their data technology platforms to allow for more sophisticated analyses.

The ability to disseminate data and report using international standards is a particularly important skill, as it ensures the integrity of data not only at the national level, but for global energy databases such as that maintained by the IEA's Energy Data Centre. The IEA offers training courses in presenting energy balances, common international questionnaires (including the IEA questionnaires) for international reporting, and dissemination techniques.

While there is flexibility in defining and constructing energy indicators, their accuracy strongly depends on the quality and detail of available energy end use data. Statisticians often lack capacity in developing measurable, quantifiable indicators that can be regularly reported. In the past, IEA has offered training courses on energy efficiency indicators with topics including: defining and developing indicators, especially through disaggregation by residential, transport, and industry sectors; interpreting indicators; and specialised techniques for tracking energy consumption. When presented alongside data collection techniques, statisticians receive a holistic understanding of how to produce and analyse data that gives a full picture of the energy market in their countries.

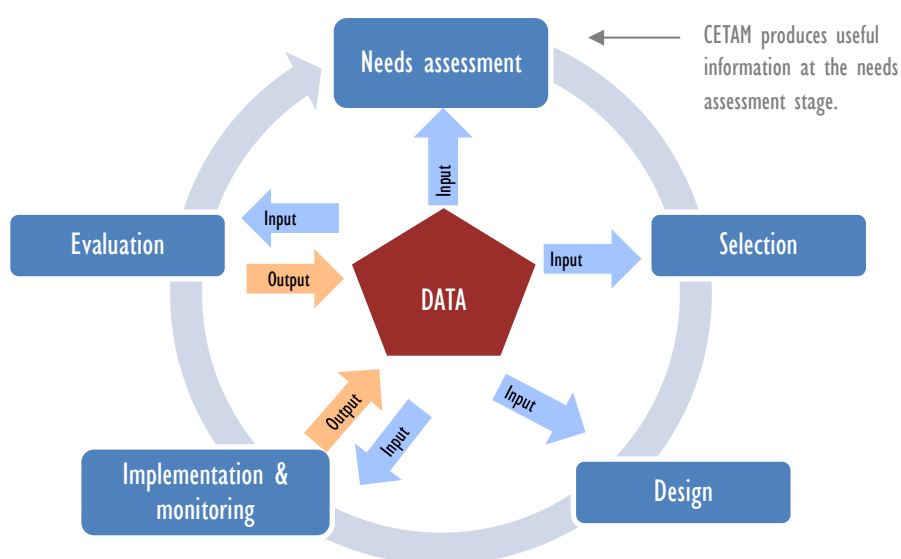
The IEA offers regular energy statistics training courses for energy statisticians, industry experts and other government officials from emerging economies. These are conducted both in Paris, France, and in emerging economies, including in the ETCs and SEMED countries. For example, a targeted energy statistics course was provided in Cairo, Egypt in late 2014, followed by training for Egyptian policy makers to plan, implement and monitor energy efficiency policies in 2015.

## Data for policy making

CETAM is, at its core, a way of analysing a range of information and datasets to produce a new set of information on technology market conditions. One of the primary uses for this information is to inform the design of policies to support deployment of clean energy technologies.

Data is an essential ingredient for policy makers as it empowers them to make evidence-based decisions. It is both necessary for policy making and is a product of the policy cycle. At early stages of the policy cycle, data tends to be an *input* that informs decision making. At the latter stages of the cycle, data is also an *output* of the policy cycle, which can feed into new policy making processes. The main stages of an ideal policy cycle are shown in figure 6 below, which also demonstrates where data is an input to the policy process (indicated by blue arrows) or output of the policy process (indicated by orange arrows).

**Figure 6 • The need for and production of data throughout the policy process**



Policies can be costly and resource intensive so should not be implemented without carefully considering the need for intervention. Therefore the first stage in the cycle is to assess policy need, by undertaking a thorough analysis of the available data. The sort of information produced by CETAM, including market penetration data, is particularly useful for the policy needs assessment stage. For example, to determine the need for tax incentives for fuel-efficient vehicles, policy makers could apply the methodology to determine: a) if fuel-efficient vehicles should be a technology priority; b) the current market penetration of such vehicles; and c) if there is a supportive enabling environment for these vehicles. The answers to these questions would provide a justification (or not) for implementing tax incentives.

During the policy selection stage of the cycle, data can help inform decisions on which policy mechanisms are most appropriate given national circumstances. Data on the maturity of the market (such as the current costs of clean energy technologies, the number of installers and installers' skill levels, etc.) can help determine which policy mechanisms are most appropriate (refer to Figure 12 on the renewable energy policy deployment journey).

After selecting a policy or suite of policies, detailed policy design can begin. Once again, decisions on the design of specific policy elements are only possible with a solid evidence base of good quality data. For example, designing a green certificate scheme for renewable electricity requires

deciding which generators will be obligated under the scheme (e.g. generators of a particular size, electricity utilities or industrial facilities, or both, etc.). Determining the obligated parties is generally based on the size of the generators, which requires detailed data on how much electricity each generator produces.

Once a policy has been implemented, the policy itself can produce useful data – provided it is designed with data collection mechanisms alongside. For example, a policy requiring commercial building owners to report building energy performance would generate a useful dataset on the energy use of the commercial building stock. Over time, policy makers should continually monitor the data generated by policies and measures as it could help inform other policy decisions. In the case of buildings, data from mandatory reporting could be used to inform minimum energy performance standards; policy makers could use the dataset generated from reporting, alongside information on the availability of efficient technologies in the marketplace, and other factors, to determine when and by how much standards should be strengthened.

The final stage of the policy cycle is the evaluation stage. Data generated over the lifetime of the policy is used to evaluate the policy's impact. During the evaluation process, indicators are produced providing a quantitative indication of the policy's impact. These comprise a useful data set for informing future policy decisions. Indicators to assess the penetration and impact of clean energy technologies, developed by applying CETAM, can be used at the policy evaluation stage, to assess whether policies are having their desired impact.

## Using CETAM to assess renewable energy technologies

This chapter outlines how CETAM can be used to assess the market for renewable energy technologies (RETs). It is organised into three sections, which correspond to the main steps of the methodology:

- **Prioritisation**, taking account of the available renewable resources, their potential match with the strategic energy needs and priorities, the potential costs of the energy produced and the appetite for engaging in the development of immature technologies.
- **Establishing indicators, metrics and data** needs to follow the evolution of the prioritized technologies.
- **Monitoring progress** towards deployment goals and internationally benchmarked costs and **assessing the enabling environment** in place to deliver the deployment and cost targets.

The potential and the extent and pace of RET deployment in a particular country or market is determined by a number of factors including the renewable resource, and the costs of delivered energy. However, RET deployment is also influenced by the “enabling environment”, which can either put barriers in the way of deployment, or provide a helpful context in which investment can flow and deployment grow<sup>9</sup>. Key elements of the enabling environment for RETs include, amongst others:

- the strategic priorities which provide the drivers for enhanced renewable energy activities
- the overall policy framework
- the remuneration framework available for the technology, that determines whether investors will be able to make a reasonable return on their investment
- the availability and cost of finance
- measures being taken to remove non-economic barriers including:
  - putting in place a clear and transparent permitting system
  - ensuring the necessary supply chain capabilities are in place
  - taking measures to tackle skills shortages
  - providing public information
- the extent to which the renewable source can be integrated into the energy system<sup>10</sup>.

In this methodology the primary indicators of market development are the level and rate of deployment of particular technologies, and the costs of deployment relative to other sources of energy and to international benchmarks. Both the rate of deployment and the costs of the energy produced are critically dependent on the enabling context. (For a fuller discussion see IEA 2015a). For this reason, Step 3 of the methodology includes a qualitative assessment of the key factors comprising the enabling environment.

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<sup>9</sup> For a more in-depth discussion of the enabling environment for RETs, see IEA 2015a.

<sup>10</sup> This is a particular issue as far as the deployment of variable renewable sources of electricity, such as wind and solar. It is though also an important factor for renewable heat, where the availability of district heating schemes can facilitate the use of renewable sources, and for biofuels in transport where blending limits may constrain deployment in the absence of facilitating measures.

## Step 1: Prioritisation

The range of renewable energy technologies is in fact a rather disparate set of options which can provide electricity, heat or transport fuels. Each renewable resource can be exploited using a number of different technology options as shown in Figure 7, which are at different stages of market maturity.

**Figure 7 • Renewable energy resources mapped to typical renewable energy technologies**



Source: Based on IEA (2011a), *Deploying Renewables 2011: Best and Future Policy Practice*.

Table 6 shows estimates of the current global levels of energy production and the range of typical costs from the principal sources and technologies for electricity, heat and transport fuel production illustrating that some technologies are widely used under commercial conditions, whereas others are still at earlier stages of deployment or still in the development phase.

The technologies can operate at widely different scales and be used to serve different markets. For example solar PV can be used at a utility scale, on commercial scale buildings or to provide electricity to individual homes. It can be integrated into a grid, or be installed in off-grid or mini-grid situations.

It is important to make some distinction between the various technologies, applications and scales of operation, since the opportunities, benefits, risks and costs may differ depending on the

circumstances. Table 7 shows the categorisation used within the IEA to collect and analyse deployment and cost data for renewables production.

Within a particular country, prioritisation between these technology options will be based on five main factors:

- the renewable resource, which determines the availability and accessibility of energy and is a key determinant of the cost
- the likely cost of generated energy
- how the renewable energy technology options match with the country's strategic priorities
- technology maturity and national ambition to develop immature technologies
- the market opportunities for the technology.

**Table 6 • Maturity and costs of some renewable energy technology options**

Technology	Status	Global Energy Production 2014	Range of costs
<b>Power Generation</b>		<b>(TWh/y)</b>	<b>(USD/MWh)</b>
Biomass	Commercial	428	45 - 240
Geothermal	Commercial	77	35 - 200
Solar PV	Commercial	184	40-150
Solar CSP	Early commercial	7.1	120 - 250
Hydro	Commercial	4024	20-90
Wind (On shore)	Commercial	677	38 -100
Wind (Off shore)	Early commercial	25	103 -265
Wave and tidal	RD&D	1.1	200 - 460
<b>Heating and Cooling</b>		<b>(EJ)</b>	<b>(USD/MW<sub>Th</sub>)</b>
Solar water heating	Commercial	1.0	160--500
Geothermal	Commercial	0.4	55-165
Traditional biomass	Commercial	32	NA
Modern biomass	Commercial	12	9 - 55
<b>Transport Fuels</b>		<b>(EJ)</b>	<b>(USD/LGE)</b>
Bioethanol from sugar and starch	Commercial	2.0	0.4 – 0.6
Biodiesel from oil crops	Commercial	1.0	0.6 -0.8
New technologies for transport fuels	RD&D – Early commercial	0.01	0.8 – 0.9

Source: Based on IEA data (IEA, 2015d) and updated with more up-to-date information.

**Table 7 • Classification of renewable options**

Technology	Sub-segments	Size
<b>Electricity Generation</b>		
<i>Solar PV</i>	Residential scale	<20 kW
	Commercial scale	20 kW to <1 MW
	Utility scale	1 MW and above
	Off-grid	Any, but typically less than 1 MW
<i>Wind</i>	Wind onshore	Any
	Wind offshore	Any
<i>Hydro</i>	Hydro small	< 1 MW
	Hydro medium	1 MW – 10 MW
	Hydro large	> 10 MW
	Pure pump	-
	Mixed capacity	-
<i>Bioenergy</i>	Agricultural residues (straw)	Distinguish between electricity only and CHP
	Landfill gas	
	MSW	
	Other bio-gases	
	Wood fuels combustion (co-firing)	
	Wood fuels combustion (dedicated)	
<i>Geothermal</i>		
<i>Ocean</i>	Tidal Barrage	
	Tidal Stream	
	Wave power	
<b>Renewable Heating and Cooling</b>		
<i>Solar Heating</i>	Residential	
	Commercial	
	District Heating	
	Industry	
<i>Bioenergy</i>	Residential	
	Commercial	
	District Heating	
	Industry	
<i>Geothermal</i>	Residential	
	Commercial	
	District Heating	
	Industry	
<b>Renewable Transport</b>		
<i>Liquid Biofuels</i>	Bioethanol	
	Biodiesel	
	Advanced biofuels	

In establishing priority RETs for a particular market, the primary consideration is the availability of an adequate renewable resource which impacts on the technical potential but also strongly influences the likely costs of the energy provided, which is the second factor for consideration. Aside from resources, likely costs are also primarily determined by the cost of finance in this methodology.

The third important factor is the extent to which deploying particular technologies can meet important strategic needs – for example to improve energy security or energy access, or to help with global or local environmental issues.

The fourth factor is whether the country wants to focus on well-developed technologies (which may need to be adapted to meet local conditions) or whether it wants – and can afford – to participate in the research, development and early commercialization efforts needed to bring a technology to commercial maturity.

The fifth factor is the market opportunities available. This refers to the extent to which there is sufficient demand for the energy supplied by RETs, and their ability to augment or replace existing sources of energy. RETs that are capable of delivering the exact form of energy required in a country in terms of fuel (electricity, heat or transport fuel), will be more likely to be prioritised.

These factors are interlinked and should be considered in relation to each other. For example, a country might only have scarce renewable resources but may elect to develop those resources regardless of the cost, due to strategic factors such as increasing energy security. Other countries may have an abundant renewable resource and little demand for energy but will choose to develop their resources to derive income from energy exports.

**Figure 8 • Step 1: The prioritisation process**

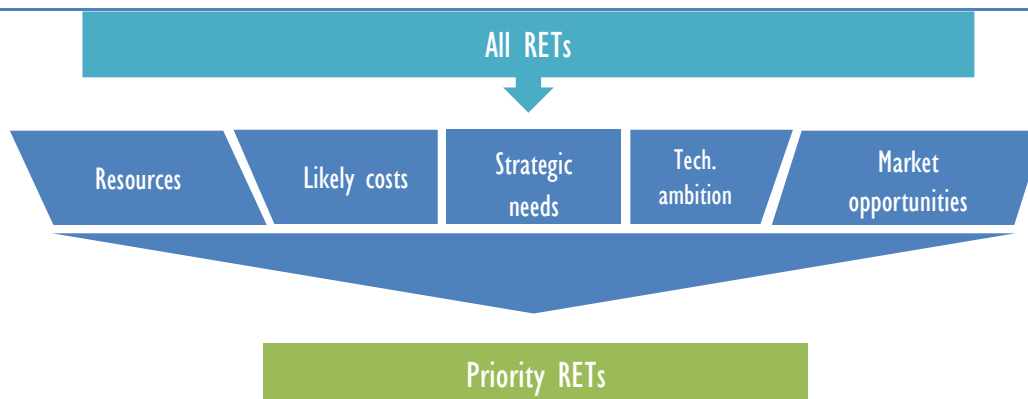


Figure 8 shows how step 1 of the methodology (prioritisation) is designed to identify priority RETs in a given country, based on the four factors outlined above. The following sections outline how these factors should be considered in the assessment.

### ***Establish renewable resources***

The primary factor to consider in prioritising RETs is the availability of an adequate resource. This determines the potential for technology deployment and strongly influences the costs of energy production. Each region needs to focus its attention on the most promising resources for their circumstances. For example, relatively few countries have easily exploitable high temperature geothermal resources, whereas many countries have areas with good wind or solar potential.

There are a number of different ways to assess a country's renewable energy resources<sup>11</sup>. A preliminary screening of physical resource potential to determine the most promising renewable resources can be quite quickly carried out based on available resource data. A more detailed quantitative assessment taking technical, economic and market issues into account is a more complex and time consuming exercise. For the purposes of prioritising RETs using CETAM, a high-level assessment of physical resources should be sufficient.

There are a range of existing resource maps and tools which can give a preliminary indication of the extent to which a country or region has good renewable resources. These are often based on satellite data and use geographical information systems to progressively apply constraints. Many of the global resource datasets can be accessed via IRENA's Global Renewable Atlas. For example, Figures 9 and 10 show parts of global maps of wind and solar potential (IRENA, 2015).

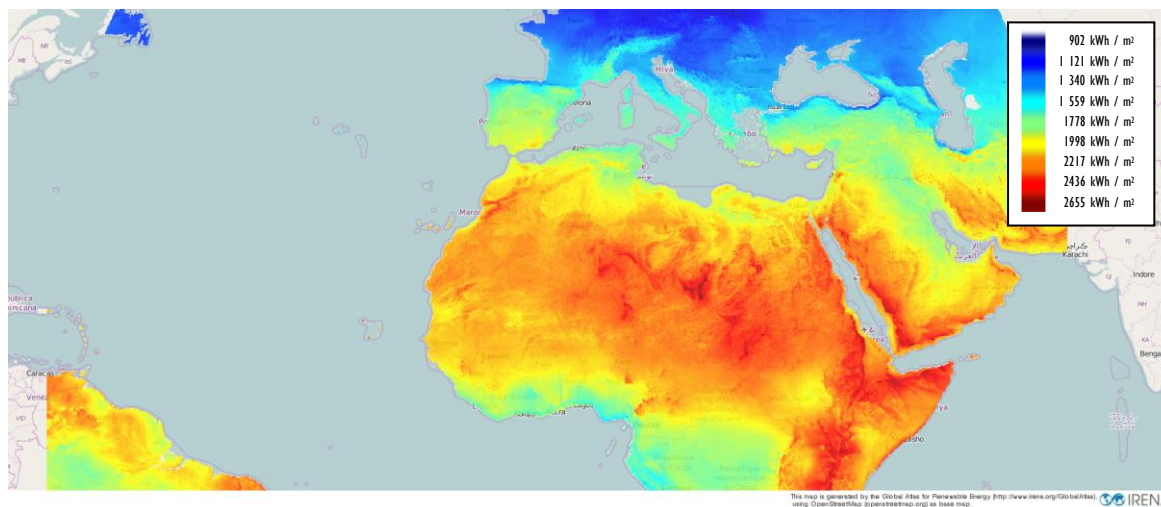
In general, the absolute availability of a renewable resource is not the major constraint as far as technology deployment opportunities are concerned. Instead, other constraints determine technology deployment, such as the real technical or economic potential. There are however some instances where resource constraints directly affect technology deployment opportunities. For example, the opportunities for large scale hydro plants which can be established in a way which is both economic and with due regard to wider environmental and social sustainability concerns may be limited. Often hydro assessments identify site specific deployment opportunities which can be sustainably exploited. Once these are used, resource potential is effectively exhausted. Overall the IEA hydropower roadmap indicates that globally around 30% of hydro potential has been exploited, but there are wide regional variations, with for example 92% of the African resource still unexploited (IEA, 2012a).

Similar situations may occur for some finite biomass resources. For example, for waste-based fuels such as landfill gas or municipal waste, resource availability is linked to waste flows, which could be reduced with better waste management practices, meaning that further opportunities may be limited. The exploitation of land-based bioenergy resources can also be limited by sustainability concerns around bioenergy production and use. Bioenergy resource assessments must therefore take into account potential impacts. These include for example impacts on land use for agriculture, and the effects of removing crop residues for bioenergy purposes on alternative uses or on the need to retain residues to preserve soil fertility, along with other potential sustainability issues (IEA and FAO, forthcoming). Some bioenergy resource assessments show the locations and scale of major biomass sources such as sawmills and agricultural processing plants.

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<sup>11</sup> For example, the National Renewable Energy Laboratory (NREL) distinguishes between four types of assessment of renewable energy potential which progressively take more constraints and factors into account (NREL (2012), *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis*).

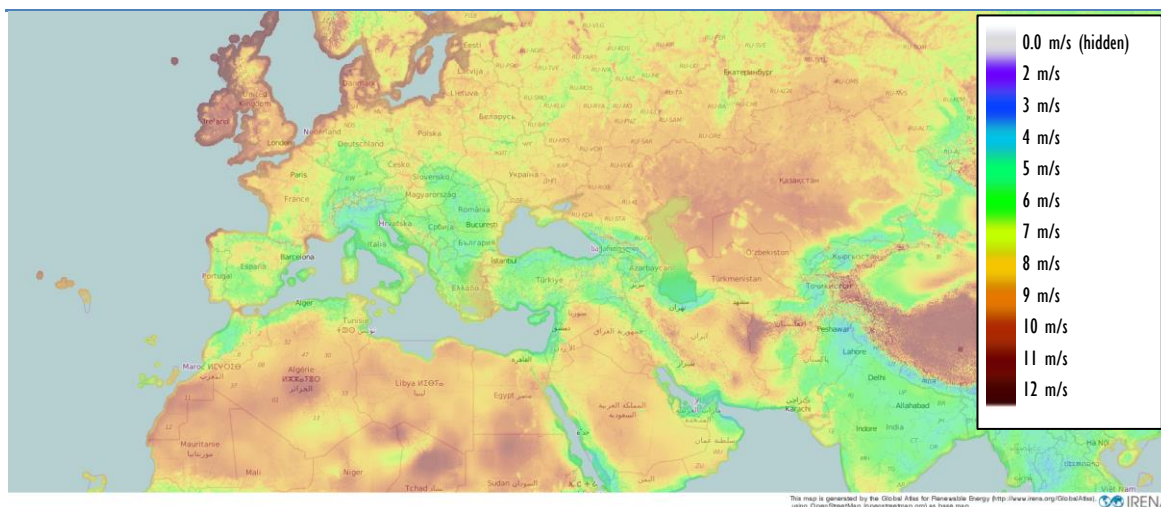
**Figure 9 • Example of a resource map showing solar PV potential**



Note: HelioClim3v4-MC Yearly Global Horizontal Irradiation for the year 2005 in kWh/m<sup>2</sup>, <http://globalatlas-test.masdar.ac.ae/?map=529>; Copyright 2013 MINES ParisTech / Transvalor; This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: IRENA (2016), "Global Atlas for Renewable Energy" webpage, <http://irena.masdar.ac.ae/>; MINES ParisTech / ARMINES / Transvalor – HC3v4 – Dec. 2015.

**Figure 10 • Example of a resource map showing wind potential**



Note: DTU 2015 Global Wind Atlas, average wind speed 1km at 200m height, <http://globalatlas-test.masdar.ac.ae/?map=103>; This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: IRENA (2016), "Global Atlas for Renewable Energy" webpage, <http://irena.masdar.ac.ae/>; Technical University of Denmark (DTU), Department of Wind Energy (DTU Wind Energy).

The preparation of detailed resource assessments has been a major activity of a number of governments supported by international bodies. Providing these more detailed assessments is a very useful way in which governments and international organisations can refine their estimates of the contribution that a particular technology could make and to identify particularly promising regions for deployment, taking into account constraints on land use (such as areas of nature conservation or particular biological diversity for example), the relationship to where grid lines exist, and other constraints and opportunities.

It should be recognized that these detailed resource and potential assessment studies are an effort-intensive and time-consuming activity. In many cases research is needed to establish resources levels on a highly disaggregated basis and to overlay the constraints on land use and other factors. Stakeholder engagement is then essential in order to identify the most promising opportunities and quantify their potential and the principal barriers to delivery. Because of this it is felt that these detailed studies are outside the scope of this particular methodology.

The methodology outlined here therefore takes a pragmatic approach to examining resource potential. It is confined to screening resources based on an overall appreciation of the *physical* resource potential, based on estimates of resource potential that have already been carried out, and on more detailed resource and potential studies where these are available. Where there is prima facie evidence that there may be promising opportunities to exploit a particular resource (say for example solar energy for water heating) but where this has not so far been explored quantitatively, then the methodology would highlight this as an area for further work.

Resources are only one driver for RET deployment and in many cases, countries with plentiful resources are yet to deploy RETs to any significant level. For example, the available wind resource in Mongolia could provide the electricity needs of the country many times over. Similarly the solar potential of Jordan is many times that of their electricity demand, and the wind potential of Kazakhstan far exceeds their domestic demand. In all of these countries, despite plentiful resources, RET deployment remains negligible so it is necessary to move beyond a simple assessment of physical resource availability to consider other constraints – for example by considering how to match supply to demand and to find opportunities for exporting wind power profitably to surrounding countries that could use the energy.

### **Likely costs**

The likely future cost of the renewable energy produced will be another important factor affecting the prioritisation. The currently achieved national costs of renewable energy production may not provide a realistic basis for this assessment, since local costs depend on the degree of local market maturity, the policy and regulatory framework in place, and financing conditions as well as the local resource conditions (e.g. levels of insolation, the wind regime, the availability and costs of biomass resources). It is therefore better to base estimates of likely achievable future costs on international benchmarks for capital, operating and finance costs and corrected for local resource conditions. In this part of the analysis it is assumed that an appropriate and helpful enabling environment can be put in place so removing substantial policy and regulatory risks (the enabling environment is considered later).

Annex 2 provides a basis for estimating the costs for the various electricity generating technologies which could be achieved based on local conditions likely to be found in the different countries covered by this study.

### **Meeting strategic needs**

Countries will also give priorities to technologies that meet their strategic needs. For example a country which is highly dependent on oil imports and which has a significant bioenergy potential may prioritise biofuels for the transport sector. Countries reliant on imported gas and with a high heating demand may give particular attention to bioenergy or solar technologies to provide heat. Priorities will also depend on to what extent there is an existing centralized supply of electricity, or whether off-grid or mini-grid renewables can provide improved energy access.

It is useful to identify the strategic drivers which can be met in part by an increase in renewable energy generation, since if a clear rationale for deploying renewables is in place policy makers are

more likely to put in place and maintain a supportive enabling framework. Such an analysis also helps identify the technology options and market sectors which can most readily contribute to the key goals.

Renewables feature significantly in global and national efforts to mitigate the climate change impacts of growing energy use and the move toward a lower-carbon energy future. However renewables can help meet a number of other important national objectives (IEA 2015a). These include:

- reducing the exposure of economies to rising or fluctuating fossil fuel prices in countries which are or which are becoming dependent on fuel imports (e.g. in Egypt)
- displacing fossil fuel consumption by making more resources available for export in oil or gas exporting countries (e.g. Kazakhstan)
- improving energy security by reducing dependence on imports and increasing the diversity of energy supply (e.g. for heat in Ukraine and other Eastern European countries)
- playing a role in reducing other environmental impacts of fossil based energy systems (e.g. in China)
- providing opportunities for economic development by stimulating the use of indigenous resources and increased employment and innovation in renewable energy system development, manufacture and operation (e.g. Morocco).

In many emerging and developing economies it is these non-climate motivations that are driving renewables deployment. While each of these drivers can apply in almost all countries with renewable energy potential, the relative weight given to each tends to vary significantly between countries depending on national priorities.

Key questions which help to establish the strength and relative weights of the key drivers include:

- Is there a specific national greenhouse gas target and is renewables seen as a key part of the strategy to achieve it?
- Are there other significant energy related environmental problems which renewables can help reduce?
- Is demand growing and are renewables seen as one way of meeting the need for more energy?
- Is energy access an issue and if so are renewables seen as part of the solution either via grid connected power or distributed off-grid solutions?
- Is energy security a significant issue? Can renewables help diversify energy supply and reduce dependence on imports, particularly when these come from one particular source?
- Are fuel import bills a big drain on the economy which indigenous resources could offset?
- Are renewables seen as a source of economic development, providing a spur to employment (for example by providing jobs in rural areas for bioenergy harvesting, or for more high-tech jobs in manufacturing renewable energy systems or components)?
- Could using renewables reduce domestic use of fossil energy in exporting countries, so freeing up more resources for export?

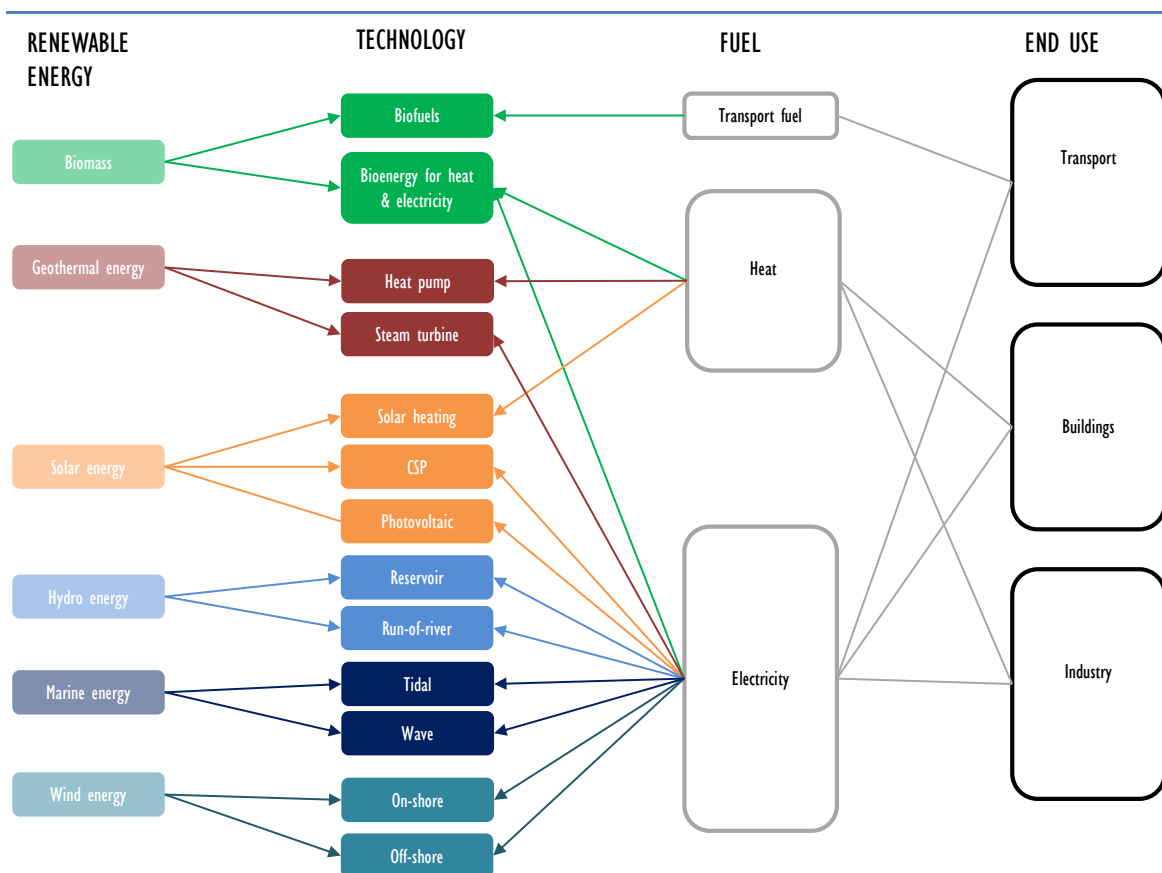
### ***Technology maturity and ambition***

An additional element which needs to be factored into the prioritisation exercise is the maturity of the technologies to be adopted and the country's appetite to participate in the early stages of development or deployment for less mature technologies. Many of the renewable technologies are already widely deployed in many markets under fully commercial terms. Others are less

mature and may be at the point where early market experience is just being obtained, where technical demonstration is still under way, or where research and development is still the priority. Considerable investment may be needed to bring the technology to the point where it can commercially be deployed. However, by participating in these activities a country could attain key skills, competences or intellectual property, which has an economic value. This depends on the appetite to invest in new technology development and deployment.

The strategic priorities, as discussed above, often determine whether a country has ambitions to be a technology developer or technology taker. For example, driven by a strategic need to diversify its energy supply and with strong R&D capabilities, Germany chose to invest in solar technology R&D, despite not having the world's best solar resources.

**Figure 11 • Renewable energy technologies mapped to renewable energy resources, fuels and end uses**



Source: Based on IEA (2011a), *Deploying Renewables 2011: Best and Future Policy Practice*.

### Market opportunities

Considering actual and projected sectoral energy consumption information allows for the identification of particular sectors or specific energy uses where renewables can make the most useful impact. This may include:

- contributions to grid connected power supply (e.g. from large scale wind, solar, geothermal or bioenergy plants)
- distributed grid-connected power supply (e.g. building integrated solar PV)
- stand-alone power production for remote sites or for specific priority energy needs, where reliable data on these uses is available, (for example PV powered irrigation)

- provision of heat through district heating or by distributed heating systems (e.g. solar heating or biomass boilers)
- use of biofuels for transport purposes.

Based on energy consumption patterns and the practicality and economics of renewables supply to these sectors, reasonable target levels for market penetration in the key sectors can be assigned. This process is best carried out based on stakeholder engagement, to identify realistic long-, medium- and short-term ambitions.

Information on major energy end uses, the fuels used by these end uses, and whether these fuels are sourced from domestic or imported energy sources is all important for informing priority RETs for market penetration assessment. Guidance on data sources and steps for identifying major energy end uses is provided under the chapter on assessing EET market penetration.

It is important to trace the relationship between major energy end uses and fuels (transport fuel, heat or electricity) to identify the country's fuel consumption patterns. The fuels used by a country will be a primary determinant of which RETs have the greatest potential to satisfy demand.

Figure 11 shows RETs mapped to renewable energy resources, fuels and end uses. RETs that are capable of exploiting domestically available renewable energy resources and can supply priority fuels for key energy end uses in the country will rank as high priority technologies in the initial longlist of RETs for assessment.

For example, where transport is a major energy end use in the country, transport fuels, and possibly some electricity, will be required. Logically, this leads to the conclusion that biofuels could be a potential RET, provided there is also an ample domestic source of biomass.

### **Overall Prioritisation**

Once each of the criteria above has been assessed an overall judgement on the priority technologies can be made. The different factors are quite distinct and so it is not simply a question of adding scores, and it is difficult to provide specific advice on weighting between the different factors since this will depend very much on local factors and preferences. However it is possible to distinguish between four categories which can be considered:

- **Ready for deployment:** options for which there is a good resource, the technology is fully commercialised internationally, the cost of energy production is attractive and there is a good fit with strategic priorities.
- **Potential:** options which there is a promising resource and which could, in principle, help meet strategic needs, but for which other factors are less positive. In these cases the appropriate option may be to carry out some feasibility studies and some pilot projects so as to test the technologies under local conditions.
- **Needing further evaluation:** resources and technologies for which there is a lack of information on the local resource characteristics and so on the likely costs. Further work to improve the information base is indicated.
- **Low priority:** options for which there is a poor resource base, high costs, poor strategic fit or where there are few market opportunities.

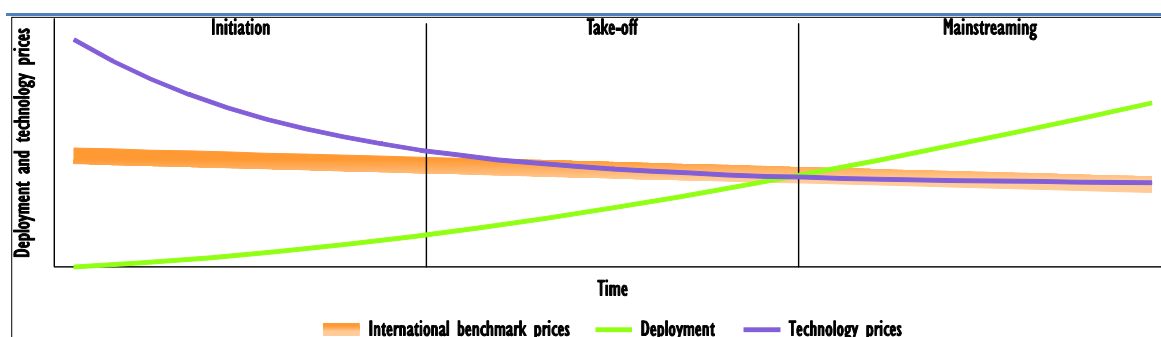
## **Step 2: Indicators, metrics and data**

In CETAM, the **level and rate of deployment** and the **cost of energy supplied** are considered to be the most significant indicators for measuring and monitoring RET market penetration.

The aim from a policy maker’s perspective is to secure an enhanced level of deployment of the prioritised technologies in order to deliver the desired results in terms of the environmental benefits, energy access, improved energy security, or economic development. The level and rate of deployment is a key indicator of the success or otherwise of the policy and regulatory initiatives put in place. It also provides a measure of the market size as far as other stakeholders are concerned.

On the other hand, policy makers want to achieve enhanced levels of deployment in the most cost-effective way possible to reduce the burden of the policy on consumers or on the budget. It is therefore critical to look at the costs at which the energy is being produced and to what extent the renewable deployment is being subsidized. This is also very relevant to other stakeholders, since the cost-competitiveness or reliance on financial support will condition future market opportunities and the dependence on financial support from governments and hence the policy risks associated with market development.

Figure 12 • The deployment journey



Source: IEA (2015d), *Medium Term Renewable Energy Market Report 2015*.

When a technology is introduced to a new market, it is to be expected that its costs will be higher than in more mature markets. Initially, equipment costs will be higher as it takes some time for supply chains to develop. The appropriate regulatory framework may not be in place and investors may expect a higher return on investment to offset the perceived risks of operating in a new market. As deployment grows it is to be expected that costs will decline and converge with international norms (taking into account differences in resource and other local factors).

Deployment will follow the “deployment journey” as shown schematically in Figure 12). IEA analysis suggests that deployment follows three distinct phases – Initiation, Take-off and Mainstreaming and that the policy priorities differ between these three phases (IEA 2011a and 2015a). The aim of policy is to try and make to the convergence with international costs as rapid as possible so as to reduce the costs of deployment. Recent experience – including in Egypt and in Dubai – have shown that good design of policies and regulations can lead to a “leap-frog” effect so that very competitive prices are achieved very early in the deployment process. The aim of this step of the assessment is to see what stage has been reached along the policy journey.

### Indicators for deployment

It is possible to choose from a range of indicators to assess the levels of deployment, which are more or less disaggregated by technology and market sector. At the lowest level it is possible to monitor the deployment of individual technologies likely to play an important role in terms of energy generation and capacity and, broken down by the principal market sectors.

Once these individual streams have been quantified they can be aggregated to provide a total renewables contribution to each of the three main subsectors – electricity, heat and transport (and expressed as a proportion of total production in each case).

A further step is to express the contribution of renewables as a fraction of total energy production or use. This is the indicator adopted as the prime metric for the renewable energy strand within the Sustainable Energy for All (SE4All) initiative, where the chosen indicator is the proportion of renewable energy in total final energy consumption<sup>12</sup>. It is also the approach used within the EU's Renewable Energy Directive, which set binding national renewable energy targets for each of the member states for 2020, in terms of the proportion of renewables in their final energy consumption.

Assembling these more highly aggregated measures of renewable energy contribution becomes more demanding on the availability and quality of the national energy statistics, covering not just the renewables sector but the whole energy economy.

For tracking market developments it is preferable to monitor deployment levels in terms of energy generation and generation capacity at a level of detail which corresponds to the individual technologies and market sectors which have been prioritized – particularly where financial support is provided to encourage market development. Depending on the priorities and on data availability and quality, more aggregated indicators can then be calculated when appropriate.

### *Energy Generation Data*

The critical information here is the level of energy generation from the specific source under consideration on an annual basis. The necessary data is usually collected on a national basis according to the basis energy statistics definitions and methodological assumptions according to the agreed UNSD International Recommendations for Energy Statistics (UNSD, 2011). The IEA and other international organisations work proactively with countries to develop national statistical competences and to improve the quality and availability of national statistics.

The availability and quality of the available data varies significantly between countries. The relevant statistics for renewable energy are sometimes not given priority in countries where this has historically played a small role in the energy mix. Even in countries with good quality energy statistics, there are often problems with some aspects of renewable energy information, particularly where those concern information on distributed systems such as off-grid electricity supply and distributed renewable heating solutions. In addition, while the traditional use of biomass plays an important role in providing energy for cooking and heating in many rural economies, the quantities used are often poorly understood.

### **Grid connected power, biofuels and commercial heat**

As the production of grid-connected renewable power is a highly regulated activity, generation information is generally available through grid operations and reported in annual national statistics and by the IEA, UN and other organisations. This is also true for biofuels blended into transport fuels, and for commercially traded heat (used for example in district heating networks). That said, as noted in the chapter on data, publicly available data on grid-connected renewables in these regions is still not easily accessible in certain countries.

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<sup>12</sup> The rationale for this choice and the methodology for its calculation can be found in the 2015 Sustainable Energy for All Tracking Report (World Bank, 2014b).

## Off-grid power and distributed heat production

For other sources – particularly for off-grid power generation and for heat supply – information on deployment levels and actual generation is harder to ascertain with certainty. National and global trends in off-grid power generation are only reported by the IEA for OECD and some of the larger developing economies. The IEA’s Solar Photovoltaic Power Systems Agreement collects information for on- and off-grid solar installations and some other countries collect data on the use of renewable energy in off-grid and mini-grid systems but this information is not yet collected and reported on a global basis, and there is indeed no internationally agreed set of definitions, although IRENA has proposed such a categorization (World Bank, 2014b).

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To better establish a quantitative picture of deployment of such distributed systems countries can employ the following methods:

- Include questions concerning distributed electricity and heat generation in national energy surveys.
- Where such uses are supported by national or sub-national financial support schemes, record installed capacities which receive support.
- Establish links with commercial suppliers of systems and their industry associations to monitor and track system sales, particularly for specific sectoral opportunities identified as being of high priority during the priority setting phases of the methodology.

For small-scale off-grid electricity installations and for heating systems, metering and monitoring the actual energy delivered may be impractical and costly. As an alternative it is possible to estimate electricity or heat generation based on local conditions and usage patterns established via a series of monitored user trials.

## Traditional bioenergy

In many emerging and developing economies, the “traditional” use of biomass is a major source of energy for cooking and heating, but also – because of the inefficient nature of the way the fuels are used – a major cause of health problems (due to impacts on indoor air quality) and other social problems. Often the biomass used for energy purposes is not collected or processed in sustainable ways, so many governments and international organisations are actively promoting a move away from such fuels towards either more efficient and sustainable ways of producing and using biomass, or towards efficient use of alternatives such as fossil fuels – indeed access to improved energy sources is one of the major pillars of the Sustainable Energy for All initiative (World Bank, 2014b).

Because of the informal nature of the ways in which this biomass is collected and used, statistics for the volumes of biomass used and the energy produced from it are notoriously difficult to obtain, with estimates often based on outdated survey information. Where improving access to modern energy systems for cooking and heating or improving the efficiency of biomass utilization (e.g. through improved cook-stove design) is deemed to be a priority, some additional efforts are merited to improve the understanding of the quantities of biomass used traditionally, along with the types of supply chain which are in place (for example, for charcoal production and distribution).

## *Indicators for renewable energy costs*

The cost of renewable energy is monitored to establish to what extent the energy supplied is competitive with other sources, and to establish how the costs compare with those in other countries or regions.

For **grid connected electricity** supply the unit costs of electricity can be estimated by looking at the total remuneration provided to the owner of a source of renewable energy. The form of remuneration depends on the way that payments are structured within a country. For example, this may be based on:

- selling the electricity via the wholesale market, perhaps supplemented by a premium or a value provided by a “green certificate” or
- a fixed price power purchase agreement or a feed-in tariff.

Different types of incentive have different characteristics over time, depending, for instance, on whether they relate to up-front investment costs or operating returns. Therefore, the remuneration for each technology in each country is expressed as a levelised return over a fixed period and discounted at a fixed rate (IEA, 2011) (See Box 1 for details).

### **Box 1 • Calculating a levelised cost**

To establish the total generation cost, it is necessary to take into account all revenue and support payments. Different types of incentive have different characteristics over time, depending, for instance, on whether they relate to up-front investment costs or operating returns. Therefore, the remuneration for each technology in a country needs to be expressed as a levelised return over a fixed period and discounted at a fixed rate.

The total generation cost is calculated taking into account two different types of remuneration: up-front and per MWh remuneration. Up-front remuneration includes all payments made at the beginning of the project, such as cash rebates. In addition, tax incentives are assumed to be received at the beginning of the project. Per MWh remuneration includes wholesale market revenues, certificate revenues, and feed-in tariff/feed-in premium payments as appropriate. Wholesale market and certificate prices are assumed to remain stable at current values.

To account for the incentive payment-scheduling issue, both investment streams are levelised to a standard period, (for example, 20 years), with a discount rate, (for example, 6.5%).

To allow a comparison of the extent to which the technology is being supported, this annualized remuneration level is compared with the costs of energy provided by conventional sources. The way of estimating this depends on what information is available and on the way the markets are structured. For large-scale production of renewable electricity one comparison could be with the wholesale electricity price. It is important, in making these comparisons, to take into account any subsidies or taxes applied also to more conventional forms of generation so as to compare like with like. For example, if the utility is not recovering all its costs via power sales then this needs to be factored into the calculation.

For **off-grid power generation and heat production** the cost of the renewable source must be estimated taking into account capital, operating and financing costs for the system and comparing these to the costs of generation using fossil based power, for example those of a diesel generating system taking into account the full costs of delivering fuel to the user (potentially in a remote location). Any support to capital, operating or fuel costs (e.g. subsidized diesel prices) must be fully taken into account.

For biofuels for transport the production costs of the fuels (e.g. ethanol or biodiesel) can be compared on an energy equivalent basis with those of gasoline and diesel, again taking account of taxes and subsidies.

## Step 3: Monitoring deployment and the enabling environment

The aim of this part of the methodology is to establish:

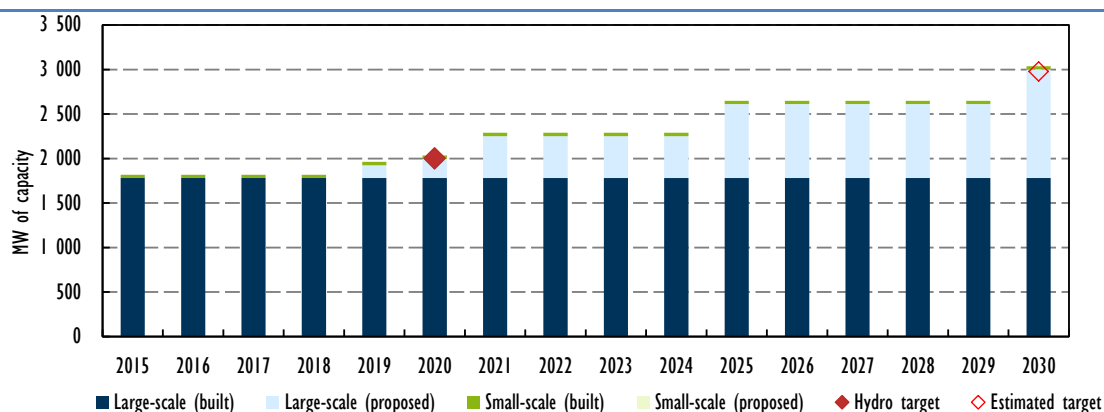
- how the level of deployment is changing and how this deployment trajectory compares with a benchmark – national expectations, regional comparisons or overall benchmark to a global scenario such as the IEA *WEO* 450 Scenario (IEA, 2011a); and
- the cost of the energy being supplied and how it compares with fossil fuel alternatives and international benchmarks for the technology.
- whether the key elements of a helpful enabling environment are in place.

### Tracking Deployment

Annual analysis of the deployment statistics discussed above allows the absolute and relative contribution of a particular renewable technology or of a combination of technologies to be assessed, and a time series provides a measure of market development.

When available, data on the pipeline of anticipated projects for future years – based for example on awards of generating contracts or on planning approvals, etc. – can be added to give a perspective on likely future deployment levels. This is often the case with large-scale renewable energy projects, where detailed plans tend to be made public well in advance of construction. In using such information on future deployment, account must be taken of the risks that the projects will not be commissioned, and where possible it may be useful to distinguish between the projects – for example between projects actually in construction, those where the finance is arranged (“financial closure”), those for which all planning permits are available, etc., and then to discount to some extent deployment associated with projects at earlier stages of development.

Figure 13 • Tracking hydropower deployment in Morocco



Source: IEA (2016c forthcoming), *Clean Energy Technology Assessment Methodology Pilot Study: Morocco*.

This information can then be compared against a series of benchmarks including:

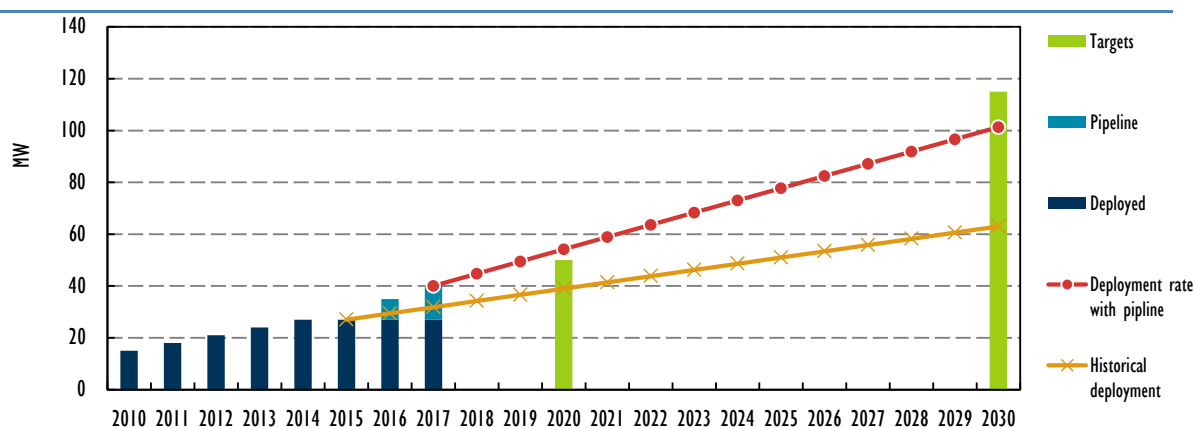
- national ambitions as set out in targets or goals;
- regional benchmarks with countries with similar conditions and ambitions; or
- international benchmarks – for example the UN’s Sustainable Energy for All Goal to double the contribution of renewables to global energy supply between 2010 and 2030.

The use of external benchmarks is recommended as they provide a check on the degree of ambition of the national targets.

Figure 13 provides an example of how deployment of large-scale RETs can be monitored using information on the project pipeline. Based on information about when projects will be completed, the total MW of new renewable energy capacity can be charted for a given period. In this case, Morocco’s target of 2000MW of hydro capacity by 2020 is shown to be feasible, given the projected deployment timeline of projects in the pipeline.

In some cases, it is very difficult to gather information about future deployment. This is particularly the case for small-scale technologies such as rooftop solar PV or solar water heaters, or when making deployment projections into the distance future. In these instances, it is necessary to check if the deployment trajectory is on track compared to a future target by estimating the “rate of deployment” using a quantitative indicator. For example, if there is a target to increase the deployment of a particular technology from a level of A in Year 1 (say 2010) to a target level of T in Year 3 (say 2020), and a deployment of B has been achieved by Year 2 (say 2015), then the relative rate of progress can be assessed by comparing the rate of increase of deployment against the rate required to meet the target.

**Figure 14 • Tracking deployment against internal and external benchmarks where detailed information on the project pipeline is unavailable**



This can be expressed using the following formula:

Rate of deployment needed to meet the target:  $R_t = (T - D/A)(Y3 - Y1)$

Achieved deployment:  $R_a = (B-A)/(Y2-Y1)$

If  $R_a > R_t$  then deployment is on track.

A similar analysis can be done taking into account the prospective deployment based on the analysis if the project pipeline where this is available.

A stylized example of such an approach is illustrated graphically in Figure 14.

In the example in Figure 14, deployment in 2010 is 15MW (A=15); has reached 27MW in 2015 (B); and the target in 2020 is 50MW, (T=50).

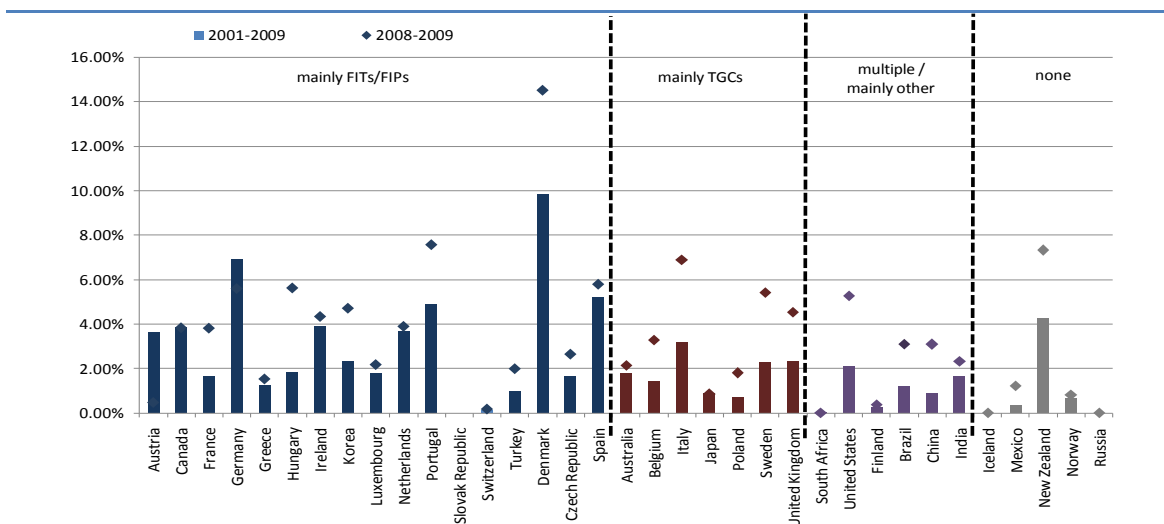
So the desired rate of progress is  $(50-15)/10 = 3.5\text{MW/year}$ . Actual progress is  $(27-15)/5 = 2.4\text{MW/year}$  indicating that progress is so far behind that needed to reach the target (represented by the orange line). However if analysis of the project pipeline indicates that a further 13 MW are likely to be commissioned by 2017, then the rate of deployment is set to increase and this provides some comfort that the overall target for 2020 is likely to be achieved, noting that there is still uncertainty as to whether the 2030 target will be reached (represented by the red line).

Example of such tracking can be found in:

- Tracking progress of EU countries towards their mandatory renewable energy targets established under the EU’s Renewable Energy Directive (EC, 2015); and
- Tracking of global and national progress towards the Sustainable Energy for All goal of doubling the contribution of renewables as a percentage of global energy use (World Bank, 2014b).

The IEA used such an approach in 2011 to develop a Policy Impact Indicator to benchmark country progress towards the levels of additional renewable power generation envisaged between 2005 and 2030 in the IEA World Energy Outlook’s 450ppm Scenario (IEA, 2011a). This allowed the assessment of the efficacy of various policy options in stimulating deployment. Figure 15 shows an example of the analysis for on-shore wind deployment. In this case a policy impact indicator was calculated by comparing the actual annual increase in deployment in a specific country with that required to meet the level of increase in generation expected in the IEA WEO 450 Scenario between 2005 and 2030. The figure shows the progress for each country, comparing countries relying on different types of policy mechanisms. The graph compares average progress between 2001 and 2008 (the bars) with progress in the year 2008/09 (diamonds) showing generally a significant acceleration.

Figure 15 • On-shore wind: Policy impact indicator



Source: IEA (2011a), *Deploying Renewables 2011: Best and Future Policy Practice*.

### Tracking and Benchmarking Costs

Once the costs of a particular technology option have been established, these can be tracked annually, to see how prices are progressing and how they compare with regional and international benchmarks.

It is interesting and instructive to compare the remuneration levels paid for a particular source of renewable energy between countries and to see how these levels are progressing. In order to make a “fair” comparison it is necessary to take account of the different resource levels from country to country – for example for wind and solar technologies. These impacts can be substantial; a solar PV system in North Africa could yield at least twice as much electricity each year as the same capacity system in central Europe, and so at the same system costs the electricity in North Africa would be substantially cheaper. It is also necessary to take local financing conditions into account.

It is therefore necessary to compare the costs achieved with international bench-mark costs adjusted to take account of local resource and financing conditions. The benchmark costs used in Part 1 of the methodology (see Annex 2) can be used for this purpose. It is also instructive to compare costs with the range of costs achieved internationally and with those from similar (e.g. neighbouring) countries.

### ***Evaluating the enabling environment***

The rate of deployment and the costs of renewable energy produced in a particular country are very much affected by the policy, regulatory and market context, which collectively are referred to as the “enabling environment”. The enabling environment needs to tackle the range of important economic and non-economic barriers to progress. These can impede or halt deployment altogether, and indirectly increase costs by requiring additional up-front investments. Factors such as a lack of clarity in the regulatory system constitutes a significant business risk and will deter potential developers and investors from entering a market.

A number of methodologies are being developed to assess the status of the enabling environment so as to check the state of “market readiness” for renewables deployment compared to established best practice. These include IRENA’s Renewables Readiness Assessment (IRENA, 2013) and the World Bank’s Readiness for Investment in Sustainable Energy Index (World Bank, 2014a). In this methodology, the approach adopted to assess the enabling environment is to conduct a qualitative assessment of the five major factors the IEA has identified which can significantly enhance or hamper the prospects for cost-effective deployment. These are:

- Policy, regulatory and institutional factors;
- Financial and market factors
- Technical and Infrastructure factors
- Social factors
- Environmental factors.

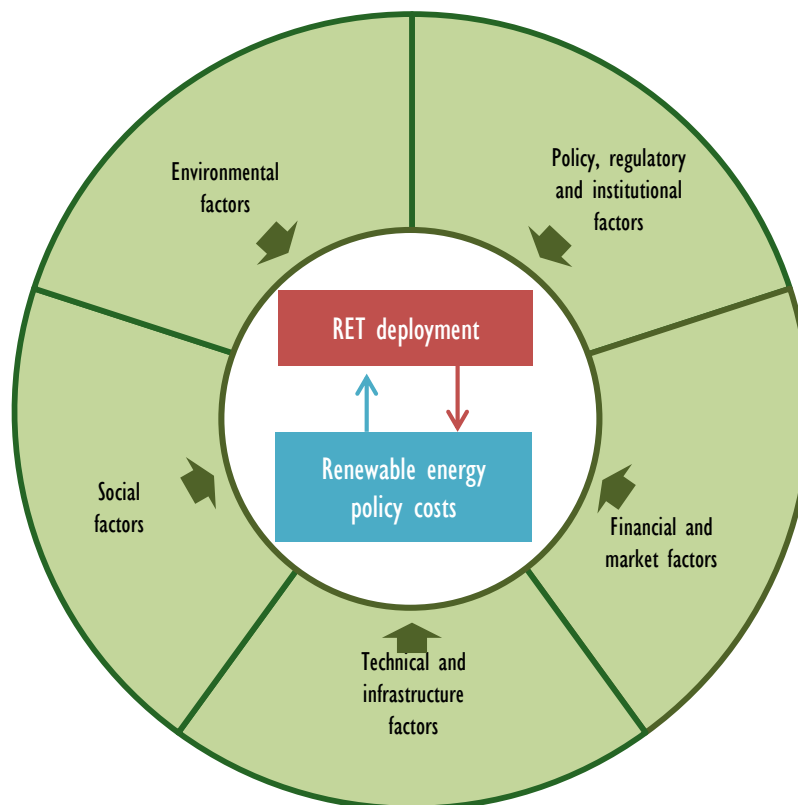
Within these factors, issues that deserve particular attention include:

- the overall policy framework
- the remuneration framework available for the technology, that determines whether investors will be able to make a reasonable return on their investment
- the availability and cost of finance
- measures being taken to remove non-economic barriers
- the extent to which the renewable source can be integrated into relevant part of the energy system.

Owing to their importance, these issues are discussed at length in the following section.

Figure 16 shows schematically how the factors that comprise the enabling environment combine to influence RET deployment and costs.

**Figure 16 • How the enabling environment affects RET deployment and renewable energy policy costs**



Note: Each of the green surrounding segments represent factors that comprise the enabling environment. Collectively, these factors influence RET deployment and policy costs.

### *Policy, regulatory and institutional factors*

#### **Policy framework**

A clear and credible national renewable energy strategy provides confidence to all stakeholders, including potential developers and investors, that renewables are being taken seriously in a country and that policies put in place will be sustained over a significant period. A well-articulated strategy providing short-, medium- and longer-term deployment targets is an important way of establishing such confidence. It should be clearly linked to the overall national energy strategy and be clearly designed to meet strategic needs – for energy security, to help meet environmental goals, or to provide economic benefits. It should be developed by engaging all the government bodies likely to be involved or affected, with inputs from the range of industry players likely to play a role in its delivery.

Clear signals that a long term market for systems and services will be available encourages the establishment of a competitive market for the principal components of renewables systems, the supply chain for other components, and services for construction and maintenance. This has an impact on the investment costs of renewables projects. It also provides confidence to developers and investors that a sizeable market will exist and so encourages their participation as the

overheads associated with establishing a presence in a market and doing due diligence on the regulatory framework are significant.

However, targets on their own are not sufficient to galvanise action and need to be backed up by a set of actions which provide a viable market and remuneration framework, tackle non-economic barriers and set a framework for integration of renewables in the whole energy system.

Key questions which allow the assessment of the robustness of the policy framework include:

- Is renewable energy included in the national energy plan?
- Are there clear targets for short, medium and long term?
- Is there a credible and detailed action plan?

### **Institutional framework**

The institutional framework within which renewable energy operates varies significantly between countries. In particular there are differences in the way that electricity markets are organised with some market-based electricity systems and some which are state owned and operated monopolies.<sup>13</sup> Significant renewable energy deployment can be stimulated in all cases. What is important from the point of view of developers is that there is clarity of responsibility between the bodies responsible for establishing renewable energy targets and policies, and for the regulation of the detailed rules and procedures which govern their implementation.

### **Permitting**

Renewable energy projects generally require a number of permits or approvals before construction and operation can begin. These may include land-use permission, environmental permits, (sometimes called planning permission), approval for grid connection and other measures necessary to comply with legal and regulatory requirements. A full environmental impact assessment study may be required in some cases.

In some cases it is not even clear to developers of renewables projects what permits are required or who is responsible for issuing them. In other cases approvals can require a complex set of documentation with unclear responsibilities and duplication of authorisation processes, taking significant amounts of time to navigate. Such complexities pose a risk to developers of projects – who are not sure whether the necessary approvals are likely to be forthcoming or if they have fulfilled all the necessary conditions – and push up the cost of developing projects.

In order to encourage development it is desirable that permitting procedures are clear before a project starts, and which ministries or regulatory bodies are responsible for managing the permitting process. There should also ideally be clearly established criteria which define whether permission is likely to be given. In some best practice cases a “one-stop shop” approach has been established where a prospective developer only has to deal with one organisation that coordinates the various approvals needed on the basis of information provided by developers. It is also best practice to monitor the time needed for the various elements of the approval process and to use this as the basis for streamlining the approvals process.

In evaluating this aspect of the enabling framework, key questions are:

- Is the permitting system transparent and efficient?

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<sup>13</sup> See the recent IEA publication *Repowering Markets: Market design and regulation during the transition to low-carbon power systems* (IEA, 2016b) which discusses the market design and regulation for low carbon power systems.

- Is guidance on permitting available?
- Are permitting times monitored?
- How long does permitting take?
- How many agencies are involved in the permitting process?

## *Financial and market factors*

### **Remuneration**

It is important that the levels of remuneration available are sufficient to provide an adequate level of return on investment. It is also vital that the contractual terms for energy supply (for example for the off-take of the power produced) are sufficiently robust or else raising finance for projects will be difficult or impossible.

One key factor is to consider if **remuneration levels are clear and predictable**. It is vitally important that investors have a clear perspective on how their income will be calculated, without which it is highly unlikely investment will take place. In addition, and as discussed earlier, investor risks will be reduced if there is a long term secure payment mechanism in place – e.g. via a long term power purchase agreement or via a fed-in tariff.

Another key factor is the **reliability of the off-taker**. It is essential that the other party to the supply agreement is reliable and credit worthy. If this is a private sector body (e.g. a utility) then it needs to be able to demonstrate that it has the financial resources to meet the terms of the contract over an extended period.

If the counterparty is a government body, then there need to be clear evidence that the government is willing and able to stand behind any contractual commitments via a guarantee. In some cases the government itself may not be seen as credit worthy, and in that case some international guarantee may be needed to ensure that the off-take contracts are “bankable”.

Finally, it is important to assess if the **revenue streams are sufficiently high to provide an adequate return to investors**. This is clearly a critical factor in ensuring deployment happens. To check this, it is necessary to compare the remuneration levels available with the costs associated with generation and to estimate if the income is sufficient to provide an adequate rate of return to investors.

In order to calculate the costs it is necessary to have an estimate of local costs broken down into the main components, i.e.:

- capital costs
- operating costs
- soft costs (such as for project development and marketing)
- finance costs.

It is also necessary to identify all sources of income and financial support available (for example capital grants or tax allowances (see Step 2)). This information allows the calculation of a rate of return on investment which can be compared with what is known to be the rate necessary to stimulate investments taking into account local financing conditions and risk perceptions or with a default rate (an 8% rate is often used in such calculations (IEA 2011)).

### **Finance**

The availability of adequate finance for the necessary investments is a key requirement for a growing renewables sector. Given the capital intensive nature of the technologies the rate at

which capital can be made available is also a key determinant of the costs of the energy produced.

National factors have strong implication for the availability and costs of finance. These can be gauged by consideration of:

- the ease of doing business
- country credit rating
- currency volatility.

Another key issue for this part of the evaluation is the availability of debt and equity finance locally, including through national or international development banks.

### *Technical and infrastructure factors*

#### **Market Access and Integration**

Market access and integration is a particular issue in the electricity sector and in particular for variable renewable energy sources such as wind and solar PV. IEA analysis has indicated that at low levels, integrating such sources should pose few problems if some relatively simple guidance is followed, although the issues vary from region to region depending on the grid configuration and on the degree to which other generating sources are flexible (IEA 2014). As the percentage of variable renewables rises, further regulatory and management steps are needed to ensure that they can be integrated without problem. At very high shares, further investment is likely to be needed to improve the flexibility of the electricity system.

Most countries within the current EBRD study areas are still at the early stages in terms of the degree of variable renewables generation so integration is not yet the main barrier to further deployment, although some countries are realizing that they have enormous potential which could outstrip national demand (e.g. Mongolia for wind, Tajikistan for hydro, Jordan for solar PV or CSP).

However, in all cases it is important that appropriate steps are taken in good time to ensure that the necessary grid infrastructure is in place to deal with additional generation, which may be in areas where the grid is weak or needs reinforcing since the lead time for such investments are likely to be at least as long as those for the generation systems themselves.

The essential steps depend on the level of penetration of the variable renewables, so in the assessment methodology different criteria are presented for the three deployment stages, as shown below.

#### **Initiation**

- Is grid access allowed?
- Are grid connection costs transparent?
- Are renewables included in grid development plans?

#### **Take off**

- Is the regulatory framework appropriate?
- Are modern grid connections codes included in the regulations?
- Are modern wind and solar forecasting methods in use?

- Are appropriate dispatch rules in place?
- Has an integration study been carried out?

### **Mainstreaming**

- Are investment plans in place to ensure sufficient flexibility?
- Is there a need to extend the capacity of regional transmission systems to optimize renewables and other generation capacity over a large area?

### **Supply chain and skills issues**

The availability of a supply chain and of sufficient skilled labour able to install and maintain renewable energy systems can have a significant impact of the cost and rate of deployment of renewable systems. In new markets there is often a shortage of experienced contractors who can do the civil and mechanical engineering works necessary to successfully install projects. Establishing such a supply chain poses a risk and a cost to developers. Skills shortages (for example for installers of systems for residential PV) can be a constraint to deployment. There are also benefits in terms of economic development which may be accessed by developing the manufacturing capacity for some components of systems.

Governments can provide support by taking steps to encourage the development of such expertise by:

- establishing centres of expertise for key technologies within the country and establishing R,D and D programmes which enable the development of understanding and skills
- supporting suitable training schemes or including aspects of renewable energy technology in more general engineering training programmes
- establishing technical standards for systems for deployment in the country (which can often be based on suitable international standards).

Key questions which can be used to evaluate this part of the enabling framework are:

- Is a supply chain in place?
- Are key components manufactured locally?
- Is there local experience of installation and maintenance?
- Are standards or certification in place?
- Is there a skills base?
- Is there a recognised centre of expertise?
- Is education and skills training under way?

### **Social factors**

Although the public acceptance of RETs is generally very high, specific energy projects can experience local public opposition for example over the potential impact of projects on wildlife, visual amenity, noise or increased traffic flows. Such concerns may be legitimate and should be taken account of through the planning and licencing approvals process, through carefully designed environmental impacts assessments and a consultation process which should include local stakeholders.

However it is also important that the public is well informed on the environmental and economic benefits and potential dis-benefits of renewables developments so as allow them to make

informed decisions (and sometimes to counter misinformation from lobby groups. In cases where a significant expansion of renewables are envisaged it is therefore good practice to put in place a public information campaign which provides un-biased evidence on the positive and negative aspects of the developments and which includes a clear description of the national rationale for the developments, citing the environmental, economic and social benefits which are expected to flow from higher levels of deployment.

### *Environmental factors*

While RETs have obvious environmental benefits, particularly in relation to carbon emissions and improved air quality, their deployment is not without potential environmental impacts. The potential downstream impacts of large-scale hydropower, for example, have been well documented as have the risks to ecosystems if biomass resources are not managed carefully.

In addition, the natural environment can present both challenges and opportunities for RET deployment, which should be considered in monitoring the enabling environment over time. For example, as the climate changes, rainfall in some parts of the world will increase, while in others will decrease. In turn, this may affect water availability for hydropower and for cooling both renewable and non-renewable electricity plants.

Therefore, monitoring environmental factors that may affect the enabling environment for RETs involves assessing how RET deployment may affect the natural environment and equally, how the natural environment is expected to change over time, in ways that could affect the performance of RETs.

## Using CETAM to assess energy efficiency technologies

This chapter outlines how CETAM can be used to assess market conditions for energy efficiency technologies (EETs). It provides a brief background section followed by three sections explaining each of the three main steps of the methodology outlined in Chapter 1:

- **Prioritisation**, which is aimed at understanding the major end uses of energy within a country and identifying priority EETs within those end uses for market monitoring.
- **Indicators and metrics** needed to monitor the penetration of priority EETs as well as energy use trends in prioritized sectors, subsectors, and end uses.
- **Monitoring** of energy use and EET penetrations over time, as well as additional priority information, by establishing data sources and market monitoring systems.

Just as assessing the market penetration of RETs enables tracking progress toward more sustainable energy supply systems, assessing the market penetration of EETs enables tracking of progress toward energy efficiency goals. However, assessing markets for EETs comes with significant challenges due to the wide spectrum of demand-side sectors, subsectors, and energy end uses that must be considered, the many different EETs that may be applicable across this spectrum, and data requirements for assessing the uptake of priority EETs over time.

For these reasons, there is no “one size fits all” approach to assessing the market penetration of EETs. Rather, appropriate approaches will vary based on the priority sectors, subsectors, and end uses within a country and the various technical, economic, and policy factors that may affect EET markets and available data within that country.

Despite these challenges, sufficient examples exist in the form of established efficiency metrics, statistics conventions, models, and literature to develop a general methodology for assessing EET market penetration within the transport, buildings, and industrial sectors. This section leverages these resources to describe such a methodology. Its key steps and sub-steps are depicted in Figure 3 and are discussed in detail in the sections that follow.

As shown in Figure 17, effective monitoring of EET markets begins with the prioritisation step, the goals of which are to identify priority end uses for efficiency improvements and to select a set of priority EETs that can enable these improvements. This step comprises collection of information and national-level energy balance data (ideally at the end use level within each sector and subsector), the analysis of key trends and policies affecting the evolution of the national energy system, and the screening and selection of EETs for market monitoring.

In step 2 of the methodology, metrics are established to monitor the uptake of selected EETs over time, ideally in combination with energy end use indicators that can be used to track the effects of technology uptake. Finally, in the monitoring step, the chosen metrics and indicators drive the ongoing collection and analysis of data on EET uptake and enabling environment factors that can either help or hinder EET deployment.

While these sub-steps are depicted in linear fashion for simplicity, in practice the process can be iterative. For example, the selection of appropriate EET penetration metrics will depend on a region’s ability to collect the required market monitoring data, and therefore these two sub-steps are interdependent.

The following general principles were followed in the development of this methodology to ensure practicality and flexibility across countries:

- Sector, subsector, and end use definitions are consistent with previous IEA work and are in common use among energy statistics agencies.
- Required data for energy use at the sector, subsector, and end use levels and associated activity levels are based on those that can be feasibly collected.
- Energy indicators follow the established IEA pyramidal approach, which outlines multiple levels of data detail to enable flexibility in indicator selection (IEA, 2014b).
- Different levels of disaggregation or specificity can be chosen for indicators and metrics based on local capabilities and data availability.
- Each step is based on generally accepted practices within the international energy statistics and efficiency analysis communities.

**Table 8 • Included sectors, subsectors, and end uses**

Sector	Subsector	End use/Segment
Transport	Road	Passenger 2-4 wheelers
		Passenger light duty vehicles
		Buses
		Heavy duty vehicles (freight)
	Rail	Passenger trains
		Freight trains
	Air	Passenger planes
		Freight planes
	Water	Passenger ships
		Freight ships
Buildings	Residential	Space heating Space cooling Water heating
	Commercial	Lighting Cooking Appliances
Industry	Aluminium	Boiler/steam systems
	Cement	Combined heat and power
	Chemicals	Process heating
	Food and beverage	Cooling/refrigeration systems
	Glass	Facility heating ventilation and air conditioning (HVAC)
	Iron and steel	Facility lighting
	Pulp and paper	Compressed air systems
	Textiles	Fan systems
	Wood products	Machine drives
	Other	Pump systems Other

The scope of this methodology is inclusive of the sectors, subsectors, and end uses in Table 8 given their importance to energy use in most regions and the availability of methods and data for assessing the penetration of EETs within them (IEA, 2007, 2009a, 2009b, 2009c, 2009d, 2011b, 2012, 2013b, 2014a, 2014b, 2014c, 2014d, 2015b). However, the general methodology can be applied to additional energy demand sectors when sufficient supporting information and data are available.

## Step 1: Prioritisation

The ultimate aim of the prioritisation step is to identify a set of priority EETs for market monitoring, which are aligned with a country's energy efficiency improvement goals. The prioritisation step consists of three sub-steps:

- 1.1. Compile national energy balance data, using energy statistics, analyses, and/or models, to identify the major end uses of energy in the current energy system.
- 1.2. Evaluate trends, drivers, and policies that may influence the relative importance of these major end uses of energy in the future, leading to the selection of priority end uses.
- 1.3. For the prioritized end uses of energy, systematically select priority EETs for market monitoring.

### 1.1 Compile energy balance data

The purpose of compiling energy balance data is to identify the sectors, subsectors, and end uses of energy within a country that account for the greatest shares of present day energy use. Furthermore, compiling these data on a historical basis can expose recent trends in energy use, which can add valuable perspectives on any growth, stagnation, or decline in energy use at the sector, subsector, fuel, or end use levels. These energy balance data, when complemented with information on the likely future evolution of the energy system in Step 1.2, can help identify the specific end uses of energy that may be the most fruitful targets for EET adoption moving forward (IEA, 2014a, 2014b).

National energy balances are most useful when they comprise good quality national level energy statistics that are disaggregated by subsector and ideally by end use, such as those summarized in Table 8. The IEA's *Energy Balances* data series (IEA, 2016a) contains historical annual energy balance data by sector, subsector, and fuel for many countries and global regions. However, further disaggregation of energy balance data into more detailed subsectors, and into specific end uses of specific fuels within subsectors, is not always available in existing national statistics. In such cases, the use of energy models and other analytical and data resources may be necessary to identify major subsectors and/or end uses of energy, as described in the following sections for the buildings, industry, and transport sectors.

The ideal outcome of the prioritisation step will be an historical energy balance that identifies trends in major end uses of energy within a country, categorized by sector, subsector, and fuel up to the most recent year feasible. This information provides a comprehensive overview of past and present energy use within a country, and enables decision makers to begin narrowing their focus to the end uses that may contribute most to national energy use moving forward.

#### *Buildings sector data*

Fuel use data for residential and commercial buildings are often available at the national level based on data from utility companies (e.g., electric power and natural gas) or national energy

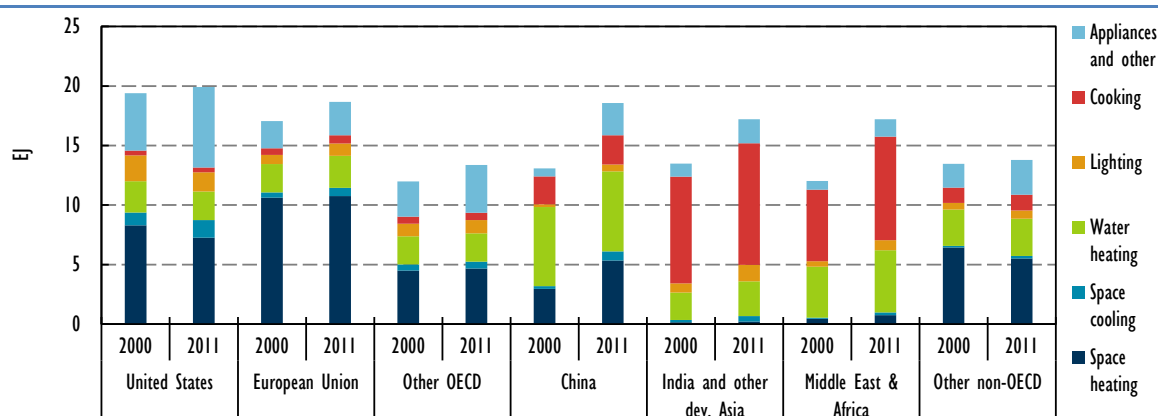
statistics agencies, given that buildings are a dominant energy using sector in most economies (IEA, 2013b). Fuel use in residential and commercial buildings can often be disaggregated into end uses using survey data and modelling approaches (IEA, 2014a, 2014b). However, the end uses of energy in the buildings sector can be challenging to estimate due to large variations in the vintages and construction types of dwellings, installed end use equipment (e.g., windows, insulation, and furnaces), local climates, and inhabitant behaviours that can occur across each subsector (IEA, 2013b; US Department of Energy [DOE], 2015a). Surveys, measurements, and models can be used to estimate the major end uses of energy within each subsector, taking account of these various factors that contribute to variability in building end uses across a region.

Furthermore, identification of the service type associated with commercial buildings can provide additional information on the drivers of end uses of energy; for example, cooking may comprise a significant fraction of energy use within a restaurant while space cooling might comprise a significant fraction of energy use within a grocery store. Common service types considered in building energy data efforts include offices, restaurants, warehouses, public assembly, health care, education, lodging, and multi-purpose buildings (IEA, 2014b; DOE, 2015a).

Surveys are a well-established method for quantifying end uses of different fuels in the building sector, and can take the form of residential and commercial inhabitant surveys. For example, periodic surveys of residential housing and commercial building characteristics in the European Union and United States capture data on such characteristics as building vintages and types, appliance ownership and usage, and fuel use data by major end use (DOE, 2015a, 2015c; BPIE, 2015) and across different climate zones, regions, and inhabitant demographics. Such comprehensive surveys are also typically quite expensive; therefore, the level of detail and sample size can vary widely in practice.

Measurements can also be conducted through home and commercial building energy metering and audit programs to compile primary data on major end uses of energy within representative samples of buildings. While such measurements can provide accurate energy data, measurement programs are typically quite costly and are therefore limited to much smaller sample sizes than building energy use surveys (IEA, 2014a, 2014b). Therefore, measurement programs are often used to augment survey programs as a way to verify collected survey data and to serve as inputs to building energy models.

**Figure 17 • Building energy consumption by end use**



Note: More information on survey, measurement, and modelling for understanding and quantifying end uses of energy in buildings can be found in *Energy Efficiency Indicators: Fundamentals on Statistics*, (IEA 2014b).

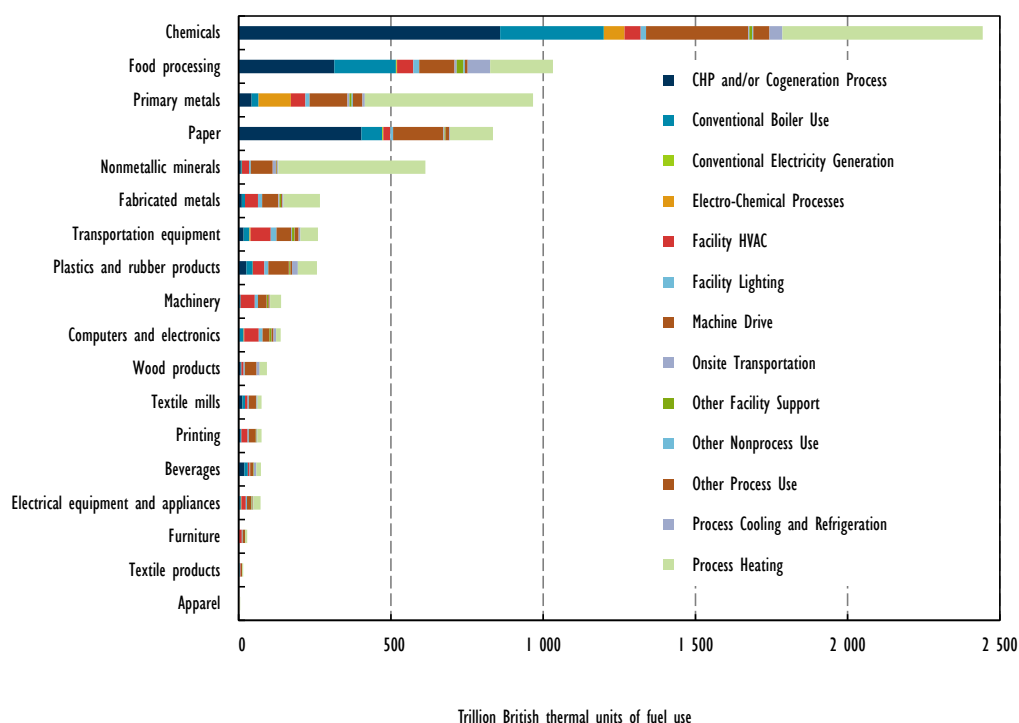
Source: IEA (2014d), *Tracking Clean Energy Progress 2014: Energy Technology Perspectives 2014 Excerpt IEA Input to the Clean Energy Ministerial*.

Models of building energy use are ideally constructed to quantify uses of energy at the end use level (IEA, 2014a, 2014b). Figure 17 summarises building end use energy trends for several world regions using IEA’s building energy model, which is fed by regional energy use data (IEA, 2014c). Depending on the modelling approach, end uses of energy can be disaggregated by building vintage, type, location, and other factors. Furthermore, local climate drivers of space heating (during cold weather) and space cooling (during hot weather) can be included in the form of heating degree days (HDDs) and cooling degree days (CDDs) in such models so that space heating and space cooling energy uses are linked to local weather.

### Industry sector data end uses

The availability of data at the end use level for different industrial subsectors varies widely, which is often due to the costs and complexities of gathering data across many different types of plants within a region as well as confidentiality considerations. The industrial sector is often divided into energy-intensive and non-energy-intensive subsectors in most countries. Energy-intensive subsectors typically include primary metals (ferrous and nonferrous), chemicals, non-metallic minerals (cement, glass), and pulp and paper, and can further include food processing and metals fabrication in some countries (IEA, 2009c). Non-energy-intensive subsectors, such as textiles, wood products, appliances, and machinery are comprised of plants that typically have lower overall energy demands than those in the energy-intensive industries. In general, when energy-intensive subsectors represent a significant fraction of a region’s industrial economic output, there’s a good chance that these subsectors will also dominate the energy use of that region’s industrial sector. However, having national-level energy data at the level of subsectors is a necessary prerequisite for identifying priority end uses of energy among all industrial subsectors.

Figure 18 • Summary of end uses of energy in the U.S. industrial sector, 2010



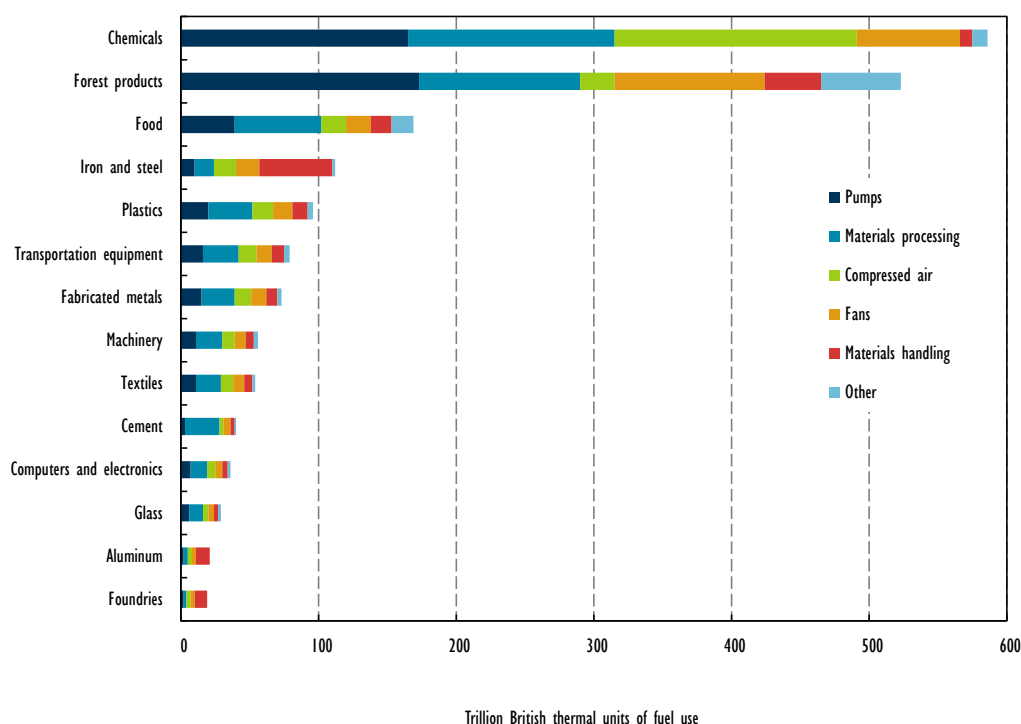
Source: DOE (2015b), "Manufacturing Energy Consumption Survey (MECS)" webpage, [www.eia.gov/consumption/manufacturing/](http://www.eia.gov/consumption/manufacturing/).

Similar to the transport and building sectors, surveys, measurements, and models are common methods of identifying major end uses of energy within the industrial sector. For example, the U.S. Department of Energy's quadrennial Manufacturing Energy Consumption Survey, gathers data on fuel consumption by major end uses within major U.S. industrial subsectors, as summarized in Figure 18 (DOE (2015b)).

Such data are useful for identifying the largest energy using subsectors, the largest end uses of energy within those subsectors, and the largest end uses of energy in the industrial sector overall for prioritisation. For example, Figure 18 shows that the chemicals, food processing, primary metals, paper, and non-metallic minerals industries comprise the largest shares of U.S. industrial energy use, while steam systems, process heating systems, CHP systems, and machine drives represent the most important end uses of energy across the industrial sector. These latter systems are often referred to as "cross-cutting" or "horizontal" technology systems, given that their core technologies (e.g., motors, pumps, compressors, fans, boilers, chillers, lamps, and air handlers) are used to varying degrees across nearly every industrial plant. Identification and targeting of priority cross-cutting systems is therefore a common strategy for promoting industrial energy efficiency, given the desirability of deploying a small set of technologies (e.g., energy efficient motors) to reach across every industrial subsector.

In some cases, major end uses within priority subsectors can be directly correlated to a few specific process technologies through facility audits, process engineering knowledge, or industrial energy models. For example, energy engineering studies reveal that process heating energy use is dominated by kiln technologies in the cement subsector, and by blast furnaces, basic oxygen furnaces, and electric arc furnaces in the iron and steel subsector. Tracing end uses of energy to a few specific process technologies can help make the process of EET selection and monitoring (to be discussed further below) more manageable.

**Figure 19 • Summary of machine drive end uses in the U.S. industrial sector, 2006**



Source: ENERGETICS (2012), U.S. Manufacturing Energy Use and Greenhouse Gas Emissions Analysis.

Engineering and energy studies can also be used to identify dominant end uses of energy within subsectors in the absence of national survey data. Figure 19 summarizes a disaggregation of the machine drive energy use in the US Manufacturing sector based on facility audits and engineering analysis, which enables further disaggregation of machine drive energy use into categories more directly related to specific cross-cutting technology systems (DOE, 2002; ENERGETICS, 2012).

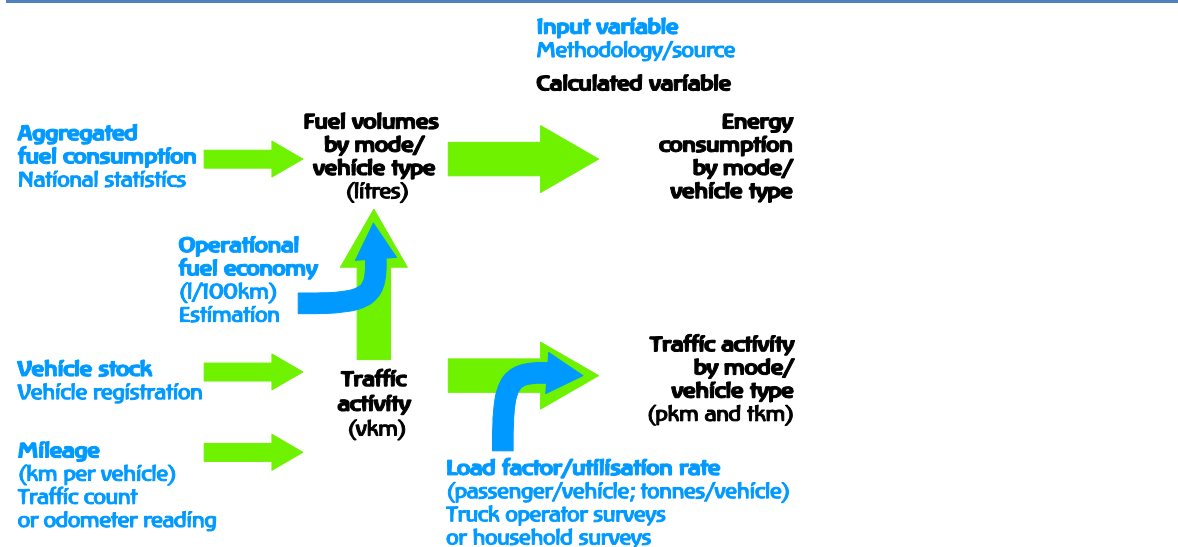
Often, energy engineering studies utilise data from facility audits, which is another important mechanism for gathering energy use data at the subsector and end use levels in industry. Audit programmes provide energy efficiency audits at industrial plants, through which data are typically collected on total fuel use, end uses, and efficiency opportunities (DOE 2015f). These data can also be archived in databases, which can serve as a valuable resource in engineering studies and industrial energy models. There are also studies and reports on end uses of energy within different industrial subsectors from various regions, which can be consulted for guidance, especially for the energy-intensive industries (EPA 2015a; IIP 2015).

Given that industrial technologies and production practices are largely similar worldwide, end use data from a subsector in one world region can sometimes be reasonable proxies for end use data in another world region. Therefore, it is often possible to use global average or non-local industrial energy use data to identify priority sectors and end uses within a country until more reliable local data can be compiled.

### Transport sector data

Many national statistical agencies will have energy use data at the levels of the transport sector and also for the use of specific fuels used (e.g., gasoline, diesel). However, further disaggregating transport subsector fuel use into its various segments (road, rail, air, and water) can often require the use of transport system models and/or mobility surveys (IEA, 2014a; 2014b).

Figure 20 • IEA Mobility Model framework



Source: IEA (2014b), *Energy Efficiency Indicators: Fundamentals on Statistics*.  
 Note: More information on transportation system models, surveys, and other sources of data on segment energy use within the transport sector can be found in (IEA 2014b).

Transport system energy models such as the IEA's Mobility Model (MoMo) (depicted in Figure 20) can provide estimates of fuel use by subsector based on estimated numbers of vehicle types, average mileage assumptions, typical transport shares between different segments, and average fuel economies of different vehicles based on manufacturer data (IEA, 2014a; IEA, 2014b). Such

general modelling capabilities can be applied to different regions using local survey or transport agency data, expert elicitation, or data inputs typical of similar countries to identify the major energy using segments within a region.

In combination with modelling efforts, mobility surveys can be conducted to gather data on vehicle types and driving behaviours of a representative sample population within a region. For example, surveys can target household and freight drivers to gather information on their driving patterns, distances driven, and vehicle types. Gas station surveys can also be conducted, during which motorists are randomly sampled during refuelling stops to gather information on fuel economy, odometer readings, and vehicle types (IEA, 2014a, 2014b).

## **1.2 Evaluate future energy demand trends, drivers, and policies**

In addition reviewing past trends in energy demand by examining national-level energy data, a review of projected future trends in energy use, energy use drivers, and existing and planned energy policies is recommended to provide further clarity on subsectors and end uses and of strategic interest for prioritisation. In particular:

- Projected future trends in energy use and drivers of this energy use are often analysed by a number of stakeholders including energy analysts, government and academic research labs, non-profit environmental organizations, and market forecasters. These resources should be reviewed to identify major predicted trends in the use of fuels as functions of societal trends and the evolution of key energy use drivers, such as population, income, and economic structure.
- Importantly, existing and planned energy policies can have a major influence on the amounts and types of fuels used in the future, by sector and end use. These policies can sometimes focus on specific subsectors and end uses (e.g., bans of incandescent bulbs in favour of compact fluorescent lamps in the residential retail market) or create a better enabling environment for EET adoption in certain subsectors and end uses (e.g., building energy codes). Relevant policies should be identified, reviewed, and compared to observed trends in Step 1.1 to identify priority subsectors and end uses from the policy perspective.

The information compiled in this sub-step is meant to complement the empirical trends observed in Step 1.1 to lead to more robust choices of priority subsectors and end uses for subsequent monitoring. For example, growing populations, trends toward larger dwellings, and increased affluence can drive greater use of electricity and natural gas in the residential sector, while existing or planned rebate programs, building codes, or other deployment policies might make the selection of energy efficient residential appliances natural choices for end use market monitoring.

## **1.3 Select priority EETs for market monitoring**

The goal of the EET selection step is to identify a manageable set of priority EETs for market monitoring, using a structured and well-documented approach for consistency and transparency. The EET selection step consists of three sub-steps:

- 1.3.1. Compile candidate lists of potential EETs for each priority end use, which represent a portfolio of relevant EETs for further consideration along with their key technology characteristics;
- 1.3.2. Apply a structured evaluation approach to assess the attractiveness of each potential EET on the basis of various technological, economic, policy, and market criteria; and
- 1.3.3. Select priority EETs for market monitoring within each priority end use.

In practice, there are a number of EETs that might also be partly or fully considered as RETs. Examples include geothermal heat pumps for building heating and cooling, solar thermal steam generation, solar water heating (or preheating) for building and industrial applications, biomass-fired furnaces and boilers, and water-sourced district cooling systems. A key distinction between such technologies and those discussed in the RET section of the methodology is that they are typically highly distributed in nature (i.e., applicable at the equipment or building level). As such, certain renewable-based EETs might be more logically identified and monitored following the EET methodology proposed in this report. However, whether a particular RET is more or less suitable for evaluation as a centralized vs. distributed technology opportunity is best made on a case-by-case basis.

### 1.3.1 Compile EET candidate lists

After priority end uses are established in the prioritisation step, the next step is to compile lists of potential EETs to be considered as candidates for prioritisation and subsequent market penetration monitoring. These EET candidate lists—or “long lists”—should represent a comprehensive portfolio of EETs that could be applied to the priority end uses within a country to help achieve its energy efficiency goals. These candidate lists should ideally capture a wide range of EET options based on international best practice technologies for each priority end use and fuel type, with the understanding that these “long lists” will undergo further evaluation (in Step 1.3.2) to narrow them down into “short lists” containing fewer priority EETs for eventual market monitoring (in Step 1.3.3).

Annex 4 contains representative EET candidate lists that have been compiled for the major sectors, subsectors, and end uses in this methodology. Each list is based on international best practice technologies obtained from a variety of literature sources, and can serve as a starting point for users of this methodology. In practice, some countries may have already identified such candidate lists as part of existing energy efficiency programs, which can take the form of pre-approved technology lists for financial subsidies, national and international efficiency labels and standards programs, national or international technology guidebooks and roadmaps, utility rebate programmes, subsector or end use level energy efficiency potential or market studies, or energy efficiency audit programs. Furthermore, given that EETs and their characteristics evolve over time, candidate lists should be treated as living documents that should be revisited and updated regularly over time to ensure that a wide portfolio of potential EET candidates is captured. For countries without established candidate lists, those in Annex 4 are a good place to start.

Several important factors should be considered in the development of EET candidate lists:

- The identification of EETs should leverage information and technology lists from existing energy efficiency programmes in various world regions when possible, given that substantial analysis, vetting, and demonstrations have contributed to the EETs within such programmes. For example, existing efficiency standards for appliances (ACEEE, n.d.; Clean Energy Ministerial, 2015), building codes (IEA, 2013a), vehicle efficiency standards (IEA, 2012), efficient motor, pump, and furnace standards (MDM, 2015), and utility rebate programs (DSIRE, 2015) can be used to efficiently identify proven EETs. In addition to the above sources of information on EETs, techno-economic studies of energy efficiency potentials can also offer guidance on how much energy can be saved at the subsector, end use, and fuel levels, and at what level of cost investment. For example, recent cost curve studies by McKinsey (2009) document major technology savings potentials in terms of their levelised costs and in different world regions.

- When compiling information on candidate EETs, it is helpful to consider the data elements required for EET evaluation in Step 1.3.2. When readily available during the development of candidate lists, additional information on the technology costs, application markets, level of maturity, and other factors should be captured in parallel. For example, to later assess the economic viability of an EET, one may require information on costs related to upfront purchase, maintenance, and operations. To later assess technical feasibility, one may need information on reference technologies that may be replaced by the EET as well as technical factors that govern its applicability; for example, super-efficient industrial boilers may be limited in heat capacity and therefore not applicable to large industrial boilers. Furthermore, energy savings and cost data for EETs can also vary by year, region, and application, which may later require normalisation into common units (e.g., present year costs to account for inflation) such that EET options can be evaluated on a consistent and credible basis. Therefore, compiling such information and data when creating EET candidate lists can help guide the data collection process and ensure that compiled data are maximally useful.
- It should be decided whether EET candidate lists should comprise only best practice technologies (BPTs) or further include best available technologies (BATs). A BPT represents the most advanced technologies that are currently in use at industrial scale and are therefore, by definition, economically viable. BATs are generally more advanced in terms of their technology level but their large-scale viability (including economic viability) is not always certain (IEA, 2009b). Because BPTs are in wide use, in general there can often be sufficient case studies, credible information, and related standards available for compiling BPT data. Conversely, because the viability of BATs can be less certain, the available information can be sparser, leading to less confidence in compiled data. In some cases, however, a BPT and BAT may be equivalent (IEA, 2009b). Determining the scope of EETs for potential monitoring up front can allow for more reasonable planning of resources for EET data compilation (e.g., data for BATs may have to be obtained from the scientific literature, pilot studies, or engineering analysis) as well as plans for addressing potential data uncertainties.

### Cross-cutting technologies

Another key consideration is the selection of cross-cutting technologies as EET candidates, which can affect priority end uses of energy across multiple sectors and subsectors. Inherently, many of the EETs applicable to buildings are cross-cutting in nature, given the commonality of technologies employed across the residential and commercial buildings sectors and across subsectors within them. For example, efficient lighting technologies such as light-emitting diode (LED) lamps can significantly improve lighting efficiency and are applicable across all residential building types (e.g., single and multi-family homes) and many commercial building types (e.g., offices and restaurants) and for both existing and new construction.

Similarly, many cross-cutting technologies exist for the industrial sector, including boilers, motors, pumps, and compressors, as discussed earlier. From a policy perspective, it is often highly desirable to promote and monitor the adoption of cross-cutting technologies, given their wide reach, the magnitude of their potential impacts, and the efficiencies of focusing on a few EETs rather than many. Furthermore, given their large markets and high volumes of sales, the data availability on EET sales and purchases from manufacturers, industry associations, and other sources are typically good.

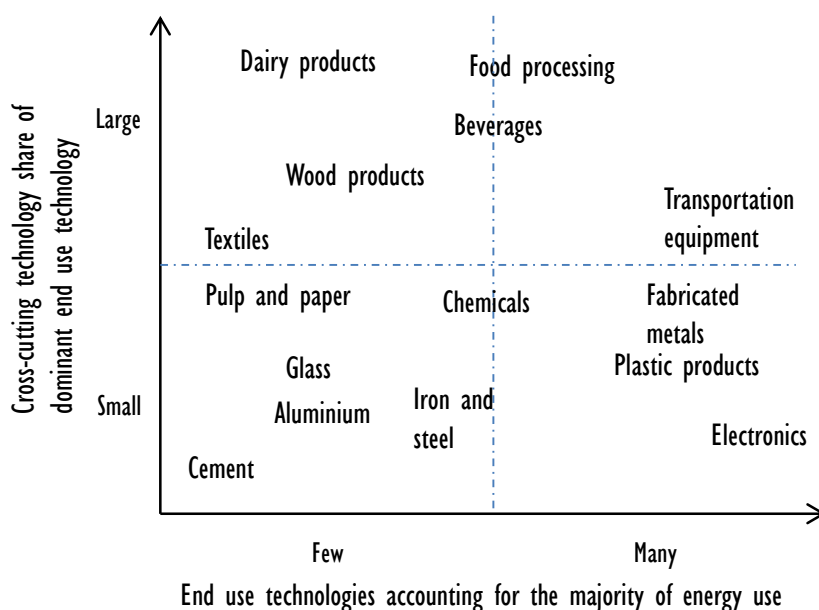
While EETs for cross-cutting applications are often attractive targets from a policy perspective, it is important to consider their correlation to overall energy use in priority subsectors and end uses as well as potential systems effects that might weaken this correlation. Ideally, one should

include candidate EETs that have reasonably strong correlations to energy use in the priority subsectors and energy uses. Otherwise, monitoring programs may not provide sufficient information to determine the drivers of energy indicator trends or to assess the effectiveness of overall energy efficiency programs, as discussed in Step 2 below. In such cases, the investments in EET monitoring may not yield the desired outcomes.

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Figure 21 provides a useful illustration of this situation for the industrial sector. In the figure, the position of U.S. industrial subsectors is plotted using two axes based on the energy end use data in Figure 18. The x-axis position represents the degree to which overall subsector energy use is concentrated in one or few end uses. For example, the energy use of cement manufacturing is dominated by one end use technology (i.e., the cement kiln), which puts cement at the left on the x-axis. Conversely, the energy use of the electronics subsector is more dispersed across multiple end use technologies (i.e., air handlers, water treatment, machine tools, and space conditioning), which puts it at the right on the x-axis. The y-axis position represents the degree to which cross-cutting technologies account for the dominant energy end uses within the subsector. For example, a cement kiln is unique to the cement industry, and therefore cement falls at the bottom on the y-axis. Conversely, the energy use of dairy processing is highly correlated to boilers, pumps, and motors, which are all cross-cutting technologies; therefore, dairy processing falls near the top on the y-axis.

**Figure 21 • The influence of cross-cutting technologies on industrial energy use**



Source: Derived from DOE (2015b), "Manufacturing Energy Consumption Survey", [www.eia.gov/consumption/manufacturing/](http://www.eia.gov/consumption/manufacturing/); ENERGETICS (2012), *U.S. Manufacturing Energy Use and Greenhouse Gas Emissions Analysis*; and Brush, et. al.,(2011), *Energy Efficiency Improvement and Cost Saving Opportunities for the Dairy Industry: An ENERGY STAR® Guide for Energy and Plant Managers*.

The figure can be divided into roughly four quadrants. Subsectors like cement, which fall into the lower left quadrant, are not likely to be heavily influenced by EETs aimed at cross-cutting technologies. Therefore, candidate EETs for such subsectors might focus more on subsector-specific process technologies.

Conversely, subsectors that fall into the top two quadrants may be more credibly monitored for energy efficiency improvements through focusing on EET candidates for cross-cutting systems, with potentially fewer cross-cutting systems of interest for subsectors that fall into the top left quadrant. For subsectors falling into the bottom right quadrant, it may be necessary to compile

broad EET candidate lists given the dispersion of end uses of energy and the unique production technologies in use in those sectors.

It is also important to consider that disaggregating subsectors into different segments may provide greater clarity for the EET candidate selection process. For example, within the dairy processing industry, the cheese segment, for which energy use is distributed across steam, motor, pump, and process heating systems, may move down and to the right due to greater dispersion of end use and the predominance of whey dryers, which is a production technology that is unique to that subsector (Brush, 2011).

### Feedstocks and fuels

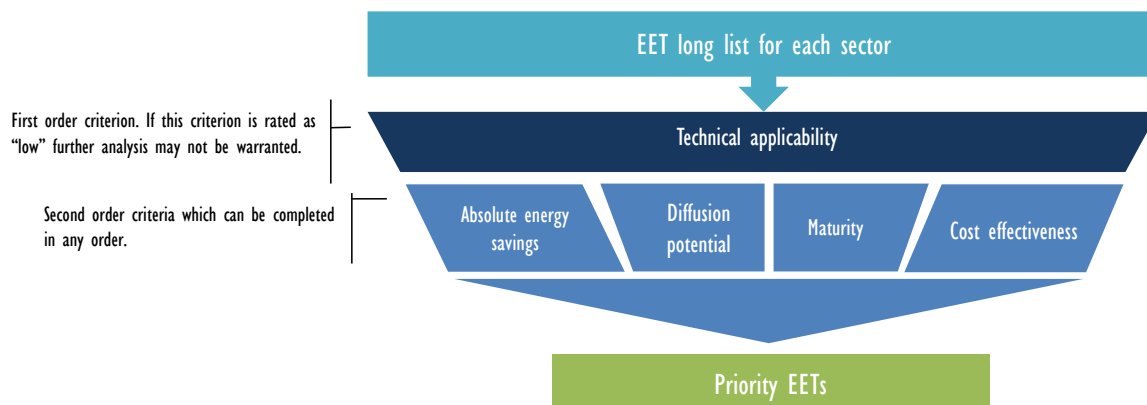
In the industrial sector, it can also be important to include on EET candidate lists changes to product feedstocks and fuel mixes. Such changes may also be considered EETs, and may be included in monitoring programs if they affect a priority subsector and end use of energy directly or if they reduce energy and/or resource demand elsewhere in a country.

The cement sector serves as a prime example of both types of energy saving effects (direct and indirect). For example, reducing the clinker content in cement through clinker substitutes such as fly ash or blast furnace slag can reduce the direct energy intensity of cement production (IEA, 2009a). Such a change is monitored commonly using the clinker-to-cement ratio, with lower ratios indicating higher rates of clinker substitution. The use of alternative fuels such as waste tires, plastics, and oils within cement kilns can lead to energy and resource demand reductions in the country through avoidance of traditional fuel demand and waste disposal. As such, alternative fuel use is another common metric that is monitored in various regions for the cement subsector (IEA, 2009a). Another example of feedstock change that might lead to indirect energy benefits is the substitution of fossil-fuel feedstocks in the chemicals industry with biomass-based feedstocks (Yao, Graziano et al., 2014). It is recommended that important indirect effects enabled by EETs in each subsector be identified such that the selection of EET monitoring metric can be designed accordingly (see Step 2). It is also important to consider feedstock market supply effects when assessing feedstock changes over time. For example, in the iron and steel subsector, the use of scrap reduces the energy intensity of steel production but the availability of scrap for feedstock may limit the extent to which this feedstock change will be viable (IEA, 2015b).

#### 1.3.2 Evaluate candidate technologies

While the purpose of the EET candidate list, or “long list,” is to compile basic information on a broad portfolio of EETs that could be promoted to improve energy efficiency in a country’s prioritized sectors, subsectors, and end uses, it may be impractical or prohibitively expensive to develop deployment programs and to establish market monitoring programs for more than a subset of EET candidates in each end use. Ideally, decision makers should select a “short list” of EETs for market monitoring in priority end uses, which represent the most attractive EETs from energy savings, economic, policy, and technical feasibility perspectives. The purpose of Step 1.3.2 is to apply a structured and transparent evaluation approach such that short lists of EETs can be identified for subsequent market monitoring.

Figure 22 • Evaluation criteria for prioritising EETs



In practice, some countries may have already established systematic approaches for identifying priority EETs based on national energy and economic goals, consistent project or technology evaluation procedures, common evaluation assumptions (including discount rates or energy savings calculation procedures), or other approaches involving quantitative and qualitative criteria and/or heuristics. Important aspects of any evaluation approach include the need for clear and replicable procedural guidance, so that all EETs are evaluated on the same bases, consistency in how the approach is applied to each EET, so that results are comparable across sectors, subsectors, and end uses, and transparent documentation of the rationale for scoring each EET.

Figure 22 and Table 9 summarize a simple yet comprehensive evaluation approach developed as part of this methodology.

For countries with established evaluation approaches for selecting priority EETs, the evaluation approach presented here might serve as a useful benchmark or alternative approach for complementing evaluation approaches already in place. For countries without established evaluation approaches, the approach presented here can serve as a solid foundation to be further developed and tailored based on country-specific evaluation priorities, data availability, and policy objectives.

- **Technical applicability** expresses the size of the application market from a technical perspective, irrespective of other factors such as technology cost or maturity. It is meant as the first screen to exclude technologies that are not applicable within a country due to the economic and technology structure of their sectors, their energy infrastructures, or other factors.
- Irrespective of cost, **diffusion potential** captures the speed or efficiency at which a technology can penetrate a market due to stock turnover, stock growth, number of adopters, or market evolution.
- **Absolute energy savings** (high, medium or low) captures the remaining potential for energy savings at the national scale associated with a technology, and is calculated by combining estimates of energy savings per installation of the efficient technology with estimates of the remaining market for the efficient technology.
- **Cost effectiveness** expresses the economic feasibility of a technology in target or similar sectors and end uses compared to a reference technology, and can be expressed using different investment valuation metrics (e.g., levelised costs of energy savings, simple payback period, return on investment).

- **Technology maturity** captures the market maturity of a technology and its perceived risk of use in the target or similar sectors.

Figure 23 shows how the evaluation criteria which characterize the technical applicability, diffusion potential, cost competitiveness, and maturity of EETs, are used to produce a priority shortlist of technologies. It is recommended that technical applicability be applied as the first evaluation criterion to quickly eliminate EETs that are not feasible in-country from a technical perspective; for such EETs, further evaluation of costs, etc., is not warranted. For EETs that are technically applicable, the additional evaluation criteria are applied. It should be noted that the technical applicability of a given EET can change over time; for example, a country may add more electric arc furnaces to its iron and steel industry for scrap recovery, which would make EETs aimed at improving the efficiency of electric arc furnaces technically feasible. Similarly, the cost and market attractiveness of a given EET may change over time due to improvements in technology costs, changing economic structures, or the evolution of consumer behaviour. Therefore, the scoring of EETs should be revisited on a regular basis.

**Table 9 • Rating system for scoring against evaluation criteria in the EET prioritisation process**

	High	Medium	Low
<b>Technical applicability</b>	Technology is technically applicable to a large share of energy use within the target sector(s) and end use(s) based on market structure, growth potential, and energy infrastructure	Technology is technically applicable to a modest share of energy use within the target sector(s) and end use(s) based on market structure, growth potential, and energy infrastructure	Technology is technically applicable to a small share of energy use within the target sector(s) and end use(s) based on market structure, growth potential, and energy infrastructure
<b>Diffusion rate</b>	Fast diffusion rate is likely due to high stock turnover rate and/or stock growth, highly horizontal technology, relatively few target adopters, and/or rapid market evolution.	Modest diffusion rate is likely due to high stock turnover rate and/or stock growth, less horizontal technology, a greater number of target adopters, and/or less rapid market evolution.	Low diffusion rate is likely due to low stock turnover rate and/or stock contraction, less horizontal technology, a greater number of target adopters, and/or slow market evolution.
<b>Typical energy savings of technology</b>	Large energy savings associated with using the technology in comparison to the average technology used.	Medium energy savings associated with using the technology in comparison to the average technology used.	Small energy savings associated with using the technology in comparison to the average technology used.
<b>Current market penetration rate</b>	Select a range to estimate currently how widespread use of the technology is in the target market from the following options: <ul style="list-style-type: none"> <li>• &lt;25%</li> <li>• 25-50%</li> <li>• 50-75%</li> <li>• &gt;75%</li> </ul>		
<b>Absolute energy savings</b>	A rating of absolute energy savings (high, medium or low) is calculated by combining estimates of energy savings per installation of the efficient technology with estimates of the remaining market for the efficient technology.		
<b>Cost effectiveness</b>	Widely cost effective in target or similar sectors and end uses compared to reference technology	Cost effective in niche applications within target or similar sectors and end uses (e.g., those with high energy prices) compared to reference technology	Cost-competitiveness is contingent on EET subsidies, removal of reference technology subsidies, further R&D, or economies of scale
<b>Technology maturity</b>	Mature technology that is commonly applied to target sector and end use in international and/or domestic markets	Mature technology that is commonly applied to similar sectors and end use in international and/or domestic markets	New technology with low penetration in target or similar sectors and end uses in international and domestic markets

Table 9 consists of a structured rating system for applying high, medium, or low scores to EETs within against the criteria shown in Figure 23. These suggested ratings have been designed to be generally applicable to most sectors, subsectors, and end uses, but could also be changed by individual countries to better reflect in-country conventions and preferences. Most important is that decision makers apply the same logic of scoring to each EET across sectors, subsectors, and end uses and strive to maintain consistency of scoring so that, ultimately, EET “short lists” can be compared at the national level.

**Figure 23 • Tool for estimating absolute energy savings**

		Typical energy savings of technology		
		High	Medium	Low
Current penetration	>75%	Medium	Low	Low
	51-75%	High	Medium	Low
	26-50%	High	Medium	Medium
	<25%	High	High	Medium

Figure 23 has been provided as a useful heuristic approach for assigning absolute energy savings potential scores to EETs, capturing information on both current EET market penetration and typical energy savings potential of a technology against a “business as usual” baseline technology, to arrive at an overall score for national energy savings potential. The ratings provided in the tool are proposed as a guide and can be determined by experts in the country conducting the evaluation.

Table 10 shows an example of how the EET prioritisation step was applied in Kazakhstan’s residential building sector to choose priority space heating technologies.

**Table 10 • The EET prioritisation step as applied to space heating technologies in Kazakhstan**

	Technical applicability	Typical energy savings (tech)	Current penetration	Absolute energy savings potential	Cost effectiveness	Diffusion potential	Maturity	Priority rating
Electric heat pump - EU labelling - A	Medium	High	<25%	High	Medium	Medium	Medium	Medium
Gas heat pump - EU labelling - A	Medium	High	<25%	High	Medium	Medium	Medium	Medium
CHP (reciprocating engine)	High	High	<25%	High	Low	Low	Medium	Medium
Loft insulation (200 to 300 mm)	High	High	<25%	High	Medium	Medium	High	High
Loft insulation (100 to 200mm)	High	High	26-50%	High	Medium	Medium	High	High
Floor insulation	High	High	26-50%	High	Medium	Medium	High	High
Double glazed windows	High	High	26-50%	High	Medium	Medium	High	High
Solid wall insulation	High	High	26-50%	High	Medium	Medium	High	High

The evaluation approach of Step 1.3.2 will yield a series of scores for each EET in each priority end use, shedding light on their attractiveness related to each evaluation criterion. In this step, decision-makers should select a manageable set of priority EETs for subsequent market monitoring, which comprise one or more priority EETs for each priority end use. The number of priority EETs selected depends on several factors. For example, there may be one or more EETs that emerge as clearly more attractive than others within a given end use based on their evaluation scores. For example, one EET may have “high” scores across all evaluation criteria while the rest may have mixed or consistently “low” scores. In such cases, the choice of priority EET may be quite obvious.

In many cases, however, there may be several EETs with a combination of attractive scores, or trade-offs between scores within specific evaluation categories, that make the prioritisation of specific EETs more challenging. In such cases, it may be desirable to employ a formal multi-criterion decision-making process in which weights are established for each evaluation category (to establish the relative importance of each criterion) and for each possible score (to provide greater weight to positive scores and less weight to negative scores within a given evaluation category). Such approaches yield an overall attractiveness score, which can be used to identify EETs for prioritisation that best meet the decision panel’s preference and objectives.

Lastly, the ultimate number of EETs prioritised may also depend on the institutional and financial resources available to institute the data collection and analysis systems necessary for effective market monitoring, and/or the likelihood or feasibility of collecting consistent and credible data on their deployment over time. Data sources could include end use surveys and audits, as discussed earlier in the methodology for identifying priority end uses, or information from manufacturers, industry associations, market research firms, or consumers on the sales and purchases of EETs within target markets, as discussed in the next two sections.

Regardless of the chosen method for selecting EETs for the “short list” of priority EETs, all decision processes should be clearly documented and applied consistently across priority end uses. Over time, decision makers should periodically revisit the prioritisation method to ensure that it reflects the best knowledge of country priorities and ultimate EET market performance, and make adjustments as necessary.

### *1.3.3 Consideration of enabling factors in EET evaluation*

The various factors within a country that together support the market adoption of EETs is known as the “enabling environment” (IEA 2015a). As the adoption of EETs is often inhibited by financial, institutional, policy, and behavioural barriers, among others, a supportive enabling environment is important for increasing EET deployment and eliminating or minimising barriers in the marketplace.

Consequently, considering a range of enabling factors can be an important component of EET evaluation. By understanding the enabling factors within a region, selections of EETs can be made on the basis of maximizing alignment with the enabling environment, which can thereby promote greater EET adoption. Conversely, an understanding of the enabling environment in a country can help prevent selecting EETs that are not well aligned with market conditions—and whose adoption may falter—such as may happen when replicating EET programs from other countries with different enabling environments. Furthermore, enabling factors considered can also reflect future conditions that may arise due to trends in development, markets, or future outcomes of envisioned or existing regulations and policies.

A detailed discussion of policy approaches for creating a positive enabling environment for EET adoption is beyond the scope of this methodology, given the many enabling factors applicable to subsectors and end uses within the transport, buildings, and industrial sectors and the many

interrelationships between these factors. The reader is referred to *Enabling Renewable Energy and Energy Efficiency Technologies - Opportunities in Eastern Europe, Caucasus, Central Asia, Southern and Eastern Mediterranean*, (IEA, 2015a), for a deeper discussion of enabling factors for EETs, which are divided into five overarching categories as follows:

- technical and infrastructure factors;
- financial and market factors;
- social factors;
- regulatory and institutional factors; and
- environmental factors.

The consideration of enabling factors in the EET short listing process can occur in different ways. Where enabling factors can be reasonably assessed, in either quantitative or qualitative fashion, ideally those enabling factors should be included in the evaluation criteria (used in step 1.3.2) for priority EET selection with the appropriate scoring rubrics. For example, the general EET evaluation approach presented in Table 9 includes consideration of *some* enabling factors by including technical applicability and cost effectiveness explicitly. Decision makers may add additional columns and scoring rubrics to the general criteria presented in Table 9 if they consider additional enabling factors as being equally important for decision-making.

In other cases, existing information such as market studies, technology roadmaps, or policy analysis can provide information that enables the consideration of enabling factors when selecting priority EETs for the “short list.” For example, Table 11 summarizes EETs that have been categorised by enabling factors related to the type of economy, climate, and building characteristics in a given region (IEA 2011b; IEA 2013b), which could be used to help narrow down the EET candidate list to those that are most attractive for further evaluation.

In practice, the consideration of enabling factors in the evaluation of short-listed EETs is an iterative process, given that enabling factors influence the type of data required to characterize EETs and the availability of different EET data affect the enabling factors that can be explicitly considered. More information on market monitoring of the enabling environment for priority EETs is provided in Step 3.

**Table 11 • Building energy technologies according to economy, climate, and construction type**

Type of economy	Climate	Technology	
		New construction	Retrofit
		Insulation, air sealing and double-glazed low-e windows for all buildings*	
Developed	Hot climate	Architectural shading Very low-solar heat gain coefficient (SHGC) windows (or dynamic shades/windows) Reflective walls/roofs Advanced roofs (integrated design/BIPV) Optimised natural/mechanical ventilation	Exterior window shading and dynamic glass/shading Reflective roofing materials and coatings Reflective wall coatings Window film with lower SHGC New low-SHGC windows
	Cold climate	Highly insulated windows Passive heating gain (architectural feature / dynamic glass/shades) Passivhaus-equivalent performance based on LCC limitations.	Highly insulated windows Low-e storm or interior panels Insulated shades and other insulating attachments (low-e films) Exterior insulating wall systems Interior high-performance insulation
Developing	Hot climate	Exterior shading and architectural features Low-SHGC windows Reflective roofs and wall coatings	Exterior shading Reflective coatings (roof and wall) Low-cost window films

	Optimised natural/mechanical ventilation	Natural ventilation
Cold climate	Highly insulated windows (possibly double-glazed with low-e storm panel) Passive heating gain (architectural feature) Optimised low-cost insulation and air sealing.	Low-e storm or interior panels Insulated shades and other insulating attachments (low-e films) Exterior insulating wall systems Cavity insulation, lower-cost (e.g. expanded polystyrene) interior insulation.

Notes: BIPV = Building integrated photovoltaic. Passivhaus, an advanced residential building programme that calls for very high levels of building envelope performance, has gained significant momentum in Europe, and is active globally (see [www.passiv.de/en/index.php](http://www.passiv.de/en/index.php)).

\* The IEA recommends a minimum performance of all new windows globally to meet the performance of double glaze low-e with low conductive frames and climate optimised-SHGC. Air sealing is needed for any building that will have heating or cooling provided. Insulation is needed for all applications. Renovation is more challenging but possible, especially for roofs in all climates.

## Step 2: Selection of indicators and metrics

The selection of indicators and metrics for monitoring EET penetration and impacts is comprised of two sub-steps:

- 2.1. Selection of energy indicators to track progress toward energy efficiency goals in priority sectors, subsectors, and end uses; and
- 2.2. Selection of market penetration metrics for monitoring the uptake of priority EETs over time.

### 2.1 Select energy indicators

Energy indicators enable the monitoring of energy use over time. They are useful in assessing EET markets, because they enable analysis of energy use trends with and without EET adoption. An energy indicator expresses energy use at the sector, subsector, or end use level per unit of activity, where an activity is defined as a fundamental driver of that energy use within a given subsector. The general form of an energy indicator can be expressed as:

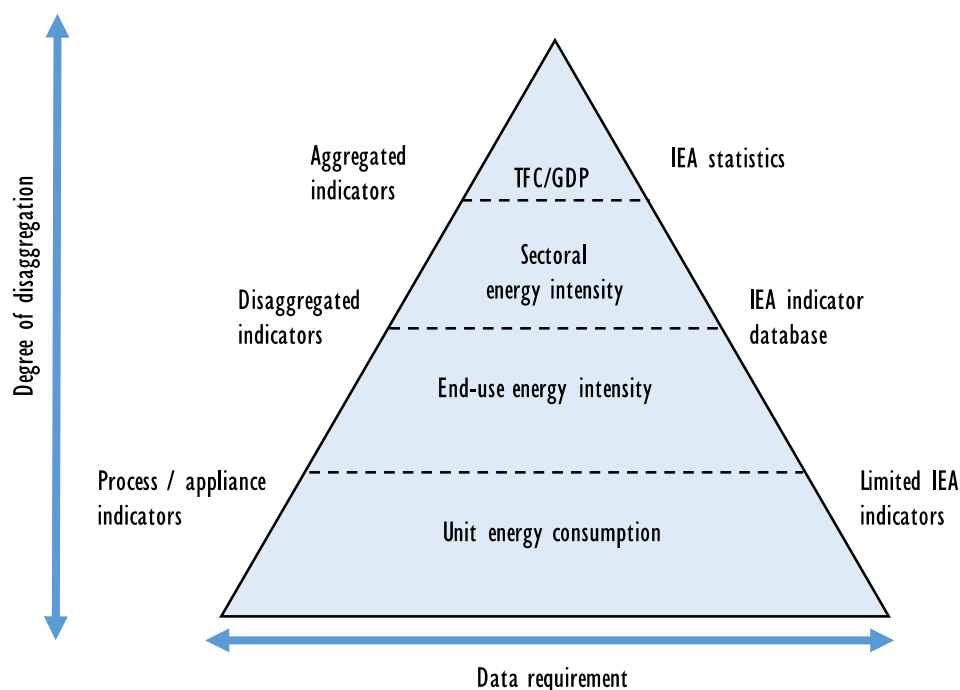
Energy indicator = (Energy use)<sub>ijk</sub> / (Activity)<sub>ijk</sub>, where i=subsector, j= end use, and k = fuel type

Examples of activities include passenger-kilometres (for passenger vehicles) or tonne-kilometres (for freight) in the transport sector, square metres of floor space (for residential or commercial buildings), or industrial output expressed in physical units (e.g., tonnes of raw steel) or monetary units (e.g., value added) (IEA 2014a, 2014b). Most commonly, energy indicators are expressed on an annual or semi-annual basis, depending on data collection cycles.

Two considerations must be made when selecting the appropriate energy indicator for a given priority end use of energy. First, one must determine the appropriate level of disaggregation of subsector energy data required to monitor changes in energy use over time (i.e., the numerator of the indicator). Second, one must determine the appropriate activity basis that drives that energy use (i.e., the denominator of the indicator). Decisions regarding the level of indicator disaggregation (and hence, data requirements) are made on the basis of balancing minimum information needs with the costs and complexities of increasingly disaggregated metrics, as depicted in Figure 24 (IEA, 2014a, 2014b).

When feasible, energy indicators should be selected at a level of end use disaggregation within each subsector that corresponds to the major end use(s) targeted for EET monitoring and deployment programs, as determined in the previous sub-step of the methodology. Alignment between the end uses captured by the energy indicator and the major end uses targeted by EET monitoring and deployment programs can allow the effects of EET adoption to be more clearly observed.

Figure 24 • Schematic representation of the IEA energy indicators pyramid



Source: IEA Notes: GDP = Gross domestic product; TFC = Total final consumption.

Source: IEA (2014b), *Energy Efficiency Indicators: Fundamentals on Statistics*.

The selection of energy indicators should also be informed by the need to assess both structural and technological changes within a country. Structural change refers to shifts between subsectors, segments, end uses, and production outputs in an economy over time, all of which generally influence a country's energy use. Examples of structural change include shifts between passenger rail and passenger cars in the transport sector, between multi-family to single-family or from rural to urban housing in the residential sector, and from primary (blast furnace) routes to secondary (electric arc furnace) routes in the iron and steel sector.

Technological change refers to shifts in technology within subsectors, such as from gasoline to electric passenger vehicles in the transport sector, from single pane to triple pane windows in the residential sector, and from standard to premium efficiency electric motors in the industrial sector (See Box 2).

As discussed next, recommended indicators can sometimes capture structural change through a sufficient level of sector or subsector disaggregation; for example, modal shifts in the transport sector can be captured by establishing separate indicators for passenger and freight segments. However, in certain cases it may be necessary to collect additional data to augment recommended indicators such that structural change can be assessed. For example, the percent of raw steel made from primary and secondary steel can be compiled alongside total subsector energy use per tonne of raw steel.

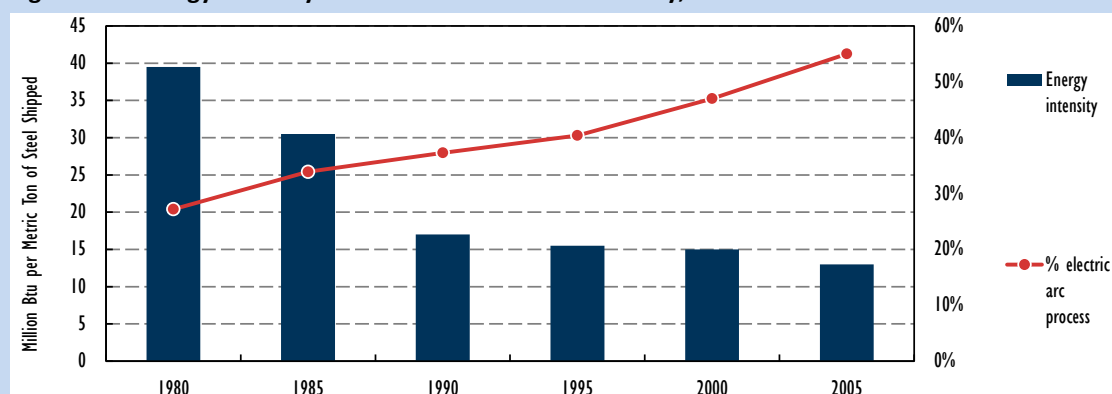
It can also be important to establish indicators by type of fuel; for example, the use of natural gas or electricity for space heating in the buildings sector and the use of electricity, diesel, gasoline, biofuels, or other fuels in the transport sector. Fuel-level indicators enable the assessment of opportunities for fuel switching (e.g., from gasoline to electric vehicles) and monitoring of overall fuel demands over time within a country.

## Box 2 • Structural versus technological change

To better understand the differences between structural change and technological change, consider the two figures below. Figure 25 depicts trends in the energy intensity of US steel production over a 21-year period expressed as million British thermal units (Btu) per tonne of crude steel. A steady decline in energy intensity can be observed. The figure also plots the percentage of total crude steel produced from scrap steel using the electric arc furnace route, which represents a structural shift in the industry. Therefore, the observed reduction in energy intensity can be reasonably well correlated to a structural shift from primary steel to secondary steel over time.

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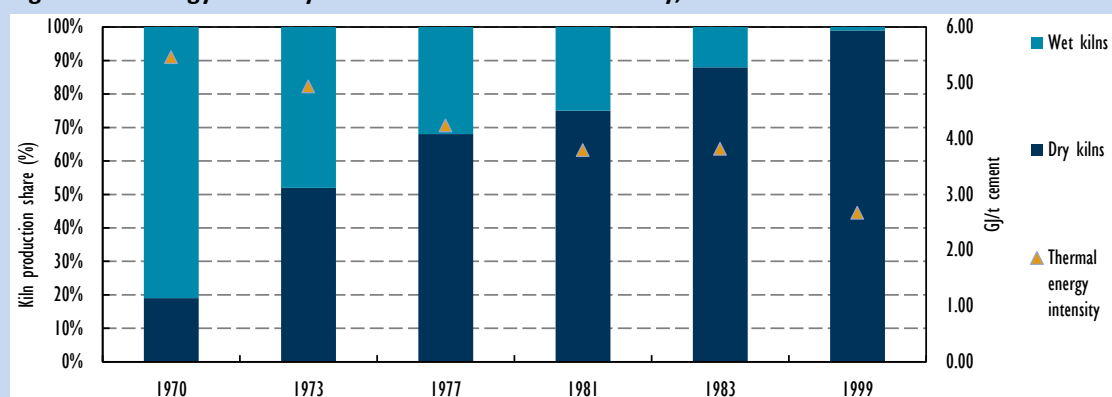
**Figure 25 • Energy intensity of the US iron and steel industry, 1980-2005**



Sources: Worrell, et. al. (2010), *Energy Efficiency Improvement and Cost Saving Opportunities for the U.S. Iron and Steel Industry: An ENERGY STAR® Guide for Energy and Plant Managers*; USGS (United States Geological Survey) (2015), *Minerals Yearbook: Volume I.-- Metals and Minerals*.

Figure 26 depicts trends in the energy intensity of Brazilian cement manufacturing over a 29-year period, expressed as GJ per tonne of clinker, and the percentage of clinker produced through energy-efficient dry kiln technologies (IEA 2015b). In this case, it is technological change (from wet kilns to energy-efficient dry kilns) that can explain the observed reductions in energy intensity over time. That is, over the 29-year period, the production pathway and feedstocks largely remained the same, but the adoption of energy-efficient kilns resulted in a lower energy intensity.

**Figure 26 • Energy intensity of the Brazilian cement industry, 1970-1999**



Source: IEA (2015b), *Energy Technology Perspectives 2015*.

## Energy indicators for the buildings and transport sectors

Tables 12 and 13 list the recommended indicator levels and activities for the transport and building sectors, respectively, as identified by the IEA (IEA, 2014a, 2014b). These recommended indicators are widely adopted because they are sufficiently disaggregated to track energy use at the major end use and segment levels, which will align well with EETs aimed at improving the

efficiencies of those end uses, and can also be applied to individual fuels within each sector. These indicators are also presently used for monitoring energy use in the transport and building sectors by different agencies and regions, and are based on energy use and activity data that are commonly or feasibly available through established data collection programs.

Depending on the breadth of subsector data obtained in the prioritisation step, the building indicators can be further refined by service type (e.g., office, food service, etc.) for commercial buildings and dwelling type (e.g., single family home, apartment, etc.) for residential buildings. It should be noted that the use of heating degree days (HDDs) and cooling degree days (CDDs) as an additional activity basis for space heating and space cooling, respectively, is optional but provides a more rigorous method for assessing trends in space heating and cooling energy use over time. Typical data sources for gathering the activity data in Tables 12 and 13 are discussed further in (IEA 2014a, 2014b).

**Table 12 • Recommended energy indicators for buildings**

Energy data	Activity data
Total space heating energy consumption	Total floor area
Total space cooling energy consumption	Total floor area cooled
Total water heating energy consumption	Total number of dwellings
Total lighting energy consumption	Total floor area
Total cooking energy consumption	Total number of dwellings
Energy consumption for all appliances of type A	Number of appliances of type A

Sources: IEA (2014a), *Energy Efficiency Indicators: Essentials for Policy Making* and IEA (2014b) *IEA Energy Efficiency Indicators: Fundamentals on Statistics*.

**Table 13 • Recommended energy indicators for transport**

Segment Subsector	Passenger (Activity basis: passenger-km)	Freight (Activity basis: Tonne-km)
Road	Powered 2- to 4- wheelers	Freight light-duty vehicles
	Passenger light-duty vehicles (PLDVs)	Heavy-duty vehicles (HDVs)
	Buses	Other
Rail	Passenger trains	Freight trains
Air	Passenger airplanes	Freight airplanes
Water	Passenger ships	Freight ships

Sources: IEA (2014a), *Energy Efficiency Indicators: Essentials for Policy Making* and IEA (2014b) *IEA Energy Efficiency Indicators: Fundamentals on Statistics*.

### Energy indicators for the industrial sector

The selection of energy indicators for the industrial sector can be complicated by several factors.

First, there can be great heterogeneity across the outputs of the industrial sector, which means unique indicators should be established for each priority industry subsector within a country. For example, energy use per tonne of clinker is a well-established indicator for cement manufacturing, while energy use per tonne of raw steel is a well-established indicator for iron and steel manufacturing. Therefore, each subsector requires unique considerations and data collection efforts to establish appropriate energy indicators.

Second, while major end uses of energy within each subsector can be identified through periodic surveys, plant audits, energy models, and engineering studies, continuous collection and reporting of plant data at the end use level is presently rare. Barriers include the lack of process-

level fuel and power monitoring at most industrial plants and confidentiality concerns related to reporting energy use with such detail. For these reasons, it is often not feasible to construct energy indicators for all industrial subsectors at the energy end use level.

However, the correlation between the total energy use of the subsector and the penetrations of EETs for major end uses within that subsector ultimately depend on the subsector. For example, in subsectors such as cement and iron and steel, process heating comprises the largest end use of energy (see Figure 18). Process heating in both subsectors is tied to just a few key process technologies (e.g., kilns for cement and furnaces for iron and steel). Therefore, the total energy use of the subsector is directly related to the penetrations of key EETs for process heating. In other words, for subsectors such as these, tracking of energy efficiency may not require monitoring of energy use at the end use level. However, observation of Figure 19 reveals that many industrial subsectors exhibit energy use that is less concentrated in a single end use and more distributed across multiple end uses. For such subsectors, an energy indicator based on total subsector energy use may not correlate as strongly to changes to a single end use, but this is a necessary limitation given the nature of energy use in such subsectors.

Third, physical activity bases (such as tonnes of clinker for cement manufacturing or tonnes of raw steel for iron and steel manufacturing) are preferable to monetary activity bases, because the former typically correlate directly to energy use while the latter are subject to variations in accounting methods, currencies, and market conditions. However, physical output data are not universally available across regions and industrial subsectors, and vary between regions and plants due to differences in output accounting methods. Therefore, it is often necessary to revert to monetary output bases for many industrial subsectors.

**Table 14 • Recommended energy indicators for major industrial subsectors**

Industrial subsector	Activity basis	Notes/sources
Aluminium	Tonnes of aluminium	Used widely (IEA, 2007, 2009c, 2014a, 2014b)
Cement	Tonnes of clinker	Used widely (IEA, 2007, 2009c, 2014a, 2014b)
Chemicals	Tonnes of product	Applicable to ammonia, ethylene, methanol, propylene, and BTX (IEA 2007, 2009c, 2014a, 2014b)
Chemicals	Value of shipments	Applicable to all other chemicals (IEA, 2014b)
Food and beverage	Value of shipments	For homogeneous products, examples of physical output exist: fluid milk, cheese (LBNL, 2012); wine (LBNL, 2006)
Glass	Tonnes of glass pulled	Established in industrial cap and trade (CARB, 2015)
Iron and steel	Tonnes of raw steel	Used widely (IEA, 2007, 2009c, 2014a, 2014b); for structural change primary and secondary steel can have separate indicators
Pulp and paper	Air dried tonne	Used widely (IEA, 2007, 2009c, 2014a, 2014b)
Textiles	Value of shipments	Examples of physical output bases exist (LBNL, 2015)
Wood products	Value of shipments	No examples of physical output bases identified
Other	Value of shipments	Inclusive of remaining industrial subsectors for which no examples of physical output bases were identified

Table 14 summarises recommended energy indicators for major industrial subsectors. These recommendations are primarily based on well-established activity bases as identified in the literature, with an emphasis on activity bases that have been utilized for energy intensity tracking of major industrial subsectors by the IEA (IEA 2009a, 2009b, 2009c, 2014a, 2014b). Specifically, physical activity bases are recommended for aluminium, iron and steel, cement, pulp and paper, and high-volume chemicals while monetary output bases are recommended for heterogeneous

industrial subsectors for which no physical output bases are in widespread use. Additionally, physical activity bases may be feasible for the glass, textiles, sawmills, and certain food and beverage subsector products as indicated in Table 14.

Typical data sources for gathering the activity data in Table 14 are discussed further in (IEA 2014b).

## 2.2 Select EET market penetration metrics

In general, EET penetration is expressed as the percentage of the market that has adopted the EET within a given country or region. However, a common challenge in developing EET penetration metrics is to determine the market basis upon which penetrations are expressed. In the most direct approach, EET penetration should be expressed per unit of activity that is used in the denominator of the chosen energy indicator for each priority end use. For example, to monitor the penetration of electric vehicles in the passenger vehicle segment of the transport sector, it is preferable to express the penetration metric as the percent of total passenger-kilometres related to electric vehicle use. Similarly, to monitor the penetration of dry kiln technologies in the cement subsector, it is preferable to express the penetration metric as percent of total tonnes of clinker produced using dry kiln technologies. Or to monitor the penetration of high-efficiency space heating furnaces in the residential buildings sector, it may be ideal to express the penetration metric as a percent of total floor area that is heated using this furnace technology.

The advantage of maintaining consistency of activity units between the selected energy indicators and EET penetration metrics is that it can respect the physical/causal relationships that occur between energy use and EET adoption in a given subsector or segment. Doing so provides policy makers with indicators and penetration metrics that can be better correlated and give greater confidence to observed trends. Another advantage is that expressing penetration metrics in this fashion can offer direct compatibility with bottom-up energy models of different subsectors and end uses. This enables energy analysts to better calibrate models and to use models to explain and explore the effects of EET adoption on the basis of observed data from the marketplace.

A disadvantage to this approach is that it can be difficult to obtain market data sufficient to determine the market share of each EET as a percentage of the overall sector activity. For example, as discussed below, sales data on the number of electric vehicles purchased within a region might be obtainable from manufacturer sales reports or vehicle registration data. However, determining the percent of total passenger-kilometres attributable to those electric vehicles would require surveys of both electric and non-electric vehicle owners to understand their respective behaviours and driving patterns. In the absence of such data, transport models could be used to estimate the percent of passenger-kilometres attributable to electric vehicles, which requires additional analysis effort and assumptions related to use patterns of different vehicle types. As a result, it may be more practical to select electric vehicle penetrations expressed as a percentage of new passenger vehicle sales or as a percentage of total passenger vehicle stock, given such percentages can be more readily developed using market data (IEA 2015b).

Similarly, in the buildings sector, data on sales of EETs (e.g., triple-paned windows, or energy-efficient appliances) might be reasonably obtainable, but expressing penetrations for those EETs as percentages of total floor space (for windows) or number of appliances would require additional assumptions about the building and appliance stocks. Again, such assumptions can be made in models using different data and analysis techniques, but such analyses would need to

occur on regular basis and using consistent methods to estimate penetrations on a percent activity basis in year over year fashion.

One exception may be industry, for which in certain subsectors data on EET adoption and production outputs may be more readily available for certain technologies. For example, a cement plant can report the type of kiln technology in use and the total annual tonnes of clinker produced from each kiln, given that these operations are central to their business. Additionally, the types of furnaces used per tonne of raw steel, per tonne of raw glass, or per tonne of ethylene produced might be readily available from most steel mills, glass plants, and ethylene plants, respectively, for a similar reason.

However, for industrial subsectors with activities based on the monetary value of outputs, expressing EET penetration as a percent of monetary output may be more problematic. For subsectors with limited heterogeneity in their production outputs, it may be more likely that a correlation will exist between changing EET penetration per unit of monetary output and changes in the energy indicator. However, for subsectors with substantial heterogeneity, expressing EET penetration as a percent of monetary output may not lead to additional useful insights due to weaker correlation between monetary output and overall subsector energy use.

### *Alternative activity bases*

Often it may not be feasible to develop penetration metrics on a percent of subsector or end use activity basis due to lack of data or weak correlations, as discussed above. In such cases, it is recommended that EET penetration metrics be expressed on one of the following bases due to ease and frequency of use:

**As a percent of the total equipment stock.** For example, the number of high-efficiency space heating furnaces divided by the estimated total number of space heating furnaces in residential homes in a region. While this basis does not capture the percent of total space heating energy use attributable to the EET, it is often fairly straightforward to calculate based on readily collectable data and stock estimates. Furthermore, longer-scale trends should expose a strong correlation between increasing fractions of installed furnaces and reductions in fuel use per square meter.

**As a percentage of ownership.** For example, the number of residential and commercial buildings with LED lighting or the number of industrial plants with premium efficiency electric motors. This basis is typically less desirable than the former basis, given that there may still be some lights in the dwelling or commercial building that are not LEDs and there may still be some non-premium efficiency motors within a plant. In other words, ownership percentages are not the same as stock percentages unless there is typically only one device per owner. However, an advantage to this basis is that ownership data can sometimes be readily obtained through consumer, household, and business surveys for technologies like lights, pumps, and motors for which there may be many devices in one structure or facility. Additionally, over the long-term, as the percent of respondents expressing ownership increases, it is likely that a corresponding decrease may be observed in the energy indicator as long as the EET targets a major end use within the priority subsector.

## **Step 3: Monitoring EET markets**

The identification and selection of priority EETs for monitoring should be sharply focused on EETs that can improve energy efficiency in priority sectors, subsectors, and end uses identified, in alignment with the chosen energy indicators for tracking energy use, and in consideration of the factors that can foster an enabling environment for the EET in Steps 1 and 2.

This step focuses on EET monitoring, which consists of the following sub-steps:

- 3.1. Identify additional information and data requirements necessary to monitor priority EETs and their enabling environments, which will improve decision makers' understanding of market barriers over time.
- 3.2. Establish data collection systems to facilitate the flow of required data and information for market monitoring over time.
- 3.3. Continuously assess data quality and requirements to identify and implement opportunities for improvement.

### 3.1 Identify additional data requirements

The purpose of this sub-step is to identify additional information and data requirements necessary to establish priority EET baselines and to monitor the enabling environments associated with the priority EETs, which will improve decision makers' understanding of market barriers over time. Identifying enabling environment factors in this sub-step is technically optional but recommended, given that enabling factors (technical, social, economic, policy, etc.) can have significant influence on the adoption potential of many EETs.

#### Baseline indicators

It is often desirable to establish baseline indicator values (also known as reference indicator values) to ensure proper understanding of markets and appropriate interpretations of potential correlations between energy indicators and EET penetration metrics over time. In general, there are two approaches to establishing baseline indicators for monitoring and assessing EET penetrations.

The first is to conduct analyses and/or gather sufficient market data to develop a quantitative relationship between installed technologies in the marketplace and the present day indicator value. This approach is only possible with the existence of a credible "bottom-up" model of a sector, subsector, segment, or end use that is populated with sufficient data to estimate the energy use attributable to all major technologies therein, inclusive of the EETs in question as well as other existing installed technologies. One example of such a model is MoMo (see Figure 20) for the transport sector, which enables estimation of total fuel use per passenger-km or tonne-km within a region on the basis of vehicle stock and operations data. In such a model, the market baseline can be expressed in rich bottom-up detail, which facilitates quantitative replications and explanations of how changes to EET penetrations will change the energy indicator value over time. In other words, the reference technology system is well understood and the value of the energy indicator is feasibly computable from the values of EET penetration metrics. This method of base-lining is strongly preferred by energy analysts, but requires deep modelling capabilities and expertise that may vary greatly by subsector and region.

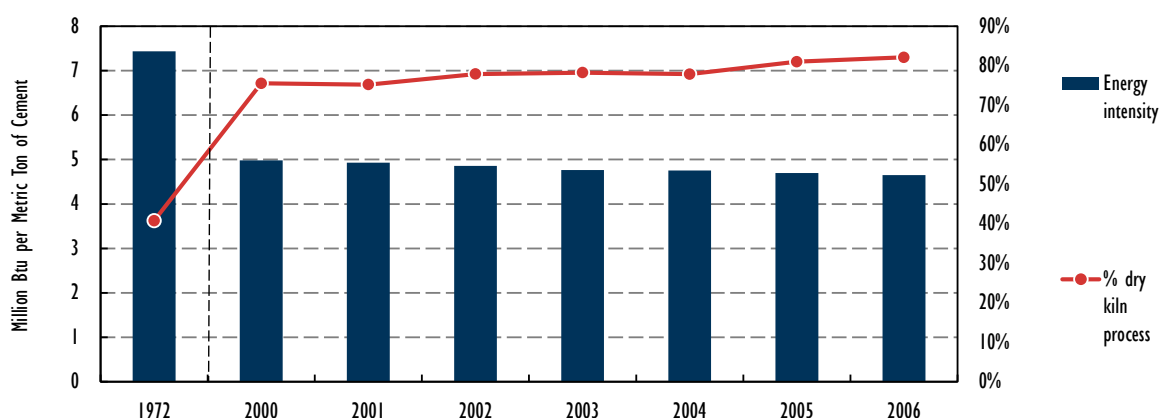
The second is to anchor the analysis in a base year for which data for energy indicators and EET penetrations are collected in consistent and credible fashion but are not mathematically linked in a quantitative model. This approach can be thought of as "decoupled," since independent data series are created for energy indicators and EET penetration metrics that are subsequently plotted together to analyse correlations over time. In other words, the baseline indicator value is not rooted in a deep understanding of all technologies in the marketplace. While this approach is scientifically less desirable than using a quantitative model, in practice due to the complexities of different subsectors and difficulties and costs associated with obtaining data sufficient to model a subsector it is often the only option. For example, Figure 27 plots an energy indicator for U.S. cement manufacturing expressed as energy per tonne of clinker and an EET penetration metric

expressed as the percent of clinker produced using dry kiln technologies (USGS, 2015). In this example, the reference value could be based in 2000 with an industry average cement plant efficiency of 5 million Btu per tonne of clinker, which allows for assessment of subsequent energy intensity reductions against increased penetration of dry kilns moving forward.

In practice, one may gather additional market data to better characterize installed technologies behind the reference indicator value such that overall trends and relationships between energy indicators and EET penetration metrics over time can be better understood and explained.

When establishing EET penetration metrics in Step 2, it is important to consider the potential sources of required data, any limitations the available data may impose on the selection of EETs and the metrics used to monitor their penetrations, and how those data will be collected, analysed, and interpreted over time in a consistent fashion. Without a robust data collection and analysis plan, an EET monitoring program is at risk of suboptimal analyses and data gaps, which may diminish the value of the program.

**Figure 27 • Energy use per tonne of clinker in US cement manufacturing**



Sources: Portland Cement Association (2008), *U.S. and Canadian Labor-Energy Input Survey 2008*; USGS (2015), *Minerals Yearbook: Volume 1.-- Metals and Minerals*.

While the sources of data will vary greatly by region, sectors, subsectors, and specific EETs, there are some common data sources used that can be considered when developing and implementing an EET monitoring program. The IEA's *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014b) summarizes a number of such sources of data on energy use, activities, and technology characteristics for each major end use sector. However, identification of the most appropriate data sources must be made within the implementing country and in the context of their priority sectors, subsectors, end uses, and EETs.

### Enabling factors

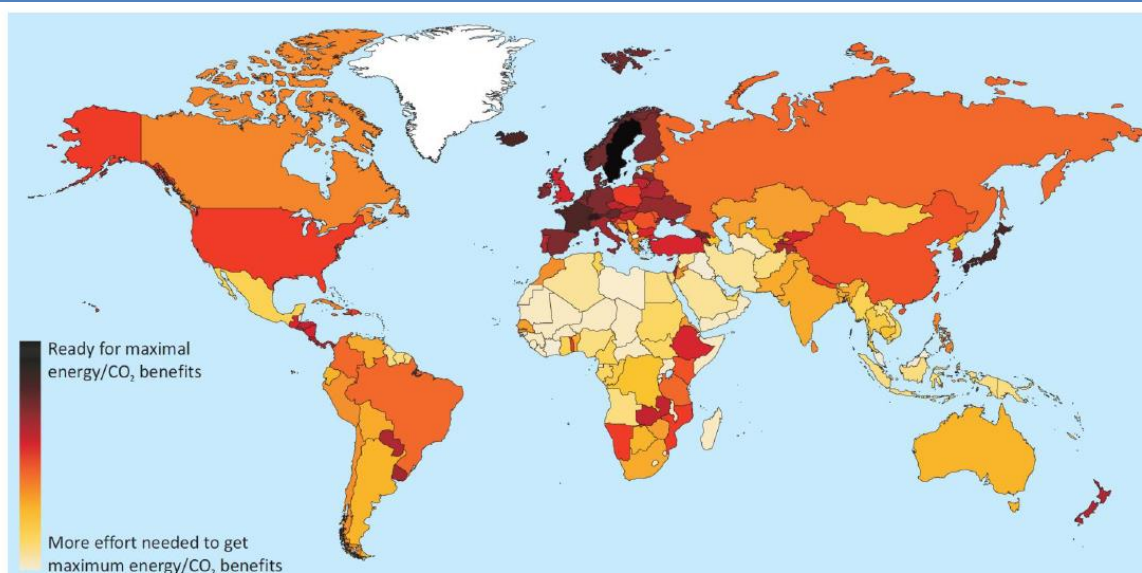
In addition to tracking EET penetration over time, it is often advisable to track the status of key policy, market, and other factors that contribute to the enabling environment for greater EET adoption. This facilitates an improved understanding of the evolution of key market conditions, and thereby complements well the utility of energy use indicators and EET penetration metrics for guiding policy and investment decisions. One option for certain EETs and subsectors are readiness or maturity indices, which have been developed for assessing the markets for select EETs in multi-factoral fashion, analogous to the consideration of enabling factors in the previous methodological step.

The IEA’s Tracking Clean Energy Progress approach provides a well-established model for consideration of technology penetration, market creation and technology developments for different sectors. For example, Table 15 depicts a readiness scoring system developed by the IEA to assess whether a country has put in place the necessary elements of a policy package to promote adoption of fuel efficient vehicles (IEA, 2012). In another example from the transport sector, Figure 28 summarises the IEA’s Low-Carbon Electric Transportation Maximisation Index rating for different countries, which expresses the readiness of country energy supplies and markets to maximize the energy and CO<sub>2</sub> emissions reduction benefits of electric vehicles (IEA, 2014c). Consideration of established readiness or maturity indices such as these can provide further input in the state of the enabling environment for EETs within specific countries and subsectors, and can help guide one toward selections of EETs for monitoring that reflect a country’s market status for key energy goals.

**Table 15 • Fuel economy readiness scoring system**

Policy	Score			
	0	1	2	3
Fuel tax	High subsidy	Low subsidy	Low tax	High tax
Status of fuel economy standard implementation	No standard	Proposed for light vehicles	Enacted for light vehicles	Enacted or proposed for light and heavy vehicles
CO <sub>2</sub> - or efficiency-based vehicle registration or ownership tax	No	Yes		
Availability of fuel economy labels	No	Yes		

**Figure 28 • Low-Carbon Electric Transport Maximisation Index**



Note: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: IEA (2014c), *Energy Technology Perspectives 2014*.

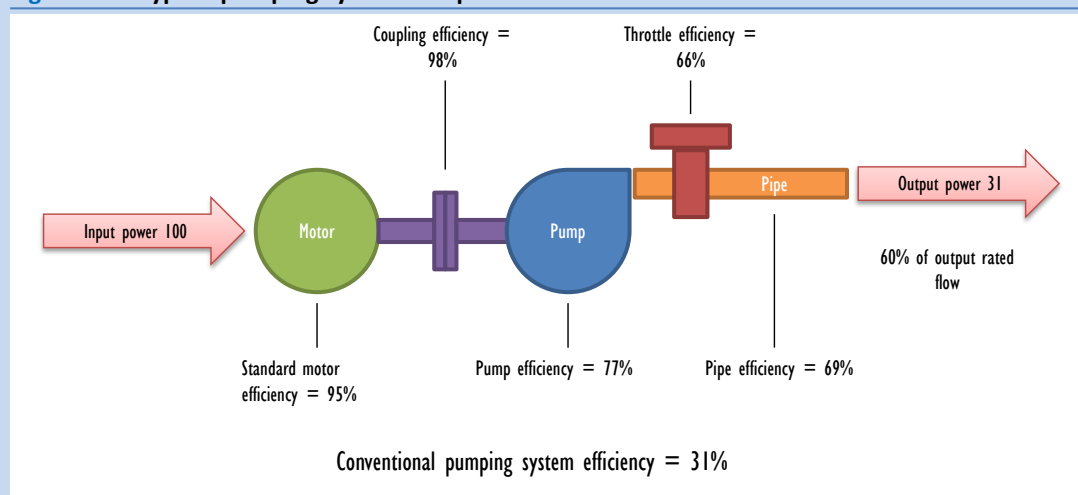
## Consideration of system effects

It may also be important to consider systems effects when monitoring priority EET markets and the effects of EET uptake on overall sector, subsector, and end use energy use, particularly for cross-cutting technologies (see Box 3). Many cross-cutting technologies are only one part of an overall system that provides an energy service; therefore, the energy use of the system is only partially influenced by the installation of an EET. For example, in space cooling for commercial buildings, a more efficient chiller will increase the efficiency of chilled water production, but if piping systems are uninsulated, compressor load scheduling is poor, and space cooling controls are suboptimal, the presence of a more efficient chiller may have less than the desired effect for reducing space cooling energy demand. Similar examples exist for many other cross-cutting technologies, including motor systems, pump systems, refrigeration systems, steam systems, and HVAC systems in the residential, commercial, and industrial sectors.

### Box 3 • Increasing pumping system efficiency in an industrial system

Pumping systems comprise a significant fraction of electricity use in the industrial sector, and particularly for the beverages, chemicals, food processing, and pulp and paper industries (ENERGETICS 2012). As depicted below, a typical pumping system is comprised of several components, including a motor, coupling, pump, valves, pipes, and end use processing equipment, all of which contribute to the energy use of the pumping system (UNIDO 2010).

**Figure 29 • Typical pumping system components and efficiencies**



Source: Based on UNIDO (2010), *Motor Systems Efficiency Supply Curves*.

Therefore, while the installation of more energy efficient motors and pumps is an important efficiency strategy, the overall energy use of the system is also influenced by the efficiency and operations of the remaining system components. Similar system dependencies exist for other important motor-driven systems, such as refrigeration systems, compressed air systems, fan and blower systems, and machine drive systems. It can therefore be challenging to assess the efficiency of such motor driven systems by monitoring installations of efficient pumps, motors, fans, and compressors in isolation. Such components are easier to track (e.g., through sales data, surveys, and facility audits) than overall system operating parameters, which often require process measurements. However, as illustrated by the data in Table 16, which is based on recent study of industrial motor system efficiency potentials by the United Nations Industrial Development Program (UNIDO 2010), operations and maintenance strategies can have similar effects on overall pumping system efficiencies as do upgrades to more efficient pumps and motors alone.

**Table 16 • Energy efficiency measures for pumping systems**

Energy efficiency measure	Typical (%) improvement in energy efficiency over current pumping system efficiency practice (Medium efficiency base case)
<b>1.1 Upgrade system maintenance</b>	
1.1.1 Fix leaks, damaged seals, and packing	2.5%
1.1.2 Remove scale from components such as heat exchangers and strainers	5%
1.1.3 Remove sediment/scale build-up from piping	7%
<b>1.2 Eliminate unnecessary uses</b>	
1.2.1 Use pressure switches to shut down unnecessary pumps	5%
1.2.2 Isolate flow paths to non-essential or non-operating equipment	10%
<b>1.3 Matching pump system supply to demand</b>	
1.3.1 Trim or change impeller to match output to requirements	15%
<b>1.4 Meet variable flow rate requirement without throttling or bypass</b>	
1.4.1 Install variable speed drive	15%
<b>1.5 Replace pump with more energy efficiency type</b>	15%
<b>1.6 Replace motor with more energy efficiency type</b>	3%
<b>1.7 Initiate predictive maintenance program</b>	9%

Source: UNIDO (2010), Motor Systems Efficiency Supply Curves.

While such system dependencies may be unavoidable from a technology perspective, effective monitoring of EET penetration for cross-cutting systems can still occur with some additional information and initiatives. For example, surveys and audits aimed at assessing best practices for cross-cutting systems— such as the presence of monitoring and maintenance programs, installations of optimal controls, and efficient operations—can shed light on whether systems characteristics will affect the correlation of EET adoption to overall energy use and which conditions may affect such correlations. Furthermore, the use of models with engineering analysis, such as building energy models (IEA, 2013b) or industrial motor, pump, steam, and process heating system efficiency models (DOE, 2015d), can help establish the extent to which specific systems conditions can affect cross-cutting energy use and which should be investigated further within specific subsectors and end uses.

Another potential way to overcome difficulties with system effects is to also gather information on energy efficiency certifications such as LEED (USGBC, 2015) in the buildings sector or ISO 50001 (ISO, 2014) in the industrial sector. Such certifications apply to the whole building or plant but are inherently indicative of strong energy management programs that would typically ensure that systems efficiencies are maximised in cross cutting systems when EETs are adopted.

Results for pumping system improvement opportunities show that practices related to improved operations, system configurations, and maintenance can lead to energy savings equivalent or greater than the energy savings associated with upgrading motors and pumps to the most efficient models alone.

### 3.2: Establish data collection systems

As discussed in Step 2, there is strong interdependency between the chosen energy indicators and EET penetration metrics and the required data for populating those metrics. In turn, the required data will drive the design of the data collection system, including:

- who provides the data (e.g., consumers, businesses, industry associations);

- who gathers the data (e.g., statistical agencies, market research firms);
- how the data are collected (e.g., surveys, audits, models);
- how often the data are collected; and
- data analysis and quality control

In this sub-step, each of these elements of the data collection system should be clearly defined and a process should be put in place to sustain the system in the future. In some countries, these elements may already be in place but need to be linked. In other countries, elements may need to be established to sustain the data collection system.

The IEA's *Energy Efficiency Indicators: Fundamentals on Statistics* report (IEA, 2014b) contains detailed guidance on the establishment of data collection systems, including what types of data to collect for each demand sector, data validation, and data dissemination. A summary of the typical data sources identified by the IEA for each demand sector is provided in Tables 17-20, which can serve as a useful reference for countries without existing data collection systems in place. The specific agencies and stakeholders that must be engaged to collect, validate, and disseminate the required data identified in Steps 2.1, 2.2, and 3.1 will vary by country.

**Table 17 • Typical data sources for the residential sector**

Data	Source	Methodology
<b>Energy data</b>		
Total residential consumption		Administrative sources Modelling
Energy consumption by source	National energy balance Utilities	Administrative sources Modelling
<b>Activity data</b>		
Floor area	National statistics offices Regional governments Real estate Taxation registers	
Number of dwellings	Land registry National statistics offices	Administrative sources Surveys
Heating equipment	Building registers Manufacturers/Vendors Subsidy registers	Administrative sources
Number of appliances	Manufacturers National statistics offices	Administrative sources Surveys

Source: IEA (2014b), *Energy Efficiency Indicators: Fundamentals on Statistics*.

**Table 18 • Typical data sources for the services sector**

Data	Source	Methodology
<b>Energy data</b>		
Total services consumption	National energy balance	Administrative sources Modelling
Service category consumption	Utilities	Administrative sources Modelling
<b>Activity data</b>		
Floor area	National statistics offices Regional governments Business taxation offices through national or regional networks Building permits offices National services sector surveys	Administrative sources    Surveys
Value added	National statistical office	Administrative sources
Unit of activity	National statistical offices Chambers of commerce, etc.	Administrative sources Surveys
Equipment	Manufacturers Importers, etc.	Administrative sources Surveys

Source: IEA (2014b), *Energy Efficiency Indicators: Fundamentals on Statistics*.

**Table 19 • Typical data sources for the transport sector**

Data	Source	Methodology
<b>Energy data</b>		
Total transport consumption	National energy balance National energy statistics	Administrative sources Modelling
Consumption by subsector	National energy balance National energy statistics	Administrative sources Mobility surveys Modelling
Consumption by segment		Mobility surveys Modelling
Consumption by vehicle type		Mobility surveys Modelling
<b>Activity data</b>		
GDP, population	National statistics offices	Administrative offices
Vehicle-km (vkm)	Vehicle registers / roadworthiness testing services / Inspecting organisations Municipalities / Transport authorities National and international databases Transport ministries	Measurements: odometer readings  Measurements: road traffic count  Administrative sources Mobility surveys Modelling
Passenger-km (pkm)	National and international databased	Administrative sources

	Transport ministries	Mobility surveys
Tonne-km (tkm)	National and international databased Transport ministries	Administrative sources Mobility surveys, freight surveys
Vehicle stocks*	Statistics offices Manufacturers National and international databases Vehicle registers	Administrative sources Administrative sources / measurements
Fuel economy	Manufacturers	Administrative sources Modelling

Note: \*The quality of the vehicle stock data may be variable depending on the quality of the scrappage statistics.  
 Source: IEA (2014b), *Energy Efficiency Indicators: Fundamentals on Statistics*.

**Table 20 • Typical data sources for the industrial sector**

Data	Source	Methodology
<b>Energy data</b>		
Total industry consumption	National energy balance	Administrative sources
Total subsectoral consumption	National energy balance Utilities	Administrative sources
Subsectoral process consumption	Manufacturers Industry associations	Facility-level audit Measurements Surveys
<b>Activity data</b>		
Value added	National statistics offices National accounts International sources*	Facility-level audit Measurements Surveys
Subsectoral production output	Manufacturers Industry associations	Facility-level audit Surveys
Process/product type output	Manufacturers Industry associations	Facility-level audit Surveys
Equipment	Manufacturers Industry associations	Administrative sources Surveys

Notes: \*For example the UNIDO International Yearbook of Industrial Statistics includes global estimates of value-added, among a number of other variables, for ISIC economic activities, etc.

Source: IEA (2014b), *Energy Efficiency Indicators: Fundamentals on Statistics*

### 3.3: Assess data quality and requirements

As this methodology is implemented in practice, it is of critical importance to continuously evaluate the previous sub-steps by analysing and interpreting the energy indicator, EET penetration, and complementary market data over time with an eye toward quality control and continuous improvement. Additionally, where available, information the evolution of enabling environment factors can also be analysed and interpreted to aid in identifying factors contributing to market success or failure.

An important component of this sub-step is continuous improvement. Questions to ask in this regard include:

- Do the results make sense? If not, why?
- Do the chosen indicators and penetration metrics result in credible trends analysis?
- Does the quality of data support robust conclusions?
- Could the chosen indicators and/or penetration metrics be improved? If so, how?

## Conclusions

This paper responds to the need for a conceptual framework for decision makers to assess and monitor deployment of clean energy technologies in the SEMED and ETC regions. Clean energy technologies could be critical for countries in these regions to achieve a range of policy goals, not least to transition to lower-carbon energy systems.

Together with its companion report *“Enabling Renewable Energy and Energy Efficiency Technologies – Opportunities in Eastern Europe, Caucasus and Central Asia”* (IEA, 2015a), the methodology presented in this publication has been developed as a starting point to build the information set necessary to increase investments in and strategies to realise the potential for increased energy efficiency and renewable energy.

Ultimately the goal is not only to enable appropriate investments in clean energy technologies, but also to allow decision makers to make informed and factual decisions about how effective the current policy and regulatory framework is at supporting the desired levels of RET and EET deployment.

Countries in the SEMED and ETC regions have taken various measures to support market penetration of clean energy technologies, ranging from investment schemes, tax measures, incentive tariffs, voluntary programmes, obligations, tradable certificates and regulatory and administrative rules. While particular national circumstances will determine the appropriate energy policy mix, tracking both technology- and sector-specific indicators is important to get a clear overview of opportunities and barriers to achieving clean energy technology deployment targets.

Establishing and maintaining sound policies requires the availability of good quality, timely, comparable and detailed data that go well beyond those currently included in energy balances, and which reflect the distinct characteristics of economic activity and resources available in each country. Information at the technology level can aid in the formulation of targeted policies and investments, which can be useful where resources are limited.

That said, care must be taken in drawing policy recommendations from the measurement of market penetration of individual technologies, or sector-specific trends, in isolation. There is growing awareness of the need to seek systemic solutions for the de-carbonisation of global energy systems. In the established energy systems of the IEA Member countries as well as in the dynamic contexts of SEMED and ETC economies, it is crucial to adopt a system perspective in the assessment of the priority areas and action options for RETs and EETs use.

## Acronyms, abbreviations and units of measure

### Acronyms and abbreviations

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BAT	Best available technology
BPT	Best practice technology
BTL	Biomass-to-liquids
CDD	Cooling degree day
CO <sub>2</sub>	Carbon dioxide
DHC	District heating and cooling
DOE	United States Department of Energy
EBRD	European Bank for Reconstruction and Development
EET	Energy efficiency technology
ETC	Early transition countries
EU	European Union
EV	Electric vehicles
FINTECC	Finance and Technology Transfer Centre for Climate Change (EBRD)
FAO	Food and Agriculture Organization
GDP	Gross domestic product
GEF	Global Environment Facility
GHG	Greenhouse gas
HDD	Heating degree day
HDV	Heavy duty vehicle
HVAC	Heating, ventilation and air conditioning
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IRESN	Institute for Research in Solar and New Energies of Morocco
ISO	International Organization for Standardization
LCOE	Levelised cost of electricity
LDV	Light-duty vehicle
LED	Light emitting diode
MoMo	Mobility Model
MTRMR	<i>Medium-Term Renewable Market Report</i>
PLDV	Passenger light-duty vehicles
PV	Photovoltaic
R&D	Research and development

RD&D	Research, development and demonstration
RETs and EETs	Energy efficiency and renewable energy technologies
RET	Renewable energy technology
RISE	Readiness for Investment in Sustainable Energy
RRA	Renewables Readiness Assessment
SEMED	Southern and Eastern Mediterranean
SE4All	Sustainable Energy For All
SHGC	Solar heat gain coefficient
TNA	Technology Needs Assessment
TPES	Total primary energy supply
UN	United Nations
UNECE	United Nations Economic Commission for Europe
WACC	Weighted average cost of capital

### Units of measure

EJ	Exajoule
Gt	Gigatonne
Gtoe	Gigatonnes of oil equivalent
GW	Gigawatt
kW	Kilowatt
Mtoe	Megatonne of oil equivalent
MW	Megawatt
MWh	Megawatt hour
PKM	Passenger kilometre
TJ	Terajoule
TKM	Tonne kilometre
TWh	Terawatt hours
USD	United States dollars
VKM	Vehicle kilometre

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## Annex 1: Step-by-step companion guide

### Introduction

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This document summarises the IEA's Clean Energy Technology Assessment Methodology (CETAM). It outlines each of CETAM's key steps and is designed as a companion to the full IEA Insights Paper, *The Clean Energy Technology Assessment Methodology: A methodology for assessing renewable energy and energy efficiency technology markets*. This document should be read in conjunction with the Insights Paper, which explains the rationale and key steps in more detail.

The three overall steps are broadly the same for assessing RETs and EETs and include:

1. Prioritisation;
2. Establishing indicators, metrics and data; and
3. Monitoring progress.

While these main steps are the same for assessing both RETs and EETs there are some key differences. For EETs the current and prospective service demand levels are used to define market potential, and priorities for action and monitoring. In the RET case market potential is defined primarily by the resource potential and the fit between particular RETs and energy priorities. This is reflected in the ways that the prioritisation stage of the methodology is executed in the two cases.

Given these differences between RETs and EETs, there are different sub-steps for analysing each technology type which necessitates presenting the steps for assessing RETs separately to those for assessing EETs. This document is therefore structured in two parts. Part I outlines the steps for assessing RETs, which are summarised in Table A1. Part II outlines the steps for assessing EETs, which are summarized in Table A2.

**Table A1 • Steps and sub-steps of the RET market penetration methodology**

Step	Description
<b>1</b>	<b>Prioritisation of resources and RETs</b>
1.1	Identify renewable resources
1.2	Estimate likely costs
1.3	Assess technology maturity and technology ambition
1.4	Establish Strategic priorities
1.5	Identify market opportunities
1.5.1	Map energy end-uses by fuel to resources
1.5.2	Identify market sector/technology pairs
1.6	Rate priority technologies
<b>2</b>	<b>Establish indicators, metrics and data</b>
2.1	Assess current deployment levels
2.1.1	Gather capacity and generation data for each RET
2.1.2	Review data quality
2.1.3	Calculate sectoral shares

2.2	Assess remuneration costs and financial support
2.2.1	Grid connected electricity
2.2.2	Off grid electricity systems
2.2.3	Renewable heat
2.2.4	Renewable transport fuels
<b>3</b>	<b>Monitoring progress</b>
3.1	Tracking deployment
3.2	Tracking and benchmarking costs
3.3	Evaluating enabling environment
3.3.1	Policy, regulatory and institutional factors
3.3.2	Financial and market factors
3.3.3	Technical and infrastructure factors
3.3.4	Social factors
3.3.5	Environmental factors

**Table A2 • Steps and sub-steps of the EET market penetration methodology**

Step	Description
<b>1</b>	<b>Prioritisation of sectors, subsectors, end uses, and EETs</b>
1.1	Compile and review national energy data and statistics
1.2	Evaluate trends in energy use, drivers, and policies
1.3	Identification of priority EETs for market monitoring
1.3.1	Evaluate future technology trends, analyses, and policies
1.3.2	Consideration of enabling factors for market success
1.3.3	Identifying specific EETs within technology systems [optional]
<b>2</b>	<b>Indicators needed to monitor the penetration of priority EETs.</b>
2.1	Identify appropriate energy indicators
2.2	Develop EET penetration metrics
<b>3</b>	<b>Measuring and monitoring</b>
3.1	Identification of additional data requirements
3.2	Establish data collection systems
3.3	Market monitoring

## Part I: Assessing renewable energy technologies

### Step 1: Technology prioritisation

This step involves identifying which RETs have the most significant potential in a country. These are then prioritised according to their state of market readiness and their potential role in meeting strategic energy objectives. This allows efforts on data collection and monitoring to be focused on the resources and technologies of greatest significance.

The methodology assumes that an overall evaluation of the renewable energy resources available in a country has been carried out, and that a quantitative assessment of the technical

potential and likely energy costs has been carried out for those with the most promise. Where such assessments have not been carried out, a significant effort will be required to establish which resources are likely to be practical and economic in the short and longer term and what the overall technical and economic potential might be. This work is judged to be outside the scope of this methodology.

There are five main sub-steps at this stage:

- 1) Identifying the renewable resources with greatest potential;
- 2) Estimating the likely costs of produced energy;
- 3) Assessing technology maturity and the country's technology ambition (whether it is seeking to be a technology developer or technology taker);
- 4) Assessing the potential for RETs to contribute to strategic energy needs; and
- 5) Identifying most significant market applications for each priority technology.

While these sub-steps are presented linearly in this document, there is no particular order in which they should take place and can be conducted in parallel. A final sub-step involves taking all five factors into account to produce an overall rating of potential RETs.

### 1.1 Identify renewable energy resources

On the basis of available information and analyses, the potential of each renewable resource is identified, allowing high potential sources to be identified.

### 1.2 Estimate the likely costs of produced energy

Establish likely cost ranges for exploiting renewable resources, based on benchmark information on technology costs and available information on resource levels and likely cost of capital in the specific markets. (See Annex 2 in Methodology Insights Paper for appropriate cost ranges).

### 1.3 Assess technology maturity and the country's technology ambition

Looking at the technologies available to make use of the most promising renewable resources, consider the maturity of the technologies (see Table A3) and the country's appetite for engaging in the development, demonstration and early commercialisation phases of new technologies.

**Table A3 • Indicative global renewable energy technology maturity**

Application	Technology	RD&D	Early commercial	Commercial
Power generation	Biomass			✓
	Geothermal			✓
	Hydro			✓
	Marine	✓		
	Solar CSP		✓	
	Solar PV			
	Wind (Onshore)			✓
	Wind (Offshore)			✓
Heating and cooling	Biomass (Traditional)			✓
	Biomass (Modern)			✓

	Geothermal			✓
	Solar water heating			✓
Transport fuels	Bioethanol from sugar and starch			✓
	Biodiesel from oil crops			✓
	New technologies for transport fuels	✓		

Notes: RD&D = research, development and demonstration.

### 1.4 Strategic Priorities

Identify the most important strategic priorities which are driving market developments in renewables by considering the questions below.

- Is there a specific national greenhouse gas target and is renewables seen as a key part of the strategy to achieve it?
- Are there other significant energy related environmental problems which renewables can help reduce?
- Is demand growing and are renewables seen as one way of meeting the need for more energy?
- Is electricity access an issue and if so are renewables seen as part of the solution either via grid connected power or distributed off-grid solutions?
- Is access to clean cooking energy an important issue?
- Are energy security and/or the cost of fuel imports a significant issue? Does this relate especially to oil or gas?
- Are renewables seen as a source of economic development, providing a spur to employment (for example by providing jobs in rural areas for bioenergy harvesting, or for more high-tech jobs in manufacturing renewable energy systems or components)?
- Could using renewables reduce domestic use of fossil energy in exporting countries, so freeing up more resources for export?

Table A4 provides examples of options that can strongly contribute to some of the most important drivers.

**Table A4 • Technology options meeting key renewable energy drivers**

Drivers	Examples of options
Meeting national greenhouse gas targets	All renewable options
Helping reduce other significant energy related environmental problems	Renewable power or heat generation reducing coal based emissions
Meeting growing electricity demand and grid access	Grid connected renewables power
Improving electricity access	Stand alone or mini-grid generation with solar PV, and wind
Improving access to clean cooking	Improved biomass cookstoves Modern biomass based fuels
Improving energy security and/or reducing the cost of fuel imports	All renewable options improving diversity of supply

Oil saving	Biofuels for transport. Grid of off-grid generation replacing oil or small-scale diesel generation
Gas saving	Grid connected renewable energy power replacing gas generation. Bioenergy, solar and geothermal for heating.
Economic development, providing a spur to employment	Bioenergy providing jobs in rural areas for harvesting and transport and processing. High-tech jobs in manufacturing renewable energy systems or components, installation and maintenance.
Increasing levels of indigenous fossil fuels for export	Large scale wind or solar generation releasing oil or gas for export

### 1.5 Identify market opportunities

Having examined supply-side factors for prioritising RET deployment (i.e. availability of renewable resources and appropriate priority technologies), the next step is to identify demand-side factors to identify the principal market sectors where renewable deployment is likely to occur and where possible to quantify short, medium and long term potential.

#### 1.5.1 Map energy end-uses by fuel to resources

Consider the distribution of current energy use between the various subsectors and identify likely future trends through modelling. The degree of disaggregation will depend on the extent and reliability of the energy use data available (See energy efficiency chapters for further discussion of this). At the end of this process, you will have a list of high-energy using sectors and sub-sectors, and the different fuels used by each end use (heat, electricity, transport fuel, etc.).

Figure A1 • Matrix of technologies and market applications

	Grid power supply	Distributed power supply			Off-grid power	Heating				Transport
		Industrial scale	Commercial scale	Residential scale		Industrial scale	Commercial scale	Residential scale	District heating	
Bioenergy	●	●	●	●	●	●	●	●	●	●
Geothermal	●	●	●	●	●	●	●	●	●	●
Hydro	●	●	●	●	●	●	●	●	●	●
Marine	●	●	●	●	●	●	●	●	●	●
Solar CSP	●	●	●	●	●	●	●	●	●	●
Solar heating	●	●	●	●	●	●	●	●	●	●
Solar PV	●	●	●	●	●	●	●	●	●	●
Wind	●	●	●	●	●	●	●	●	●	●

Notes: ● = promising; ● = possible; ● = unlikely.

### 1.5.2 Identify market sector/technology pairs

Examine how RETs could contribute in each important end use sector, using Figure A1 as guidance. For example if there is a rapid growth in grid-connected electricity demand then technologies able to help meet this need will be favoured. If gas is being used for heating and gas prices are projected to grow, then renewable technologies which can replace gas for heating (e.g. bioenergy) may be prioritised. This step is best done through an interactive discussion with key stakeholders including government, academic experts, and industry players including developers and investors.

### 1.6 Rate priority technologies

The final sub-step in the prioritisation stage is to rate each of the RETs against the prioritisation criteria to come up with an overall prioritisation rating, using the following rating system:

- **Ready for deployment:** options for which there is a good resource, the technology is fully commercialised internationally, the cost of energy production are attractive and there is a good fit with strategic priorities.
- **Some potential:** options for which there is a promising resource and which could in principle could help meet strategic needs, but for which other factors are less positive. In these cases the appropriate option may be to carry out some feasibility studies and some pilot projects so as to test the technologies under local conditions.
- **Needing further evaluation:** resources and technologies for which there is a lack of information on the local resource characteristics and so on the likely costs. Further work to improve the information base is indicated.
- **Low priority:** options for which there is either a poor resource base, high costs, poor strategic fit or where there are few market opportunities.

→ *The outcome of Steps 1.1 to 1.6 will be a list of priority RETs for deployment.*

## Step 2: Establish indicators, metrics and data

The key indicators used in this methodology are the levels of deployment of the priority technologies, and the costs of the energy they produce and the level of financial support provided in comparison with other energy sources.

### 2.1 Assess current deployment of priority technologies

This step involves quantifying the current level of deployment of RETs. At the end of this step, the existing level of market penetration of the technologies will be established.

#### 2.1.1 Gather capacity and generation data for each technology

At this step, the ideal is to establish the production capacity and level of generation from each technology in the relevant market sectors. For example, Table A5 shows the information which would be ideally collected in a situation where solar PV could contribute to utility scale, commercial and residential scale energy needs

For grid connected electricity generation and for the supply of commercial heat to district or community heating schemes these numbers are generally available via national energy statistics.

**Table A5 • Example of current technology deployment matrix for solar PV**

Priority technology	Deployment of PV systems by installation type	Annual Generation	Capacity
Solar PV	Large-scale solar PV farm on-grid: (>?? MW)	(MWh)	MW
	Commercial/industrial scale solar PV: (>??MW)	(MWh)	MW
	Residential scale : (< kW)	(MWh)	MW
	Off-grid applications:	(MWh)	MW

For off-grid power and heat generation the statistics may be harder to obtain. Relevant information may be included within national energy surveys or may be available centrally through permitting or planning applications. Where such uses are supported by national or sub-national financial support schemes (e.g. grant funding or tax relief) then there is likely to be a record of installed capacities receiving support. Commercial suppliers of key systems (e.g. solar PV system vendors or installers) or their industry associations may be able to provide sales or installation data.

For distributed small scale systems for electricity or heat and for off-grid systems it may be particularly difficult to obtain real measurements of the actual energy delivered, since at a small scale metering may be impractical or costly. Electricity or heat generation must then be estimated based on capacity figures and on local resource and utilization conditions.

For biofuels production and blending statistics are usually available via the regulatory bodies supervising fuel blending and distribution. Production data can be ascertained via specific producers or their industry associations.

### 2.1.2 Data quality review

Identify shortcomings in the availability or quality and consistency of the necessary deployment data. If the data is lacking or inconsistent or does not allow the degree of analysis desired then potential improvements need to be discussed with policy makers and industry players to remedy these shortcomings. (See Section 2 of the Methodology Insights Paper).

### 2.1.3 Calculate sectoral shares

Express the level of energy generation as a percentage of total sectoral energy production or demand (i.e. percentage of electricity, heat or transport fuel use) if reliable overall energy statistics are available. Where possible calculate the percentage of renewables as a share of total final energy consumption (see accompanying IEA *Insights Paper* for calculation procedure).

**→ The outcome of Step 2.1 will be the quantification of current RET deployment levels.**

## 2.2: Assess remuneration, costs and financial support for currently deployed priority technologies

This step involves checking the levels of remuneration and costs for each key technology and identifying the extent to which the energy generation is financially supported by governments or customers.

### 2.2.1 Grid Connected Electricity

Identify the level of remuneration received by generators of each of the priority technology/market streams which produce grid connected electricity, taking into account all revenue and support payments including market prices, special tariffs (e.g. feed-in tariffs), green certificate revenues, capital grants and tax reliefs and any other payments or incentives.

Calculate the total generation cost taking into account two different types of remuneration: up-front and per MWh remuneration. Up-front remuneration includes all payments made at the beginning of the project, such as cash rebates. In addition, tax incentives are assumed to be received at the beginning of the project. Per MWh remuneration includes wholesale market revenues, certificate revenues, and FIT/FIP payments as appropriate. Wholesale market and certificate prices are assumed to remain stable at current values.

To account for the incentive payment-scheduling issue, both investment streams are levelised to a standard period (e.g. set at 20 years) with a discount rate (e.g. at 6.5%).

Compare the renewable generation remuneration level with that of the total cost of generation from each grid connected renewable electricity source to the system (taking into account all sources of income and support (including fuel subsidies and tax reliefs and payments) and all expressed as a levelised cost of electricity.

### 2.2.2 Off-grid electricity systems

Identify the costs of distributed power generation based on estimates of the capital and operating costs available from official or industry sources and using a financing rate judged locally typical for these installations. Calculate a levelised production cost.

Compare with alternatives (e.g. grid supplied electricity at the point of consumption or alternative distributed generation options e.g. distributed diesel generation (taking account of subsidies and taxes)?

### 2.2.3 Renewable heat

Based on capital and operating costs, calculate the costs of renewable heat generation options and compare with fossil based alternatives.

### 2.2.4 Renewable transport fuels

Establish the costs of locally produced biodiesel or bioethanol (or of internationally supplied biofuels) and compare these with fossil based gasoline or diesel fuels.

**→ The outcome of Step 2.2 will be the quantification of current RET deployment costs.**

## Step 3: Monitoring progress and evaluating the enabling environment

The aim of this part of the methodology is to establish:

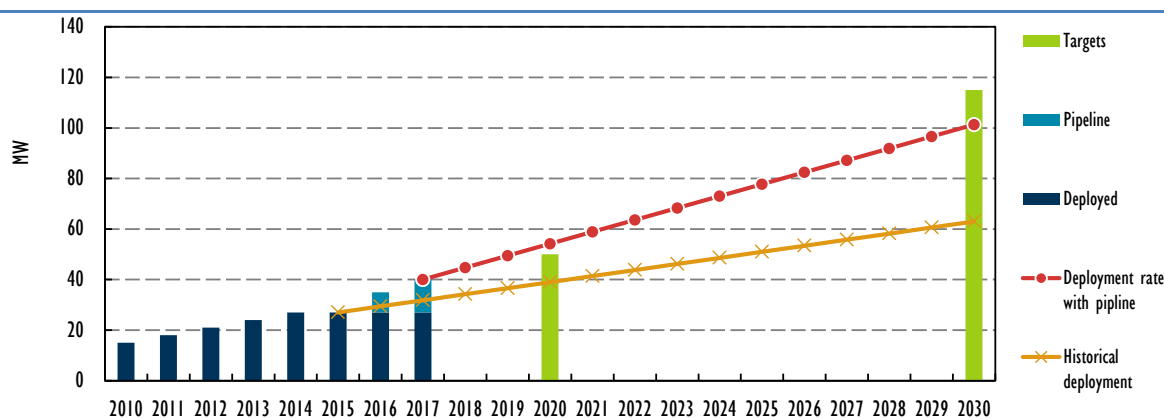
- How the level of deployment is changing and how this deployment trajectory compares with a benchmark – national expectations, regional comparisons or overall benchmark to a global scenario or ambitions.
- What is the cost of the energy being supplied and how does this compare with the fossil fuel alternatives and with international benchmarks for the technology.
- Whether the main components of the enabling environment necessary to allow renewables to be deployed as cost-effectively as possible are in place.

### 3.1 Tracking deployment

First, identify available data on deployment for key technologies and market segments as identified in Step 2.1 to provide a deployment time series.

Second, identify appropriate benchmarks which should include national ambitions as set out in targets or goals but may also include regional benchmarks with countries with similar conditions and ambitions or international benchmarks – for example the UN’s Sustainable Energy for All Goal to double the contribution of renewables to global energy supply between 2010 and 2030. A stylised example of such an approach is illustrated in Figure A2.

Figure A2 • Tracking Deployment against internal and external benchmarks



Third, check if the deployment trajectory is on track compared to future targets by using a quantitative indicator. If information on the pipeline of future projects is available, this can be used to assess progress against future targets. If project pipeline information is not available, estimate the ‘rate of deployment’ based on past trends.

For example, if there is a target to increase the deployment of a particular technology from a level of A in Year 1 (say 2010) to a target level of T in Year 3 (say 2020), and a deployment of B has been achieved by Year 2 (say 2015), then the relative rate of progress can be assessed by comparing the rate of increase of deployment against the rate required to meet the target.

$$\text{Rate of deployment needed to meet the target: } Rt = (T - D/A)(Y3 - Y1)$$

$$\text{Achieved deployment: } Ra = (B-A)/(Y2-Y1)$$

If  $Ra > Rt$  then deployment is on track.

A similar analysis can be done taking into account the prospective deployment based on the analysis of the project pipeline where this is available.

In the example in Figure A2, deployment in 2010 is 15MW (A=15); has reached 27MW in 2015 (B); and the target in 2020 is 50MW, (T=50).

So the desired rate of progress is  $(50-15)/10 = 3.5\text{MW/year}$ . Actual progress is  $(27-15)/5 = 2.4\text{MW/year}$  indicating that progress is behind that needed to reach the target (shown by the orange line). However, taking into account information about the project pipeline in years 2016 and 2017, a new deployment rate can be calculated, showing the 2020 target is more likely to be achieved (red line).

### 3.2 Tracking and benchmarking costs

Once the costs of a particular technology option have been established (see above) these can be tracked annually, to see how prices are progressing and how they compare with regional and international benchmarks.

To allow a valid comparison with these benchmarks it is necessary to consider local effects. For example, to remove the effects of the differences in resource endowments on electricity generation costs, the total annualized remuneration should be multiplied by the number of full load hours which can be anticipated in the different markets, so giving an estimate of the annual income in terms of capacity (MW/Year) rather than per unit of generation.

**→ The outcome of Steps 3.1 and 3.2 will be a quantified assessment of RET deployment progress against goals and tracking of RET costs over time.**

### 3.3 Evaluating the enabling environment

The aim of this part of the methodology is to establish whether the main components of the policy and regulatory framework necessary to allow renewables to be deployed as cost-effectively as possible are in place (see Insights paper). This requires a dialogue with policy makers in the relevant ministries and regulatory bodies as well as with other key stakeholders including actual or potential developers and investors. This should allow the identification of any unnecessary impediments to deployment to be identified and the necessary remedial actions defined.

The questions below provide a structure for the discussion and analysis of impediments to deployment, based on identified best practice. Depending on the priorities identified in stage 1 of the methodology, it may be necessary to consider these issues separately for the main sub-sectors (electricity, heat and transport fuels) and/or for the main technology options considered to be promising.

The responses to the questions will allow identification of the main barriers to renewables deployment.

#### 3.3.1 Policy, regulatory and institutional factors

##### Policy context

- Is renewable energy included in the national energy plan?
- Are there clear targets for short, medium and long term?

- Is there a credible and detailed renewable action plan?

#### Permitting

- Is the permitting system transparent and efficient?
  - Is guidance on permitting available?
  - Are permitting times monitored?
  - How long does permitting take?
  - How many agencies involved?

### 3.3.2 Financial and market factors

#### Remuneration

- Are clear and predictable remuneration levels in place?
- Is the off-taker reliable?
- Are the revenue streams sufficiently high to provide an adequate return to investors?
  - Are there available data on:
    - Capital costs
    - Operating costs
    - Soft costs
    - Finance costs
  - Do the potential revenue streams (see Section 2) provide an adequate rate of return on investment? (Suggested hurdle rate of 8% rate of return.)

#### Finance

National factors such as the ease of doing business, the country's credit rating or currency volatility have strong implications for the availability and costs of finance. In addition, questions for consideration include:

- Are debt and equity finance available locally?
- Are national or international development banks active?

### 3.3.3 Technical and infrastructure factors

#### Market access and integration

##### Renewable electricity

For the market integration of grid connected renewable electricity supplies the measures that need to be put in place depend on the actual and projected market shares of variable renewables (VRE) such as wind and solar PV. At low shares the priority is in ensuring fair access to the grid and that adequate grid capacity is available in areas where VRE generation is likely to be significant. As shares rise then more measures are needed – first from a management and regulatory perspective and then in terms of investments to improve system flexibility. The relevant analytical questions therefore depend on the existing and projected market share.

**Table A7 • Relevant questions for assessing market access and integration at each stage of the renewable energy deployment journey**

Stage of renewable energy market share	Suggested questions to assess market access
Initiation (below 1% VRE Penetration)	<p>Is grid access allowed?</p> <p>Are grid connection costs transparent?</p> <p>Are renewables included in grid development plans so that adequate grid capacity will be available where initial deployment is likely to be concentrated?</p>
Take off (below 10% VRE Penetration)	<p>Is the regulatory framework appropriate?</p> <p>Are modern grid connections codes included in the regulations?</p> <p>Are modern wind and solar forecasting methods in use?</p> <p>Are appropriate dispatch rules in place?</p> <p>Has an integration study been carried out?</p>
Mainstreaming (above 10% VRE Penetration)	<p>Are investment plans in place to ensure sufficient flexibility?</p> <p>Is there a need to extend the capacity of regional transmission systems to optimize renewables and other generation capacity over a large area?</p>

### Renewable heating

For stand-alone renewable energy heating applications integration is not usually a serious impediment. Where there are existing district heating systems, or where there is potential for the widespread development of such systems then integration can be a more serious issue particularly where there is monopoly management of heat sources which can supply heating grids. The key question is:

- Are there market impediments to the use of renewables in district/community heating systems?

### Renewable transport fuels

Biofuels production and use can be hampered by physical and regulatory barriers to integration. From a physical perspective the lack of suitable storage, blending and distribution facilities can hold back deployment. From a regulatory perspective, unnecessarily tight constraints on the blending limits for biofuels within fuels specifications either set by regulations or by vehicle manufacturers can constrain use. At higher blend shares (above around 10% of bioethanol or biodiesel) there are real constraints to blending which need to be addressed – for example by encouraging the deployment of flex-fuel vehicles (as in Brazil), and by ensuring that there is a distribution network for higher blend fuels (e.g. as in Sweden).

- Are there physical constraints related to storage, blending or distribution networks which are constraining biofuels use?
- Are there regulatory constraints hindering the attainment of target blending levels?
- If higher blending shares are envisaged what steps are being taken to facilitate integration through the encouragement of flex-fuel vehicles and necessary infrastructure?

### Supply chain and skills issues

- Is there a skills base?
  - Is there a recognised centre of expertise?
  - Is education and skill training under way?
- Is a supply chain in place?
  - Are key components manufactured locally?

- Is there local experience of installation and maintenance?
- Are standards or certification in place?

### 3.3.4 Social factors

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- If renewable projects require relocation of populations, have social impacts been measured and how are impacts minimised/ compensated?
- Is there a good understanding of the benefits of renewable energy technologies in the community?
- Is there a public information campaign on renewables?

### 3.3.5 Environmental factors

- Have studies been conducted on possible environmental impacts of renewable projects?
- Are current and future environmental conditions projected to affect RET deployment?

**→ The outcome of Step 3.3 will be an assessment of the enabling environment for RET deployment.**

## Part II: Assessing energy efficiency technologies

### Step 1: Prioritisation

The ultimate goal of the prioritisation step is to select a portfolio of EETs whose uptake will be monitored to help assess progress toward national energy and climate policy goals. The process of selecting priority EETs for monitoring starts with review and compilation of national energy data at the sector, subsector, and end use levels, is followed by an assessment of relevant trends in energy system drivers and policies, and concludes with a structured evaluation procedure to identify priority EETs. To illustrate these sub-steps, the selection of efficient on-site space heating technologies in the residential building sector is used as a concrete example.

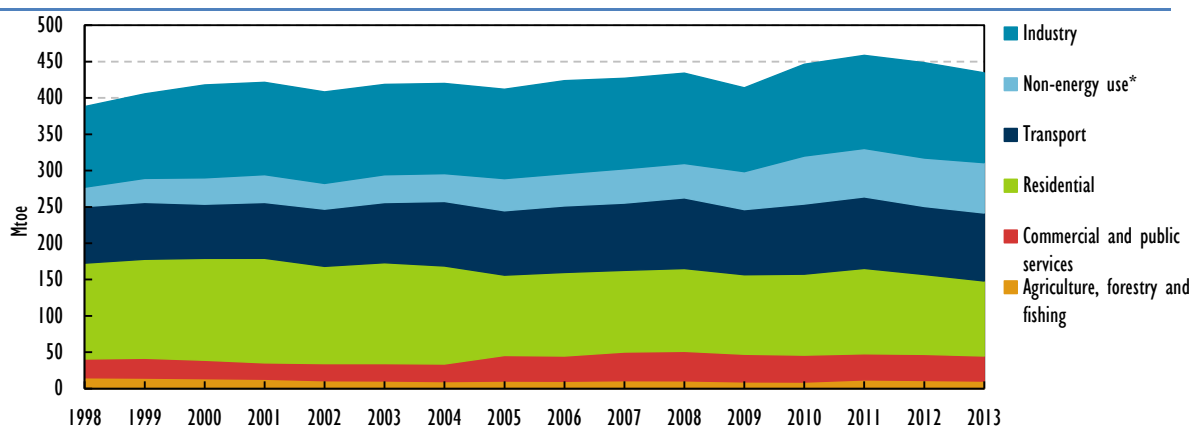
#### 1.1: Compile and review national energy data and statistics

The goal of this step is to assemble data on the end uses of energy within the target country. As discussed in the companion IEA *Insights Paper*, sources of such data include national energy statistics agencies and other ministries that track energy use (e.g., national transportation agencies), national-level energy system models, energy use surveys, and research and policy reports. Ideally, data should be collected that provide the following level of detail:

- All major fuels used in the country
- Fuel use disaggregated by major economic sector (industry, transport, services, residential, etc.)
- Within each economic sector, further disaggregation of fuel use by sub-sector (e.g., iron and steel and cement within the industry sector and freight and passenger modes within the transport sector)
- Within each sub-sector, fuel use disaggregated by energy end use (e.g., share of electricity use by space heating, space cooling, appliances, water heating, lighting, and cooking in the residential sector)

Ideally, these data would be compiled as a time series that exposes key trends in energy use at the end use level over time, which enables identification of important components of future energy use. Further advice on steps to take in the absence of reliable national energy statistics is provided in the main body of the report, such as the use of energy systems models.

**Figure A3 • Total final consumption of energy by demand sector, 1998-2013**

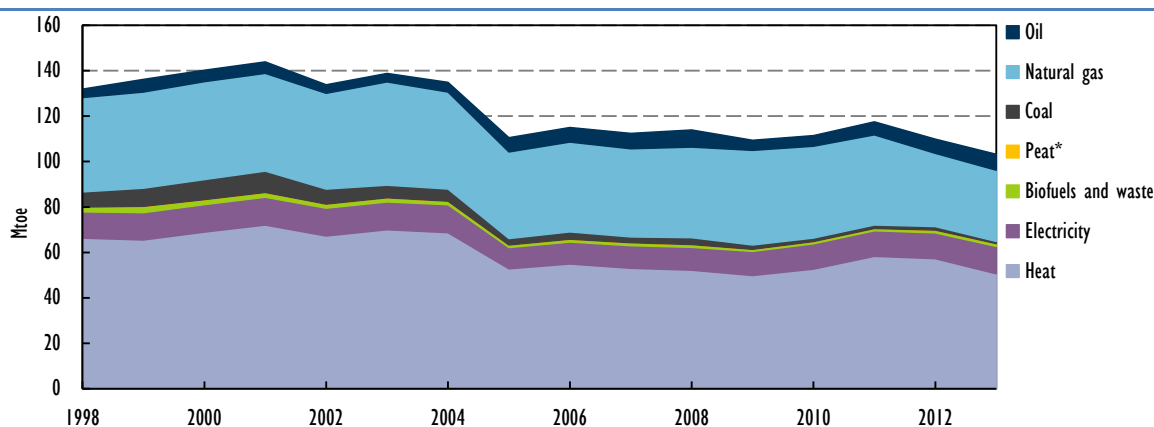


Note: \* Non-energy use includes fuels used as raw materials in industry.

Source: IEA (2016, forthcoming), Energy Balances of Non-OECD Countries 2016, [www.iea.org/statistics](http://www.iea.org/statistics).

Figures A3 to A5 present such data for the Russian Federation as an illustrative case. In Figure A3, it can be observed that Russia’s total final consumption of energy (TFC) for all demand sectors, expressed in million tons of oil equivalent (Mtoe), changed little between 1998 and 2013, and that the industry sector, residential sector, and transport sector account for the largest shares of TFC. Therefore, one or more of these three sectors could be chosen as a priority sector for further analysis in the prioritization step. Figure A4 presents the TFC of the residential sector by fuel type, which is the priority sector considered as an illustrative example in the remainder of this guide. The uses of heat (from district heating systems) and onsite natural gas comprise around 80% of residential fuel use, suggesting the nature and current efficiency of district heat and natural gas use in Russian homes are particularly worthy of a closer look.

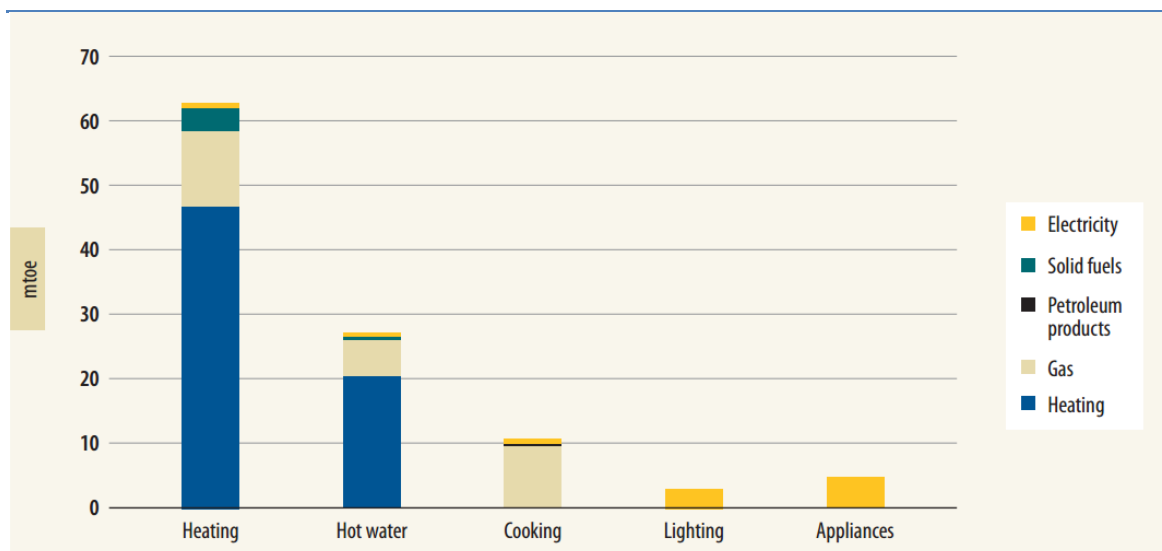
**Figure A4 • Total final consumption in the Russian residential sector by fuel, 1998-2013**



Notes: \* Negligible.

Source: IEA (2016, forthcoming), Energy Balances of Non-OECD Countries 2016, [www.iea.org/statistics](http://www.iea.org/statistics).

**Figure A5 • End uses of energy within the Russian residential sector**



Source: World Bank (2014), *Energy Efficiency in Russia: Untapped Reserves*, Washington, DC. © World Bank, <https://openknowledge.worldbank.org/handle/10986/20675>, License: CC BY 3.0 IGO.

As described in the main body of the report, data on specific end uses of specific fuels within demand-side sectors and subsectors can be hard to come by, and are typically not generated or collected on an annual basis by most national governments. However, the use of semi-annual energy surveys, available engineering studies, and energy systems models can often provide

credible end use estimates that can be used to identify priority end uses and EETs in this methodology.

Figure A5 provides an example of such end use data, which were obtained from a recent World Bank techno-economic study of energy efficiency potentials for Russia. The end use data in Figure A5 suggest that space heating is by far the largest end use of energy in Russian dwellings, with a 58% share of onsite energy use, followed by hot water heating, with a 25% share of onsite energy use. District heat accounts for the majority of fuel use in space heating and water heating, followed by natural gas, which is also used significantly for cooking.

## 1.2: Evaluate future energy use, drivers, and policies

In addition to the use of national-level energy data, a review of projected future trends in energy use, energy use drivers, and technology priorities, as well as a review of existing and planned energy policies, are recommended to provide further clarity on subsectors and end uses of strategic interest for monitoring. In particular:

- Past and projected future trends in energy use and drivers of this energy use are often analysed by a number of stakeholders including energy analysts, government and academic research labs, non-profit environmental organizations, and market forecasters. These resources should be reviewed to identify major predicted trends in the use of fuels as functions of societal trends and the evolution of key energy use drivers, such as population, income, and economic structure.
- Importantly, existing and planned energy policies can have a major influence on the amounts and types of fuels used in the future, by sector and end use. These policies can sometimes focus on specific subsectors and end uses (e.g., bans of incandescent bulbs in favour of CFLs on the residential retail market) or create a better enabling environment for EET adoption in certain subsectors and end uses (e.g., mandatory building energy codes). Relevant policies should be identified, reviewed, and compared to observed trends in Step 1.1 to provide additional insights for identifying priority subsectors and end uses from the policy perspective.

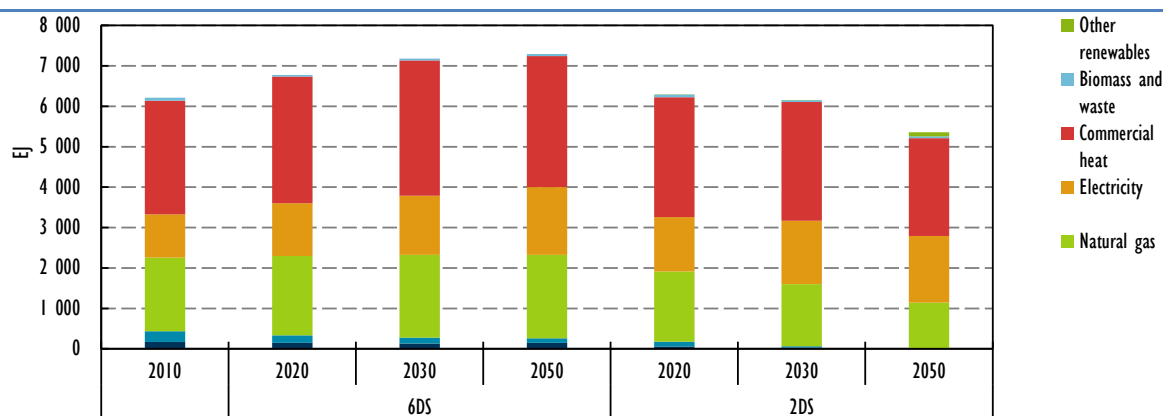
The information compiled in this sub-step is meant to complement the statistical trends observed in Step 1.1 to lead to more robust choices of priority subsectors and end uses for subsequent monitoring. For example, growing populations, trends toward larger dwellings, and increased affluence can increase demand for energy services in the residential sector, while existing or planned rebate programs, building codes, or other deployment policies might make the selection of residential space heating a desirable choice for end use market monitoring.

For example, Figures A6 and A7 summarize IEA energy use scenarios to 2050 for the Russian residential sector, which take Russian building characteristics, population and economic growth trends, and energy technology adoption options into consideration. The 6DS scenario results, which largely represent a continuation of current practices, suggest significant growth potential in total space heating energy use in Russian buildings in the absence of building energy efficiency improvements. The 2DS scenario results, which consider aggressive deployment of efficient building technologies and policies, suggest that growth in residential space heating demand can be mitigated through greater efficiency and that natural gas may play an increasingly important role in overall building energy use.<sup>14</sup>

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<sup>14</sup> For more information on building energy use in Russia, and explanations of priority technology selections, see the IEA's Transition to Sustainable Buildings: Strategies and Opportunities to 2050.

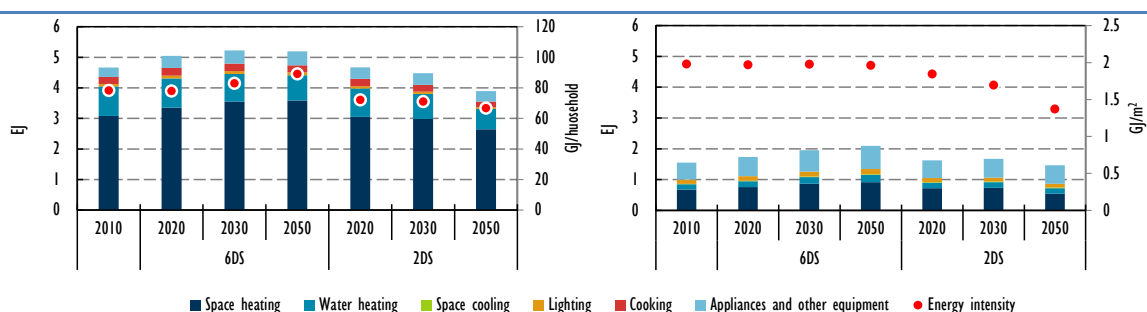
Figure A6 • Energy consumption in Russian buildings by energy source in the IEA 6DS and 2DS



Note: Other renewables includes wind, solar and geothermal.

Source: IEA (2013). *Transition to Sustainable Buildings: Strategies and Opportunities to 2050*.

Figure A7 • Russia residential and services sectors energy consumption and intensities



Source: IEA (2013). *Transition to Sustainable Buildings: Strategies and Opportunities to 2050*.

Furthermore, recent IEA analysis of policy and technology opportunities for more efficient buildings in different world regions (Figure A8) identified advanced building envelopes and more efficient heating end use equipment as major priorities for Russia's building sector. Similarly, the World Bank's *Energy Efficiency in Russia: Untapped Reserves* report identified space heating and water heating as top priorities for improving the energy efficiency of Russia's building sector.

Figure A8 • IEA regional priorities in the buildings sector

	ASEAN	Brazil	China	European Union	India	Mexico	Russia	South Africa	United States
<b>TECHNOLOGY</b>									
<b>Advanced envelope – cold climate</b> (highly insulating windows, air sealing and insulation)			●	●			●		●
<b>Reduced cooling loads – hot climates</b> (reflective technologies and advanced cooling equipment)	●	●				●			
<b>Heat pumps</b> (water heating and/or space heating and/or space cooling)				●			●		●

	ASEAN	Brazil	China	European Union	India	Mexico	Russia	South Africa	United States
<b>TECHNOLOGY</b>									
<b>Solar thermal</b> (water heating and/or space heating)		●			●	●		●	
<b>More efficient use of biomass</b> (more efficient cooking and water heating, and leading to modern biogas)	●				●			●	
<b>POLICY</b>									
<b>Building codes with supporting infrastructure</b> (education, product ratings, and implementation to pursue holistic approach with advanced envelopes)	●	●	●		●	●	●	●	
<b>Appliance and equipment standard</b> (promoting advanced appliances, lighting, heat pumps, heat pump water heater, gas condensing boilers, miscellaneous electrical loads, efficient cooling)	●	●	●		●	●		●	
<b>Deep renovation of existing buildings</b> (systems approach with advanced envelopes and high performance equipment)				●			●		●
<b>Zero energy new buildings</b> (advanced holistic building design with integrated renewable energy)				●					●

Note: red indicates immediate priority, while orange indicates medium term goal. This figure is not intended to be an exhaustive list, but intentionally shows only two immediate priority areas and two medium term goals per country or region to help highlight which technologies and policies will have the largest impact in the country or region. Most of the technology and policy categories could be applicable to all countries.

Source: IEA (2013). *Transition to Sustainable Buildings: Strategies and Opportunities to 2050*.

**→ The outcome of Steps 1.1 and 1.2 should be a list of subsectors, end uses, and (possibly) fuels of strategic interest for EET market monitoring.**

As an illustrative example, the remainder of this guide will focus on residential buildings as one priority sector—given the extent of current residential sector energy use and the significant potential for future growth—space heating as one priority end use—given its dominance in current and future residential building energy use—and natural gas as one priority fuel—given its significant share (roughly 25%) on onsite energy use for space heating. However, in practice, multiple sectors, subsectors, end uses, and fuels should be chosen for identification of priority EETs for market monitoring to ensure broad impact and progress toward national energy and climate policy goals.

### 1.3: Identification of priority EETs for market monitoring

The goal of the EET selection step is to identify a manageable set of priority EETs for market monitoring, using a structured and well-documented approach for consistency and transparency. The EET selection step starts with the compilation of an EET candidate list, is followed by the application of an evaluation approach to rate the attractiveness of each potential EET candidate, and concludes with the selection of priority EETs for market monitoring.

### 1.3.1: Compile EET candidate lists

The EET candidate lists—or “long lists”—should represent a comprehensive portfolio of EETs that could be applied to the priority end uses within a country to help achieve its energy efficiency goals. These candidate lists should ideally capture a wide range of EET options based on international best practice technologies for each priority end use and fuel type, with the understanding that these “long lists” will undergo further evaluation (in Step 1.3.2) to narrow them down into “short lists” containing fewer priority EETs for eventual market monitoring (in Step 1.3.3). The main body of this report contains representative EET candidate lists that have been compiled for the major sectors, subsectors, and end uses in this methodology. Each list is based on international best practice technologies obtained from a variety of literature sources, and can serve as a starting point for users of this methodology. In practice, some countries may have already identified such candidate lists as part of existing energy efficiency programs, which can take the form of pre-approved technology lists for financial subsidies, national and international efficiency labels and standards programs, national or international technology guidebooks and roadmaps, utility rebate programs, subsector or end use level energy efficiency potential or market studies, or energy efficiency audit programs.

**Table A8 • Summary data on efficient space heating technology options**

	Efficiency (%)	Typical Capital cost (per joule of useful heat)	Fuels	Operating cost (per joule of useful heat)
Conventional boilers/furnaces	60-84	Low-medium	Oil, natural gas	Medium-high
Condensing boilers	85-97	Medium	Oil, natural gas	Medium-high
Wood stoves/furnaces	<70	Low	Biomass	Low-medium
High-efficiency fireplaces	70-80	Low-medium	Biomass, natural gas	Low-medium
Pellet stoves	75-85	Low-medium	Biomass	Low-medium
Masonry heaters	80-90	Medium	Biomass	Low-medium
Electric resistance heaters	100	Low	Electricity	Medium-high
Heat pumps (electric)	200-600	Low-medium (air conditioning)/medium-high (space/water heating)	Electricity	Low-medium
Heat pumps (gas driven)	120-200	Medium-high	Gaseous fuels	Low-medium
Solar thermal	100	Low-high	Solar	Low-medium

Source: IEA (2013). Transition to Sustainable Buildings: Strategies and Opportunities to 2050.

Table A8 summarises a representative “long list” of candidate EETs for residential heating equipment, drawn from recent IEA analysis of space heating technologies and based on typical international values. Similar “long lists” could be compiled for EETs applicable to residential building envelopes as provided in the main body of the report. Continuing the illustrative example, the remainder of this guide focuses on the application of the methodology to space heating technologies in particular using Table A8 as the candidate list.

### 1.3.2: Apply an evaluation approach

The purpose of Step 1.3.2 is to apply a structured and transparent evaluation approach such that short lists of EETs can be identified for subsequent market monitoring. In practice, some countries may have already established systematic approaches for identifying priority EETs based on national energy and economic goals, consistent project or technology evaluation procedures, common evaluation assumptions (including discount rates or energy savings calculation procedures), or other approaches involving quantitative and qualitative criteria and/or heuristics. Important aspects of any evaluation approach include the need for clear and replicable procedural guidance, so that all EETs are evaluated on the same bases, consistency in how the approach is applied to each EET, so that results are comparable across sectors, subsectors, and end uses, and transparent documentation of rationale for choice of evaluation scores/outcomes for each EET.

The main body of the report includes a proposed EET screening approach that can be used in the absence of existing evaluation frameworks within a country, or to enhance existing in-country evaluation frameworks as desirable. The proposed screening approach consists of the following major screening criteria, with an associated scoring rubric:

- Technical applicability
- Diffusion rate
- Absolute energy savings, which is based on
  - Typical energy savings
  - Current market penetration rate
- Cost effectiveness
- Technology maturity

**Table A9 • Prioritisation screening results for efficient space heating technology options**

	Technical applicability	Diffusion rate	Absolute energy savings	Cost effectiveness	Technology maturity
Conventional boilers/furnaces	High	High	Low	Medium	High
Condensing boilers	High	High	High	Medium	High
Wood stoves/furnaces	Medium	Medium	Low	Low	High
High-efficiency fireplaces	Medium	Medium	Medium	Low	High
Pellet stoves	Medium	Medium	Medium	Low	High
Masonry heaters	Low	Low	Medium	Medium	High
Electric resistance heaters	High	High	Medium	Medium	High
Heat pumps (electric)	Medium	Medium	Medium	Medium	High
Heat pumps (gas driven)	Medium	Medium	Medium	Medium	High
Solar thermal	Low	Medium	High	Medium	High

Table A9 presents screening results for the candidate technologies in Table A8, using the scoring guidance in the main body of this report, the data in Table A8, and international average characteristics for each candidate EET.

Continuing the illustrative example, given the dominance of natural gas in Russia's energy system and high access to reliable electricity, those EETs that make highly-efficient use of natural gas

(condensing boilers, which have 85-97% efficiency at medium capital cost) or electricity (cold climate air-sourced heat pumps, which have a range of efficiencies depending on the climate zone at low-medium operating costs) are selected on the basis of acceptable technical applicability and costs and likely market diffusion rates, and potentially significant energy savings compared to conventional onsite boilers and furnaces.

### 1.3.3: Consider the enabling environment

As discussed in the main body of the report, the enabling environment refers to the collection of technical, economic, and societal factors that affect the “market readiness” for a given EET as well as its chances of market success. In this sub-step, a preliminary review of the following enabling factors should be conducted as an additional screening exercise to ensure that priority EETs are selected with a reasonable enabling environment in the present day and for which the enabling environment is poised to improve in the future. In other words, one should choose EETs for monitoring that also have high implementation potential so that progress toward national energy and efficiency goals can be assessed over time. Specifically, the following enabling factors should be assessed:

- Technical and infrastructure factors.
- Financial and market factors.
- Social factors.
- Regulatory and institutional factors.
- Environmental factors.

**Table A10 • Illustrative enabling factor assessment**

Enabling factors	Condensing natural gas furnaces	Cold climate air-source heat pumps
<b>Technical infrastructure</b> and	High compatibility with existing supply infrastructure Ease of retrofit installation: high Ease of new construction installation: high Extreme cold efficiency loss: low	High compatibility with existing supply infrastructure Ease of retrofit installation: low-medium Ease of new construction installation: medium-high Extreme cold efficiency loss: medium-high
<b>Financial and market</b>	Availability: high	Availability: medium
<b>Social</b>	Consumer awareness: high Consumer risk perception: low	Consumer awareness: low-medium Consumer risk perception: medium
<b>Regulatory institutional</b> and	Efficiency labels and standards programs exist Incentives programs exist	Efficiency labels and standards programs exist Incentive programs exist
<b>Environmental</b>	Incremental air pollution savings when replacing natural gas furnace	Air pollution savings depend on electricity grid mix and power plant location

An example enabling factor assessment for two potential priority EETs emerging from Step 1.3.1 (condensing furnaces and cold climate air-source heat pumps) to illustrate a potential outcome of this sub-step is shown in table A10.

**→ The outcome of Step 1.3 will be short lists of EETs for market monitoring in the target country.**

In our current example, natural gas condensing furnaces will be further assessed on the basis of the evaluation procedure results and enabling environment factor considerations.

## Step 2: Indicator selection

The purpose of this step is to develop and/or identify appropriate indicators for tracking the fuel use intensities of priority sectors, subsectors, and end uses over time as well as the penetration of priority EETs over time.

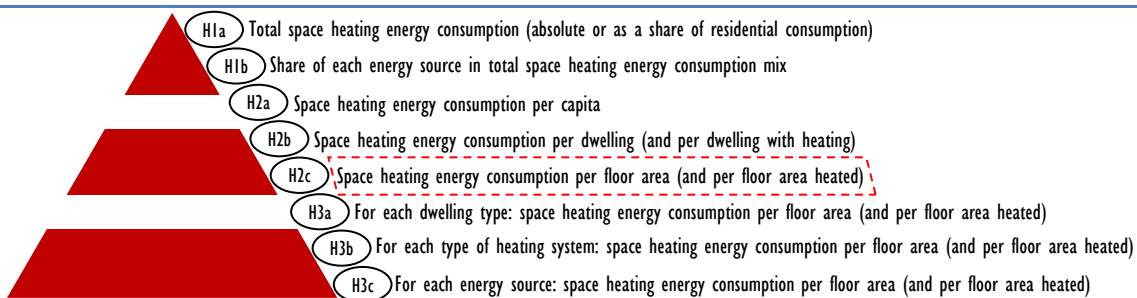
### 2.1: Identify appropriate energy indicators

This sub-step is aimed at identifying appropriate energy indicators for the priority sectors, subsectors, end-uses, and (possibly) fuels that enable credible monitoring of energy use over time on the basis of an appropriate activity quantity. The basic form of an energy indicator is as follows:

**Energy indicator = (Energy use)<sub>ijk</sub> / (Activity)<sub>ijk</sub>, where i=subsector, j= end use, and k = fuel type**

The IEA has established recommended energy indicators for all major subsectors and end-uses, as described in the main report and further elaborated in the IEA's *Indicators Manuals*. The possible and recommended indicators for residential space heating are summarized in Figure A9; the ideal selection will depend on available data for fuel use and activities within the target country, and the associated costs and benefits of improving indicator resolution to the recommended indicator (H2c) or beyond. It may be necessary to compile additional data to enable the use of ideal energy indicators, which would involve identifying ideal forms, sources, data collection mechanisms, and data analysis and quality control processes for each selected indicator.

**Figure A9 • Energy indicator levels for residential space heating**



Source: IEA (2014), *Energy Efficiency Indicators: Fundamentals on Statistics*.

In the current example, the IEA recommended energy indicator for residential space heating is selected (national space heating energy/m<sup>2</sup> of heated floor area).

**→ The outcome of Step 2.1 will be a list of energy indicators for the priority subsectors, end uses, and fuels in the target country.**

### 2.2: Develop EET penetration metrics

The goal of this sub-step is to develop suitable metrics for monitoring of market penetration of priority EETs in the target country. Pending available data, once constructed, EET penetration

metrics might also be used for retrospective market penetration analysis using historical data to assess market penetration trends to date.

Here it is necessary to evaluate the different options for the form of the penetration metric, and select the form(s) that balance a country's ability to gather and process key data from existing or plausible sources with the strength of the relationship to the energy indicator established in Step 2.1. As discussed in the main report, the following are common forms of EET market penetration metrics based on available data:

- Penetration expressed as the percent of end use activity basis that is represented by the priority EET
- Penetration expressed as the percent of annual sales of EET class (note that such data can be further converted to penetration by activity basis using an energy technology stock model)
- Penetration expressed as the percent of ownership units with the priority EET installed

While other forms may be possible, a choice must be made and justified among the available options, including those above, with an ideal goal of choosing the form for which increasing penetration is most directly correlated to decreasing energy indicator values. Table A11 summarises these options as applied to the example of penetration of condensing furnaces within the residential space heating end use category.

**Table A11 • Illustrative evaluation of penetration basis options**

Penetration basis	Pros	Cons
Percent of natural gas heated floor area that is heated by condensing furnaces	Corresponds directly to activity basis affecting energy use	Requires comprehensive and regular national residential energy use surveys
Percent of new residential natural gas furnace sales attributable to condensing furnaces	Data collection burden may be eased through use of market or retail sales data or consumer surveys Can be related to activity basis using building energy technology stock models	Potential lack of reliable or consistent sales data Requires the use of energy models, which can be expensive to maintain Expert assumptions required to relate to activity basis
Percent of dwellings with natural gas condensing furnaces	Data collection burden may be eased through use of consumer surveys or site audits Can be related to activity basis using building energy technology stock models	Potential lack of reliable or consistent consumer survey data Requires the use of energy models, which can be expensive to maintain Expert assumptions required to relate to activity basis

In practice, this sub-step is heavily dependent on the data which are available to construct the chosen energy indicators and EET penetration metrics as discussed in Step 3.

**→ The outcome of Step 2.2 will be a list of penetration metrics for the priority EETs in the target country.**

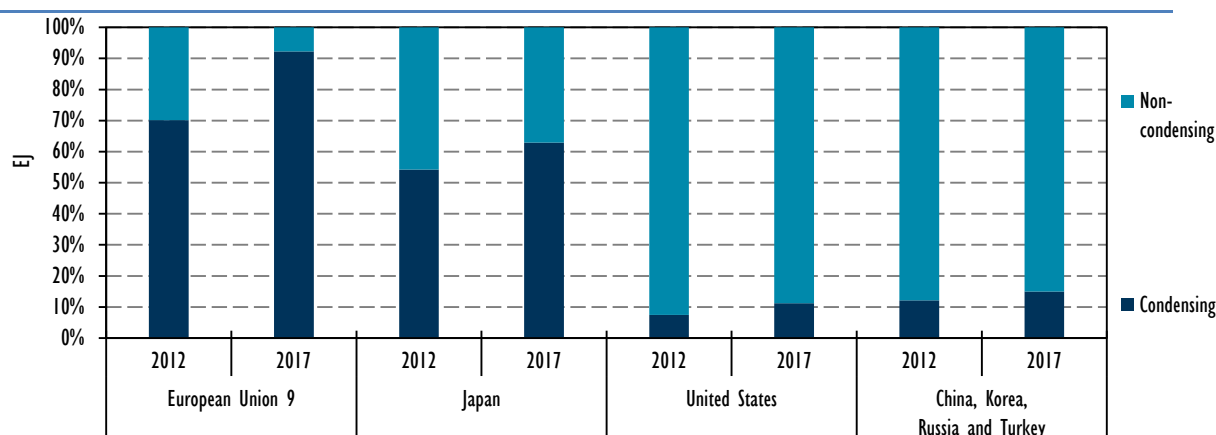
In the current example, the chosen EET penetration metric is the percentage of annual residential natural gas furnaces sales attributable to condensing furnaces. As mentioned in the main report, these data can be coupled with a technology stock model (e.g., natural gas furnaces per household, heated floor area per household, lifetime of furnaces) to estimate the percentage of dwellings or heated floor area attributable to this EET.

### Step 3: Measuring and monitoring

In this step, the goal is to establish data systems and conduct data collection and analyses to assess EET market penetrations and energy indicator values established in Step 2. In other words, this step implements the approach and enables monitoring of changes in energy use, EET penetrations, and enabling factors over time to assess progress toward national energy and climate goals.

For example, Figure A10 shows the percentage of sales of condensing boilers in the European Union and other key world markets (as presented in IEA's 2015 Tracking Clean Energy Progress report), which enables market monitoring over time. Similar monitoring can be employed for the case of condensing natural gas furnaces using the penetration metric described in Step 2.2.

**Figure A10 • Condensing boilers market share in key world regions**



Source: IEA (2015), *Tracking Clean Energy Progress 2015: Energy Technology Perspectives 2015 Excerpt, IEA Input to the Clean Energy Ministerial*.

#### 3.1: Identification of additional data requirements

The purpose of this sub-step is to identify additional information and data requirements necessary to monitor the enabling environments associated with the priority EETs, which will improve decision makers' understanding of market barriers over time. This sub-step is technically optional but recommended, given that enabling factors (technical, social, economic, policy, etc.) can have significant influence on the adoption potential of many EETs.

While the enabling factors that should be considered and, ideally, monitored will vary widely by country, end use, and EET, examples of additional data that might help to assess the enabling environment for efficient lighting are listed in Table A12.

**Table A12 • Example information sources for assessing enabling environment**

Enabling factor	Example information sources
Technical infrastructure and	<ul style="list-style-type: none"> <li>Number of new dwellings constructed</li> <li>Average installed furnace age</li> <li>Number of dwellings with shared vs. non-shared space heating</li> <li>Technology performance trends for condensing furnaces</li> </ul>
Financial and market	<ul style="list-style-type: none"> <li>Cost trends for natural gas and other commercial fuels for heating</li> <li>Trends in condensing furnace technology costs</li> <li>Presence of financial incentives for energy efficiency (rebates, tax reductions)</li> <li>Presence of retail and contractor businesses in the condensing furnace market</li> <li>Adoption of complementary technologies (e.g., smart thermostats)</li> </ul>

<b>Social</b>	Trends in renting vs. property ownership Attitudes toward energy efficiency, first costs, etc. Consumer technology awareness and satisfaction surveys
<b>Regulatory and institutional</b>	Presence of building energy standards Presence of appliance energy standards (furnaces) Financial incentives for energy efficiency
<b>Environmental</b>	Local air emissions considerations Fuel makeup of electrical grid Resource security or scarcity

**→ The outcome of Step 3.1 will be a list of additional information to support the assessment of the enabling environment(s) for priority EETs.**

In the example case of condensing natural gas furnaces for Russian residential buildings, the list would need to be compiled based on local analyses of each enabling factor.

### 3.2: Establish data collection systems

As discussed in Step 2, there is strong interdependency between the chosen energy indicators and EET penetration metrics and the required data for populating those metrics. In turn, the required data will drive the design of the data collection system, including:

- Who provides the data (e.g., consumers, businesses, industry associations)
- Who gathers the data (e.g., statistical agencies, market research firms)
- How the data are collected (e.g., surveys, audits, models)
- How often the data are collected
- Data analysis and quality control

In this sub-step, each of these elements of the data collection system should be clearly defined and a process should be put in place to sustain the system moving forward. In some countries, these elements may already be in place but need to be linked. In other countries, elements may need to be established to sustain the data collection system.

**→ The outcome of this step will be a plan for who will collect which data, how, and when to populate the chosen energy indicators and EET penetration metrics and any required complementary information identified in Step 3.1.**

For the illustrative example, the data collection system could be further defined as follows:

- Who provides the data?
  - Major wholesalers and retailers of condensing natural gas furnaces
- Who gathers the data?
  - National energy statistical agency through a partnership with wholesalers and retailers and furnace/appliance industry associations
- How the data are collected?
  - A structured survey specifying annual sales units by heat capacity and efficiency
- How often the data are collected
  - Annually

### 3.3: Market monitoring

The goal of this sub-step is to apply the previous sub-steps by analysing and interpreting the energy indicator, EET penetration, and complementary market data over time with an eye toward quality control and continuous improvement. Additionally, where available, information the evolution of enabling environment factors can also be analysed and interpreted to aid in identifying factors contributing to market success or failure.

An important component of this sub-step is continuous improvement. Questions to ask in this regard include:

- Do the results make sense? If not, why?
- Do the chosen indicators and penetration metrics result in credible trends analysis?
- Do the quality of data support robust conclusions?
- Could the chosen indicators and/or penetration metrics be improved? If so, how?

**→ The outcomes of this step include presentation and interpretation of trends in energy indicators and EET penetration metrics over time, and opportunities for continuously improving the chosen metrics, data collection systems, and analysis mechanisms.**

### References

- IEA (2016, forthcoming), *Energy Balances of Non-OECD Countries 2016*, [www.iea.org/statistics](http://www.iea.org/statistics).
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## Annex 2: RET benchmark costs

### Introduction

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The likely and actual costs of producing renewable energy are an important element in the methodology for estimating market penetration and potential for renewable energy technologies. Costs play an important role in two parts of the methodology. First the likely cost of energy production is an important factor in the prioritisation stage (Step 1) as less costly generation options are likely to be favoured. Second, the actual cost of generation from a particular source and the cost trends over time are one of the key market indicators (along with deployment) used to characterise and track how a market is evolving. The benchmark costs contained in this document can be used at both stages. During the prioritisation step, they can be used as the basis for estimating the likely costs of generation. During the metrics and monitoring phases, they can be used to put local costs into an international perspective and help highlight issues in the enabling framework which could be addressed in order to facilitate cost reductions.

### Calculation of generation costs

The approach suggested here is based on the calculation of the levelised costs of electricity (LCOE) generated. In this approach electricity costs are calculated based on estimates of the capital and operating costs and of other operating parameters for a particular technology. The value of the sum of the capital and operating costs, discounted over the life of the project is equated to the present value of the electricity generated, and this allows calculation of a fixed figure for the cost of the electricity produced over the lifetime. The discount rate used in the calculation can be varied to reflect the perceived investment risks. One way of looking at LCOE is that it is the electricity tariff with which an investor would precisely break even on the project after paying debt and equity investors, after accounting for required rates of return to these investors.

This approach also has a number of limitations. For example it says nothing about the value of electricity produced in a competitive electricity markets with variable prices, which will depend on the location and time of generation, and it does not take into account issues and costs associated with integration of a particular generation source into a network<sup>15</sup>.

Despite these shortcomings, LCOE remains a transparent measure of generating costs and is a widely used tool for comparing the costs of different power generating technologies in modelling and policy discussions and is therefore useful for this kind of benchmarking exercise.

### Factors affecting energy costs

The **capital and operating costs** of systems vary significantly between national markets even when the same, or a similar, technology is used. Analysis shows lower costs in established, growing markets with significant potential, as competition between suppliers reduces costs. In more mature markets the costs of construction, installation and the various necessary ancillary

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<sup>15</sup> For a fuller discussion of the merits and disadvantages of using LCOEs to assess generation costs see the publication, *Projected Costs of Generating Electricity (2015 Edition)*, published by the IEA and Nuclear Energy Agency (NEA).

services will also be lower as experienced and competitive supply chains are developed. The policy and regulatory framework sends signals which have a strong impact on perceptions about the likely size of the market, and so influences capital costs and the willingness of equipment suppliers and developers to invest time and resources in exploring and developing particular country markets

Given the capital intensive nature of most renewable energy projects, generation costs are also very sensitive to the **cost of capital** needed to finance projects. This can be measured in terms of the weighted average cost of capital (WACC) which takes into account the expected returns on equity and debt and the proportion of each which can be borrowed. The WACC depends first on the overall financial climate in a country which affects investor risk perception, the availability and cost of equity and debt for investment. These issues are reflected in a number of indices including the investment rating, ease of doing business index and other measures.

In addition, the cost of capital for renewable projects is strongly influenced by the specific project risks as perceived by investors. These depend on the degree of confidence in the technology and on the experience and expertise of developers. The renewable energy policy and regulatory framework also has a strong influence on the costs of capital. In particular the way in which generators are rewarded is important. Remuneration systems which provide stable and predictable long-term income streams for investors reduce risk and so allow for lower cost financing and so generation costs. The use of competition coupled to the award of long term stable power purchase agreements has proved an effective way of both providing stable and predictable income streams and of stimulating technical and financial innovation, and has led to significant reductions in generating costs (IEA, 2015a). Other parts of the enabling framework can also affect the costs of projects and risk profile – for example complex and unpredictable permitting processes can discourage experienced developers and push up project risks and costs.

**Physical elements** – such as the wind regime or the intensity and duration of solar energy define how much energy is produced by a system in a specific place and so affect the delivered energy costs. The costs of the bioenergy feedstocks also play an important role.

## Estimating Benchmark Costs

The aim of this section is to provide some benchmark cost figures which allow indicative costs for the main technologies to be estimated in particular market circumstances likely to prevail in the countries of interest to EBRD.

There is no attempt here to establish precise country or project specific costs – even within a country the costs of energy from particular projects will vary significantly depending on specific conditions. Rather this methodology attempts to identify a likely range of costs which can be expected in the local circumstances and which is generally sufficient to provide indicative benchmark numbers helpful for priority setting and checking how achieved costs compare with international norms.

For these benchmarking purposes the **analysis assumes that the policy and regulatory framework has been optimised** by adopting best practice in terms of remuneration mechanisms, permitting procedures etc., so as to give an estimate of what could be achieved in the medium term. In new markets it is likely that costs of generation will initially be higher for a number of reasons.

The analysis first establishes **a range of capital costs and operating conditions** based on analysis of current global experience. These are based on the IEA's work on tracking trends in technology costs. Such analysis is summarised in the annual *Medium Term Renewable Energy Market Report*

(IEA, 2015b). Ranges have been chosen which provide a representative spread of costs rather than the full range seen in all markets – i.e. excluding particularly low or high cases – so as to provide reasonable estimates of the costs that could be achieved in the target countries once markets have matured and if a favourable enabling regime was in place.

The estimates are based on current (2016) costs in US dollars. For some technologies – notably wind and solar PV – costs are continuing to fall and so it is likely that these data may need to be updated regularly. However it is anticipated that the costs in the target countries are likely to fall within the ranges given for the next few years.

Table A13 summarises the estimates of capital and operating costs and operational parameters used in this analysis.

The **costs of capital** in particular markets depend on many factors related to economic performance and the perceived risks of investment. For this analysis we have considered a spread of costs of capital ranging from very low rates (such as can be achieved in very stable economies with a good business climate and investment rating, through to countries where credit risks are judged to be high. Underlying rates of 5, 10, 15 and 20% have been used to represent the full range of possibilities.

**Table A13 • Summary of estimates for costs and operational parameters used to estimate benchmark costs**

Technology	Capital Costs M\$/MW		Operating costs as % of Capital	Lifetime (Years)	Full load hours		Fuel cost USD/GJ		Efficiency %
	Low	High			Low	High	Low	High	
<b>Bioenergy and Wastes</b>									
Cofiring	0.25	0.35	15%	15	7008		0.00	10.50	35%
Wood electricity	2.00	4.50	5%	25	7008		0.00	10.50	30%
Wood co-generation	4.00	6.50	5%	25	7008		0	10.5	30%
Anaerobic digestion	3.70	8.00	12%	20	6132		-15.0	0.0	30%
Landfill gas	1.50	2.50	10%	15	6000		0	0	35%
MSW	8.00	13.00	10%	25	7008		-13.6	-0.5	23%
MSW co-generation	9.00	15.00	5%	25	7008		-13.6	-0.5	23%
<b>Other Renewable Technologies</b>									
Onshore wind	1.70	2.40	2%	20	1752	3942	n/a	n/a	n/a
PV (Utility)	1.00	2.00	1%	20	800	1800	n/a	n/a	n/a
PV (Commercial)	1.30	3.00	1%	20	700	1600	n/a	n/a	n/a
PV (Residential)	2.00	4.00	1%	20	600	1500	n/a	n/a	n/a
CSP	5.00	7.70	1%	25	0	3500	n/a	n/a	n/a
Hydro	2.00	6.00	3%	35	2000	6600	n/a	n/a	n/a

Notes: Notes: CHP = Combined heat and power, GJ = Gigajoule, MSW = Municipal solid waste, MW = Megawatt, n/a = Not applicable, PV = Photovoltaic.

For each of the principal resources and technologies the main **resource factors** influencing energy costs have been identified. These affect costs principally in terms of the annual electricity output that can be achieved by a given capacity (i.e. the full load hours that can be achieved) or

for bioenergy and waste technologies the costs at which fuel can be procured. These factors are discussed below. In each case, four ranges of resource have been identified as: excellent, good, fair and poor. Analysis of the resource in a particular country then allows a typical operating regime to be identified.

### Bioenergy

For bioenergy power generation, the main resource based factor determining costs is the cost of the feedstock used (unlike the other renewable technologies where the resource is essentially free). For each of the principal bioenergy ranges of feedstocks costs are rated as follows.

**The costs associated with wood and agricultural residues** depend on the extent to which extensive and well developed forestry and timber or agricultural sectors provide ample sources of wood or agricultural residues available at or close to potential generating sites, or whether such resources are dispersed or scarce and have to be transported long distances or imported.

**For municipal solid waste (MSW) for energy production and for feedstocks for anaerobic digestion**, the fuel costs depend on the waste management and disposal regulatory framework that is in place. Where no strong waste management regime is in place the feedstocks can be supplied at essentially zero cost. As stronger regulations for controlling waste disposal push up the costs of alternative disposal methods (e.g. landfill costs) then the MSW has a negative cost since the treatment plant can charge a disposal fee. Where measures including landfill taxes are in place to discourage landfilling then alternative costs can be very high (as much as USD 150/tonne, equivalent to USD-14/GJ in some European countries). Both MSW combustion and anaerobic digestion are expensive electricity generation technologies, with high capital costs because of the extensive systems needed to ensure that the plant emissions to air and water are properly controlled. This means that generation costs tend to be high except in cases where waste management regimes are strict and a substantial income is available from disposal fees.

**Landfill gas:** this methane rich gas is produced when MSW is placed in landfills and unless controlled poses a significant threat to health and safety as well as being a potent greenhouse gas. The analysis here assumes that the gas is available at zero cost in all circumstances. Table A14 summarises the estimates of the bioenergy fuel cost for these technologies.

**Table A14 • Bioenergy input fuel costs and classification**

	Resource Costs USD/GJ			
	Excellent	Good	Fair	Poor
Wood and agricultural residues for co-firing, electricity or CHP operation	0	4	7	10.5
Landfill gas	0	0	0	0
MSW for electricity generation or CHP and wastes for anaerobic digestion	-14	-9	-5	-0.5

Notes: CHP = Combined heat and power, GJ = Gigajoule, MSW = Municipal solid waste.

### Other renewable electricity generating technologies

For these technologies the climatic conditions determine the yield of electricity from a given installed capacity. For wind and solar PV this depends on the intensity and on the pattern of the resource. This can be summarised in terms of the annual output from a given capacity, usually expressed in terms of the “full-load hours” that can be achieved.

For solar CSP the situation is more complex. This technology only works successfully and economically where there are high levels of direct normal radiation. The output from a plant then depends on the levels of solar insolation but also on other factors including how much energy

storage has been built into the plant to allow continued generation even when radiation levels are low.

Table A15 shows the ranges of full-load hours assumed for these technologies in cases where the resource is judged to be excellent, good, fair and poor.

**Table A15 • Other renewables: full-load hour ranges and classification**

Technology	Resource Quality as Expressed in Full Load Hours			
	Excellent	Good	Fair	Poor
On shore wind	3942	2891	2278	1752
Solar PV				
Utility scale	1800	1500	1000	800
Commercial scale	1600	1300	900	700
Residential scale	1500	1200	800	600
Solar CSP	3500	2800	2500	-
Hydro	6600	5000	3500	2200

## Results

The results of this analysis are summarised in the tables below showing the anticipated electricity generation costs in particular circumstances depending on the quality of the resource and on prevailing financing conditions.

Note that some combinations are unlikely to occur. Co-firing of biomass with coal requires very large quantities of resource which have been pre-processed to meet a tight specification. This means that the biomass costs to service this need are likely to be more expensive than those which can be used in smaller scale local generation. Similarly solar CSP is only likely to be practical and economic where the solar regime is good or excellent.

This methodology allows benchmark generation costs for a particular situation to be estimated – for example in a country with an excellent wind resource and with low cost capital available with a WACC of 5%, wind power costs might be expected to be within a range of USD 41 to 58 /MWh. Where there is only a fair wind regime, and the cost of capital is higher (say 15%) then benchmark costs rise to USD 132-184 /MWh.

**Table A16 • Benchmark costs for varying resource and costs of capital – bioenergy and waste technologies**

Benchmark Generation Costs USD/MWh									
	Resource	Poor		Fair		Good		Excellent	
		Cost Range		Cost Range		Cost Range		Cost Range	
Biomass Co-firing									
WACC	20%	121	126	85	90	N/A			
	15%	119	124	83	88				
	10%	118	122	82	86				
	5%	117	120	81	84				
Biomass Power Generation									
WACC	20%	198	288	156	246	120	210	72	162
	15%	184	257	142	215	106	179	58	131
	10%	172	229	130	187	94	151	46	103
	5%	161	204	119	162	83	126	35	78
Biomass CHP									
WACC	20%	180	270	138	228	102	192	54	144
	15%	153	226	111	184	75	148	27	100
	10%	127	185	85	143	49	107	1	59
	5%	105	148	63	106	27	70	-21	22
Biomass Anaerobic Digestion									
WACC	20%	196	424	136	364	76	304	16	244
	15%	169	365	109	305	49	245	-11	185
	10%	143	310	83	250	23	190	-37	130
	5%	121	261	61	201	1	141	-59	81
Landfill Gas									
WACC	20%	62	103	N/A					
	15%	58	96						
	10%	54	90						
	5%	49	82						
MSW Power Generation									
WACC	20%	338	553	274	489	203	418	131	347
	15%	284	465	220	401	148	330	77	259
	10%	233	383	169	319	98	248	26	176
	5%	188	310	124	246	53	175	-18	104
MSW CHP									
WACC	20%	199	415	135	351	64	280	-7	209
	15%	138	314	74	250	3	178	-68	107
	10%	81	218	17	154	-54	83	-125	12
	5%	31	134	-33	70	-104	-1	-175	-72

Notes: CHP = Combined heat and power, MSW = Municipal solid waste, N/A = not applicable, USD = United States dollars, WACC = weighted average cost of capital

**Table A17 • Benchmark costs for varying resource and costs of capital – other renewables technologies**

Benchmark generation costs USD/MWh									
	Resource	Poor		Fair		Good		Excellent	
		Cost Range		Cost Range		Cost Range		Cost Range	
<b>Onshore wind</b>									
WACC	20%	214	302	164	232	130	183	95	134
	15%	170	239	130	184	103	145	75	106
	10%	129	181	99	140	78	110	57	81
	5%	92	130	71	100	56	79	41	58
<b>Solar PV - Utility scale</b>									
WACC	20%	269	538	215	431	144	287	120	239
	15%	212	424	170	340	113	226	94	189
	10%	159	319	127	255	85	170	71	142
	5%	113	226	90	180	60	120	50	100
<b>Solar PV - Commercial scale</b>									
WACC	20%	400	923	311	718	215	497	175	404
	15%	315	728	245	566	170	392	138	318
	10%	237	546	184	425	127	294	104	239
	5%	168	387	130	301	90	208	73	169
<b>Solar PV - Residential</b>									
WACC	20%	718	1436	538	1077	359	718	287	574
	15%	566	1132	424	849	283	566	226	453
	10%	425	850	319	637	212	425	170	340
	5%	301	602	226	451	150	301	120	241
<b>Concentrating solar power</b>									
WACC	20%	N/A		424	653	379	583	303	467
	15%			329	507	294	453	235	362
	10%			240	370	215	330	172	264
	5%			162	249	145	223	116	178
<b>Hydro</b>									
WACC	20%	147	442	84	253	59	177	45	134
	15%	129	386	74	221	51	154	39	117
	10%	111	332	63	190	44	133	34	101
	5%	86	258	49	148	34	103	26	78

Notes: N/A = not applicable, USD = United States dollars, WACC = weighted average cost of capital

## References

IEA (2015a), *Enabling Renewable Energy and Energy Efficiency Technologies - Opportunities in Eastern Europe, Caucasus, Central Asia, Southern and Eastern Mediterranean*, Insights Paper Series, IEA/OECD Publishing, Paris.

IEA (2015b), *Medium Term Renewable Energy Market Report 2015*, IEA/OECD Publishing, Paris.

## Annex 3: Examples of energy balances of ETCs and SEMED countries

### II.174 - ENERGY BALANCES OF NON-OECD COUNTRIES (2015 edition)

<b>Moldova</b>											
<b>2013</b>											
Thousand tonnes of oil equivalent											
<b>SUPPLY AND CONSUMPTION</b>	Coal	Crude oil	Oil products	Natural Gas	Nuclear	Hydro	Geotherm. solar etc.	Biofuels & Waste	Electricity	Heat	Total
Production	-	10	-	0	-	27	0	269	-	-	305
Imports	152	1	811	1736	-	-	-	-	125	-	2826
Exports	-	-	-34	-	-	-	-	-0	-	-	-34
Intl. marine bunkers	-	-	-	-	-	-	-	-	-	-	-
Intl. aviation bunkers	-	-	-22	-	-	-	-	-	-	-	-22
Stock changes	-5	-	-2	1	-	-	-	-1	-	-	-6
<b>TPES</b>	<b>147</b>	<b>11</b>	<b>754</b>	<b>1738</b>	<b>-</b>	<b>27</b>	<b>0</b>	<b>268</b>	<b>125</b>	<b>-</b>	<b>3070</b>
Transfers	-	11	-10	-	-	-	-	-	-	-	1
Statistical differences	-1	-1	-	-	-	-	-	-	0	-	-2
Electricity plants	-	-	-	-816	-	-27	-0	-0	313	-	-530
CHP plants	-	-	-13	-259	-	-	-	-1	73	165	-34
Heat plants	-7	-	-1	-83	-	-	-	-6	-	89	-9
Blast furnaces	-	-	-	-	-	-	-	-	-	-	-
Gas works	-	-	-	-	-	-	-	-	-	-	-
Coke/pat.fuel/BKB/PB plants	-	-	-	-	-	-	-	-	-	-	-
Oil refineries	-	-21	18	-	-	-	-	-	-	-	-2
Petrochemical plants	-	-	-	-	-	-	-	-	-	-	-
Liquefaction plants	-	-	-	-	-	-	-	-	-	-	-
Other transformation	-	-	-	-	-	-	-	-0	-	-	-0
Energy industry own use	-	-	-	-	-	-	-	-	-27	-1	-28
Losses	-1	-	-3	-58	-	-	-	-0	-97	-40	-200
<b>TFC</b>	<b>138</b>	<b>-</b>	<b>745</b>	<b>522</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>260</b>	<b>387</b>	<b>214</b>	<b>2265</b>
<b>INDUSTRY</b>	<b>55</b>	<b>-</b>	<b>16</b>	<b>223</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>1</b>	<b>128</b>	<b>51</b>	<b>474</b>
Iron and steel	-	-	-	0	-	-	-	-	0	-	0
Chemical and petrochemical	-	-	-	0	-	-	-	0	3	1	5
Non-ferrous metals	-	-	-	-	-	-	-	-	-	-	-
Non-metallic minerals	53	-	8	34	-	-	-	-	14	0	110
Transport equipment	-	-	-	-	-	-	-	-	0	-	0
Machinery	-	-	-	0	-	-	-	-	4	0	4
Mining and quarrying	-	-	2	-	-	-	-	-	1	-	3
Food and tobacco	2	-	2	15	-	-	-	0	30	47	95
Paper pulp and printing	-	-	-	2	-	-	-	-	1	1	3
Wood and wood products	-	-	-	0	-	-	-	0	5	0	5
Construction	-	-	4	1	-	-	-	-	1	-	6
Textile and leather	-	-	-	0	-	-	-	-	4	2	6
Non-specified	-	-	-	170	-	-	-	-	65	0	236
<b>TRANSPORT</b>	<b>-</b>	<b>-</b>	<b>488</b>	<b>6</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>5</b>	<b>-</b>	<b>499</b>
Domestic aviation	-	-	-	-	-	-	-	-	-	-	-
Road	-	-	476	1	-	-	-	-	-	-	478
Rail	-	-	9	-	-	-	-	-	-	-	9
Pipeline transport	-	-	-	5	-	-	-	-	2	-	7
Domestic navigation	-	-	-	-	-	-	-	-	-	-	-
Non-specified	-	-	2	-	-	-	-	-	3	-	5
<b>OTHER</b>	<b>84</b>	<b>-</b>	<b>198</b>	<b>293</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>259</b>	<b>253</b>	<b>163</b>	<b>1250</b>
Residential	58	-	152	210	-	-	-	251	158	109	939
Comm. and publ. services	25	-	3	79	-	-	-	8	90	53	259
Agriculture/forestry	1	-	43	3	-	-	-	1	5	1	53
Fishing	-	-	-	-	-	-	-	-	-	-	-
Non-specified	-	-	-	-	-	-	-	-	-	-	-
<b>NON-ENERGY USE</b>	<b>-</b>	<b>-</b>	<b>43</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>43</b>
in industry/transf./energy	-	-	34	-	-	-	-	-	-	-	34
of which: chem./petrochem.	-	-	1	-	-	-	-	-	-	-	1
in transport	-	-	6	-	-	-	-	-	-	-	6
in other	-	-	2	-	-	-	-	-	-	-	2
<b>Electricity and Heat Output</b>											
<b>Electr. generated - GWh</b>	<b>-</b>	<b>-</b>	<b>16</b>	<b>4162</b>	<b>-</b>	<b>310</b>	<b>1</b>	<b>2</b>	<b>-</b>	<b>-</b>	<b>4491</b>
Electricity plants	-	-	1	3327	-	310	1	1	-	-	3640
CHP plants	-	-	15	835	-	-	-	1	-	-	851
<b>Heat generated - TJ</b>	<b>240</b>	<b>-</b>	<b>532</b>	<b>9686</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>182</b>	<b>-</b>	<b>-</b>	<b>10640</b>
CHP plants	-	-	487	6429	-	-	-	-	-	-	6916
Heat plants	240	-	45	3257	-	-	-	182	-	-	3724

II.104 - ENERGY BALANCES OF NON-OECD COUNTRIES (2015 edition)

Egypt

2012

SUPPLY AND CONSUMPTION	Thousand tonnes of oil equivalent										
	Coal	Crude oil	Oil products	Natural Gas	Nuclear	Hydro	Geotherm. solar etc.	Biofuels & Waste	Electricity	Heat	Total
Production	-	34968	-	44184	-	1211	129	1617	-	-	82109
Imports	462	2966	10052	-	-	-	-	1	7	-	13487
Exports	-71	-9683	-2245	-5064	-	-	-	-24	-41	-	-17128
Intl. marine bunkers	-	-	-1833	-	-	-	-	-	-	-	-1833
Intl. aviation bunkers	-	-	-888	-	-	-	-	-	-	-	-888
Stock changes	-	-	2472	-	-	-	-	-	-	-	2472
<b>TPES</b>	<b>391</b>	<b>28251</b>	<b>7558</b>	<b>39120</b>	<b>-</b>	<b>1211</b>	<b>129</b>	<b>1594</b>	<b>-34</b>	<b>-</b>	<b>78220</b>
Electricity and CHP plants	-	-	-6503	-22292	-	-1211	-129	-	14135	-	-16000
Oil refineries	-	-27086	27133	-	-	-	-	-	-	-	47
Other transformation <sup>1</sup>	-192	-1165	2091	-5091	-	-	-	-	-2039	-	-6397
<b>TFC</b>	<b>198</b>	<b>-</b>	<b>30279</b>	<b>11736</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>1594</b>	<b>12062</b>	<b>-</b>	<b>55869</b>
<b>INDUSTRY</b>	<b>196</b>	<b>-</b>	<b>3740</b>	<b>5983</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>3430</b>	<b>-</b>	<b>13350</b>
Iron and steel	196	-	-	-	-	-	-	-	-	-	196
Chemical and petrochemical	-	-	-	-	-	-	-	-	-	-	-
Non-metallic minerals	-	-	-	-	-	-	-	-	-	-	-
Other/non-specified	-	-	3740	5983	-	-	-	-	3430	-	13153
<b>TRANSPORT</b>	<b>-</b>	<b>-</b>	<b>16533</b>	<b>404</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>44</b>	<b>-</b>	<b>16980</b>
Domestic aviation	-	-	543	-	-	-	-	-	-	-	543
Road	-	-	15619	404	-	-	-	-	-	-	16023
Other/non-specified	-	-	271	-	-	-	-	-	44	-	315
<b>OTHER</b>	<b>2</b>	<b>-</b>	<b>7148</b>	<b>1144</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>1594</b>	<b>8588</b>	<b>-</b>	<b>18477</b>
Residential	2	-	4842	1144	-	-	-	781	5139	-	11908
Comm. and public services	-	-	-	-	-	-	-	-	2913	-	2913
Agriculture/forestry	-	-	2306	-	-	-	-	-	536	-	2841
Other/non-specified	-	-	-	-	-	-	-	814	-	-	814
<b>NON-ENERGY USE</b>	<b>-</b>	<b>-</b>	<b>2857</b>	<b>4206</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>7063</b>
<b>Electricity and Heat Output</b>											
Electricity generated - GWh	-	-	24959	123824	-	14084	1497	-	-	-	164364
Heat generated - TJ	-	-	-	-	-	-	-	-	-	-	-

2013

SUPPLY AND CONSUMPTION	Thousand tonnes of oil equivalent										
	Coal	Crude oil	Oil products	Natural Gas	Nuclear	Hydro	Geotherm. solar etc.	Biofuels & Waste	Electricity	Heat	Total
Production	-	34820	-	45112	-	1113	131	1644	-	-	82821
Imports	444	3028	9944	-	-	-	-	1	7	-	13424
Exports	-59	-9886	-2194	-5171	-	-	-	-24	-42	-	-17375
Intl. marine bunkers	-	-	-1791	-	-	-	-	-	-	-	-1791
Intl. aviation bunkers	-	-	-907	-	-	-	-	-	-	-	-907
Stock changes	-	-	1366	-	-	-	-	-	-	-	1366
<b>TPES</b>	<b>386</b>	<b>27962</b>	<b>6418</b>	<b>39941</b>	<b>-</b>	<b>1113</b>	<b>131</b>	<b>1621</b>	<b>-35</b>	<b>-</b>	<b>77538</b>
Electricity and CHP plants	-	-	-6354	-22760	-	-1113	-131	-	14432	-	-15927
Oil refineries	-	-26464	26535	-	-	-	-	-	-	-	71
Other transformation <sup>1</sup>	-189	-1499	1435	-5198	-	-	-	-	-2082	-	-7533
<b>TFC</b>	<b>197</b>	<b>-</b>	<b>28033</b>	<b>11983</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>1621</b>	<b>12316</b>	<b>-</b>	<b>54149</b>
<b>INDUSTRY</b>	<b>195</b>	<b>-</b>	<b>3655</b>	<b>6108</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>3502</b>	<b>-</b>	<b>13461</b>
Iron and steel	195	-	-	-	-	-	-	-	-	-	195
Chemical and petrochemical	-	-	-	-	-	-	-	-	-	-	-
Non-metallic minerals	-	-	-	-	-	-	-	-	-	-	-
Other/non-specified	-	-	3655	6108	-	-	-	-	3502	-	13266
<b>TRANSPORT</b>	<b>-</b>	<b>-</b>	<b>14585</b>	<b>412</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>44</b>	<b>-</b>	<b>15042</b>
Domestic aviation	-	-	656	-	-	-	-	-	-	-	656
Road	-	-	13664	412	-	-	-	-	-	-	14076
Other/non-specified	-	-	265	-	-	-	-	-	44	-	310
<b>OTHER</b>	<b>1</b>	<b>-</b>	<b>7090</b>	<b>1168</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>1621</b>	<b>8769</b>	<b>-</b>	<b>18649</b>
Residential	1	-	4838	1168	-	-	-	794	5247	-	12048
Comm. and public services	-	-	-	-	-	-	-	-	2975	-	2975
Agriculture/forestry	-	-	2252	-	-	-	-	-	547	-	2799
Other/non-specified	-	-	-	-	-	-	-	827	-	-	827
<b>NON-ENERGY USE</b>	<b>-</b>	<b>-</b>	<b>2702</b>	<b>4294</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>6996</b>
<b>Electricity and Heat Output</b>											
Electricity generated - GWh	-	-	24387	128962	-	12940	1528	-	-	-	167817
Heat generated - TJ	-	-	-	-	-	-	-	-	-	-	-

1. Includes transfers, statistical differences, energy industry own use, and losses.

## Annex 4: Selected best practice EETs for assembling technology long lists

### LIGHT DUTY VEHICLE TECHNOLOGIES

Gasoline and diesel ICE vehicle technologies
Tyres: low rolling resistance
Engine low friction design and materials
Lightweight components other than Body in White (BIW)
Variable valve actuation and lift
Direct injection
Starter-alternator (increased battery)
Light-weighting (high-strength steel)
Dual clutch transmission
Light-weighting (aluminium)
Aerodynamics - spoilers
Aerodynamics - front air dams
Aerodynamics - side skirts
Aerodynamics - under-body panels

Gasoline and diesel ICE hybrid vehicle technologies
Mild hybrid (start-stop system recuperation)
Full hybrid - electric drive
Tyres: low rolling resistance
Lightweight components other than Body in White (BIW)
Engine low friction design and materials
Variable valve actuation and lift
Light-weighting (high-strength steel)
Direct injection
Light-weighting (aluminium)
Aerodynamics - spoilers
Aerodynamics - front air dams
Aerodynamics - side skirts
Aerodynamics - under-body panels

Technology
Electric vehicles
Fuel cell electric vehicles

### Hydrogen vehicle technologies

Hydrogen internal combustion
Hydrogen fuel cells

### HEAVY DUTY VEHICLE TECHNOLOGIES

#### HFT Diesel energy technologies

Eco roll freewheel function
Controllable air compressor
Oil and water pump with variable speed
Acceleration control
Green zone indicators
Predictive cruise control
Smart alternator, battery sensor, electric accessory drive
Low rolling resistance tyres
Variable valve actuation
Sequential turbo/downsizing
Speed control (injection)
Pneumatic booster – air hybrid
Aerodynamic fairings
Active aerodynamics
Single wide tyres
Aerodynamic trailer / Boat tail
Light-weight materials
Automated manual transmission
Turbo-compound (Mechanical / Electric)
Bottoming cycles/waste heat recovery (e.g. organic Rankine)
Dual fuel systems

#### Natural Gas Vehicles-HFT technologies

On-board gas fuelling system
Eco roll freewheel function
Controllable air compressor
Oil and water pump with variable speed
Acceleration control
Green zone indicators
Predictive cruise control
Smart alternator, battery sensor, electric accessory drive

Low rolling resistance tyres
Variable valve actuation
Sequential turbo/downsizing
Speed control (injection)
Aerodynamic fairings
Active aerodynamics
Single wide tyres
Light-weight materials
Aerodynamic trailer / Boat tail
Automated manual transmission
Turbo-compound (Mechanical / Electric)
Bottoming cycles/waste heat recovery (e.g. organic Rankine)

### MFT technologies

Eco roll freewheel function
Controllable air compressor
Oil and water pump with variable speed
Acceleration control
Green zone indicators
Predictive cruise control
Smart alternator, battery sensor, electric accessory drive
Variable valve actuation
Sequential turbo/downsizing
Speed control (injection)
Start/stop automatic
Pneumatic booster – air hybrid
Light-weight materials
Automated manual transmission
Dual fuel systems

### Natural Gas Vehicles-MFT technologies

On-board gas fuelling system
Eco roll freewheel function
Controllable air compressor
Oil and water pump with variable speed
Acceleration control
Green zone indicators
Predictive cruise control
Smart alternator, battery sensor, electric accessory drive
Variable valve actuation
Sequential turbo/downsizing
Speed control (injection)
Start/stop automatic

Pneumatic booster – air hybrid
Light-weight materials
Automated manual transmission
Dual fuel systems

### HFT Hybrid technologies

Hydraulic hybrid
Eco roll freewheel function
Controllable air compressor
Oil and water pump with variable speed
Acceleration control
Green zone indicators
Predictive cruise control
Smart alternator, battery sensor, electric accessory drive
Low rolling resistance tyres
Variable valve actuation
Sequential turbo/downsizing
Speed control (injection)
Pneumatic booster – air hybrid
Aerodynamic fairings
Active aerodynamics
Single wide tyres
Light-weight materials
Aerodynamic trailer / Boat tail
Automated manual transmission
Turbo compound (Mechanical / Electric)
Bottoming cycles/waste heat recovery (e.g. organic Rankine)
Dual fuel systems

### INDUSTRY TECHNOLOGIES

#### Cross-cutting industry technologies

Heat exchanger
Insulate valves and fittings
Improved process control (including flue gas monitoring)
Automatic monitoring of steam traps
Feed-water economiser
Flash condensate
Return condensate
Minimise short cycling (via multiple boiler operation and/or boiler downsizing)
Vapour recompression
Vent condenser
Reducing Wall heat losses

Improved process controls (e.g. air-to-fuel ratio)
Reducing Radiation heat losses
Efficient design burners (e.g. low NOx)
Flue gas heat recovery
Oxygen enrichment
Reducing wall heat losses on already insulated areas
Electronically controlled pumps
Systems optimisation
Improved process measuring and control
Improved insulation
Speed-controlled compressor and fan
Improved compressor / heat exchanger
Multi-compressor refrigeration systems
Multi-level compression and sorption process
Isolate flow paths to non-essential equipment
Use of pressure switches
Install variable speed drive
More efficient pump
More efficient motor
Install variable speed drive
Replace oversized fans with more efficient type
More efficient motor
Replace existing condensate drains with zero loss type
Eliminate artificial demand with pressure optimisation/control
Install sequencer
Install dedicated storage with metered recovery
Variable speed drive
Size replacement compressor to meet demand
Improvement of automatic control

#### Sugar processing technologies

Falling film evaporator
Pressure-driven membrane integrated into multiple-effect evaporator
Continuous vacuum pans
Condensate juice heaters
Use of vapour bleed from the evaporators in other heat uses (as low pressure steam for different heat users like raw juice purification, clarified juice pre-heating and crystallization sections.)
Install variable speed drive
Replace miller with diffuser for juice extraction (cane)

Replace steam-powered mill drive with electric drive
Replace steam-powered mill drive with hydraulic drive
Replace drum drier with steam drier
Fluidised bed dryer for cooling and conveying
Drum-type beet slicer instead of disk slicer

#### Cement industry technologies

Vertical Roller Mill instead of Ball Mill
Classifiers (High-Efficiency Separators)
Efficient transport system
Roller mill for coal preparation instead of impact or tube mill
Dry kiln to dry kiln with preheater and pre-calciner
Dry kiln with preheater to dry kiln with preheater and pre-calciner
Additional preheater cyclone stages
Process Control and management system
High efficient clinker cooler technology
Heat recovery for power generation
Kiln shell heat loss reduction
Variable speed drives for kiln fan
Modern multi-channel burner
Low pressure drop cyclones (suspension preheater)
High Pressure Grinding rolls or vertical roller mills
Introduction of pre-grinder
Energy management & process control in grinding
High Efficiency Classifiers (for finish grinding)
High efficiency motors
Adjustable Speed Drives

#### Iron and steel technologies

Coke Dry Quenching / Coke Stabilised Quenching
Coal Moisture control
Heat recovery of COG
Top gas utilisation (Coke Oven Gas Recovery)
Sinter plant heat recover
Improved process control
Utilisation of waste fuels
Blast Furnace Gas recovery
Hot-blast stove automation

Improved Hot Stove Combustion Control
Waste heat recuperator on hot blast stove
Top pressure recovery turbines
Pulverized Coal Injection (to 130 kg/ton iron)
Injection of natural gas to 140 kg/ton iron
Injection of coke oven gas/basic oxygen gas
Heat recovery from slag
Improved blast furnace control systems
Top gas recycle blast furnace
ULCORED
Midrex
HISARNA
HYL
Contiarc Furnace
DC Arc furnace
Scrap preheating
Oxy-fuel burners
Eccentric bottom tapping on existing furnace
Improved process control (neural networks)
Transformer Efficiency - Ultra High Power Transformers
Flue gas monitoring and control
Process to continuously melt, refine and cast high quality steel
Waste Heat Recovery for EAF
Waste Heat and Gas Recovery
Thin slab casting
Strip casting (e.g. Castrip, Eurostrip)
Hot charging
Process Control in Hot Strip Mill
Insulation of reheating furnace
Recuperative burners
Automated monitoring and targeting systems
Heat recovery on the annealing line

#### Chemical and petrochemicals technologies

More selective furnace coils
Improved transfer line exchangers
Secondary transfer line exchangers
Increased efficiency cracking furnaces
Pre-coupled gas turbine to cracker furnace
Higher gasoline fractionator bottom temperature
Improved heat recovery quench water
Reduced pressure drop in compressor inter-stages
Additional expander on de-methanizer
Additional re-boilers (cold recuperation)

Extended heat exchanger surface
Optimization steam and power balance
Improved compressors
Improved product recovery systems
Low pressure steam recovery
Gear pump to replace extruder
Online compounding extrusion
Re-use solvents, oils and catalysts
Increased selectivity catalyst
Optimal design EO/EG-sections
Multi-effect evaporators (Glycol)
Recovery and sales of by-product CO2
Process integration
Optimize recycle loops
Gas-phase direct chlorination of ethylene
Catalytic cracking EDC
Condensate recovery and process integration
Recover exothermic heat
Recuperative incinerators

#### Transport equipment manufacturing technologies

High efficiency welding/inverter technology
Multi-welding units
Frequency modulated DC-welding machine
Hydroforming
Electric robots
Minimize stabilization period
Infrared paint curing
UV paint curing
Microwave heating
Wet on wet pain
New paint—powders
New paint—powder slurry coats
New paint—water-borne latex base coat
New paint—solvent-borne clear coat
Ultrafiltration/reverse osmosis for wastewater cleaning
Carbon filters and other volatile organic carbon (VOC) removers
High pressure water jet system

#### Food processing technologies

Membrane filtration
Heat pumps
Mechanical and thermal vapour recompression

Spark ignition reciprocating engines
Compression ignition reciprocating engines
Combined-cycle turbine
Open-cycle turbine
Back-pressure steam turbine
Extraction steam turbine
New modes of heat transfer
Infrared radiation heating
Microwave and high-frequency radiation
Ohmic heating
Induction heating
Cold process pasteurization and bacterial control
Microfiltration and ultrafiltration treatment
High-pressure (hyperbaric) treatment
Ultraviolet treatment
Treatment with electric or magnetic fields
Electron beam treatment
High-efficiency homogenization valves
Falling film evaporator
Pressure-driven membrane integrated into multiple-effect evaporator
Multiple effect evaporators
Thermal vapour recompression
Mechanical vapour recompression
Concentration using membrane filtration
Continuous vacuum pans
Condensate juice heaters
Use of vapour bleed from the evaporators in other heat uses (as low pressure steam for different heat users like raw juice purification, clarified juice pre-heating and crystallization sections.)
Install variable speed drive
Replace miller with diffuser for juice extraction (cane)
Replace steam-powered mill drive with electric drive
Replace steam-powered mill drive with hydraulic drive
Replace drum drier with steam drier
Exhaust heat recovery
Use of multiple stage drying
Use of crystallization (dry whey only)
Using other concentration techniques
Fluidised bed dryer for cooling and conveying
Drum-type beet slicer instead of disk slicer
Reclamation/adding plates
Compact immersion tube heat exchangers
Helical heat exchangers
Induction heating of liquids
Heat exchanger enhancement techniques
Piping insulation

Compressor control systems and scheduling
Dedicating a compressor to defrosting
Adjustable-speed drives
Using an economizer with a single stage, low temperature compressor
Automatic purging of condensers
Floating head pressure control
Indirect lubricant cooling
Use of axial condenser fans
Adjustable-speed drives on condenser fans
Adjustable-speed drives on evaporator fans
Cycling of evaporator fans in cold storage
Raising system suction pressure
Compressor heat recovery
Free cooling
Cooling towers
Tank Insulation for storage tanks
Geothermal cooling
Mixing in storage tanks

### Pulp and paper technologies

Black liquor gasification
High-temperature odor free recovery boiler
Continuous digester
Batch digester modifications
Black liquor concentration (e.g. via falling film black liquor evaporation)
Lime kiln modifications
Heat recovery (TMP,GW)
High-efficiency grinding (GW)
Enzymatic pre-treatment
Efficient refiner and pre-treatment (including wood shavings, conical refiners, RTS)
Thermo-pulping
Improvements in Chemi-thermomechanical pulping
Efficient screening
De-inking flotation optimization
Drum Pulpers instead of vat type pulpers
Efficient dispersers
Heat recovery from bleaching
Heat recovery from de-inking effluent
Incineration of residues
Efficient refiners
Chemical modification of fibres
Reducing air requirements (enclosed hood)
Direct drying cylinder firing
High consistency forming
Infrared Moisture Profiling

Shoe press
New drying techniques (steam impingement drying, condensing belt drying, impulse drying)
Dry sheet forming
Hot press
High concentration size press for paper surface coat
Heat recovery and integration

## RESIDENTIAL & COMMERCIAL SECTOR TECHNOLOGIES

### Cooking technologies

Coal cookstove
Oil cookstove
Efficient oil cookstove
Gas Hob
Gas oven
Electric hobs
Electric oven
Biomass cookstove
Save80 biomass cookstove (80% more efficient)
Induction cookstove
LPG and biogas cook stoves
Rocket cook stoves
Solar cook stoves

### Lighting technologies

Linear fluorescent bulb
CFL bulb
LED
High-Intensity Discharge Lamps (HID)
Daylight sensors
Presence sensors
Algorithmic lighting

### Space cooling technologies

Air conditioner - EU labelling - A
Air conditioner - EU labelling - B
Air conditioner - EU labelling - C

Air heat pump - EU labelling - A
Air heat pump - EU labelling - B
Air heat pump - EU labelling - C
Absorbtion chillers
Loft insulation (200 to 300 mm)
Loft insulation (100 to 200mm)
Floor insulation
Double glazed windows
Triple glazed windows
Solid wall insulation
Air sealing
Reflective walls/roofs
Low-E windows
Energy-plus windows in cold climates (highly insulating and dynamic solar)
Window attachments (automatic solar control, e.g. exterior solar shades and blinds)
Window attachments (highly insulating, e.g. cellular shades, low-e films)

### Appliances

Refrigerators - Vacuum Insulation Panels on doors
Refrigerators – Vacuum Insulation Panels on cabinet walls
Refrigerators – Additional 10-15 mm insulation on door and cabinet walls
Refrigerators – Increasing surface area of the evaporator by 10-20%
Refrigerators – Increasing surface area of the condenser by 5-10%
Refrigerators – Higher-efficiency reciprocating compressor
Refrigerators - EU labelling - A+
Refrigerators - EU labelling - A++
Refrigerators - EU labelling - A+++
Dishwashers - EU labelling - A+
Dishwashers - EU labelling - A++
Dishwashers - EU labelling - A+++
Notebook computers energy star rating A
Televisions - EU labelling - A+
Televisions - EU labelling - A++
Televisions - EU labelling - A+++
Washing machines - EU labelling - A+
Washing machines - EU labelling - A++
Washing machines - EU labelling - A+++
Tumble driers - EU labelling - C

Tumble driers - EU labelling - B
Tumble driers - EU labelling - A
Combined washer driers - EU labelling - C
Combined washer driers - EU labelling - B
Combined washer driers - EU labelling - A

### Water heating technologies

Conventional water heater - EU labelling - C
Conventional water heater - EU labelling - B
Conventional water heater - EU labelling - A
Solar water heater - EU labelling - C
Solar water heater - EU labelling - B
Solar water heater - EU labelling - A
Heat pump water heater - EU labelling - C
Heat pump water heater - EU labelling - B
Heat pump water heater - EU labelling - A
Hot water storage tank - EU labelling - C
Hot water storage tank - EU labelling - B
Hot water storage tank - EU labelling - A

### Technology

Radiators - EU labelling - A
Radiators - EU labelling - A+
Radiators - EU labelling - A++
Electric heat pump - EU labelling - A
Electric heat pump - EU labelling - A+
Electric heat pump - EU labelling - A++
Gas heat pump - EU labelling - A
Gas heat pump - EU labelling - A+
Gas heat pump - EU labelling - A++
Fully-automated biomass boiler
Semi-automated biomass boiler
Pellet-fired boiler
Biomass-fired boiler
Solar thermal space heating system
Wood stoves/furnaces
Pellet stoves
Masonry heaters
Electric resistance heaters
CHP (reciprocating engine)
CHP (gas turbines and micro-turbines)
CHP (fuel cells)

Loft insulation (200 to 300 mm)
Loft insulation (100 to 200mm)
Floor insulation
Double glazing windows
Triple glazed windows
Solid wall insulation
Air sealing
Reflective walls/roofs
Low-E windows
Windows (double low-e glazed, low-conductive frames)
Energy-plus windows in cold climates (highly insulating and dynamic solar)
Window attachments (automatic solar control, e.g. exterior solar shades and blinds)
Window attachments (highly insulating, e.g. cellular shades, low-e films)

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