

IRENA REMAP 2030

Doubling the Global Share of Renewable Energy A Roadmap to 2030

WORKING PAPER

Acknowledgement

This report was prepared by the IRENA Secretariat. The report benefitted from the presentations, active participation and feedback given by a wide range of stakeholders who contributed to the process to date. These stakeholders include both IRENA Members (Australia, Denmark, Ethiopia, France, Germany, Grenada, Iraq, Italy, Japan, Kenya, Malaysia, Nigeria, Saudi Arabia, South Africa, Sweden, Tonga, United Arab Emirates, and the United States of America) and SE4ALL partners.

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This introductory report provides information on the development of IRENA's global Renewable Energy Roadmap (REMAP 2030), which is being developed in response to requests from IRENA's Members and in support of the UN Secretary-General's *Sustainable Energy for All* (SE4ALL) Initiative.

REMAP 2030 aims to identify realistic pathways to double the share of renewable energy in the global energy mix by 2030, thereby achieving the SE4ALL's third aspirational target.

This report is sub-divided into three sections:

1. Chapters 1 and 2 provide information on the SE4ALL context and the proposed Roadmap process.
2. Chapters 3, 4 and 5 discuss progress made to date in the Roadmap process, including initial recommendations for areas of action.
3. Chapter 6 discusses how IRENA Members and other stakeholders can get involved in the Roadmap process.

Members are invited to provide comments and feedback on this report, which outlines the point of departure for the development of REMAP2030.

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Executive Summary

IRENA's global Roadmap will show how to double the share of renewables by 2030.

In the context of the 2012 “*International Year for Sustainable Energy for All*” (SE4ALL), the United Nations Secretary-General has launched the SE4ALL initiative. The aim of this initiative is to achieve three global interlinked energy policy objectives by 2030: 1) ensuring universal access to modern energy services; 2) doubling the global rate of improvement in energy efficiency; and 3) doubling the share of renewable energy (RE) in the global energy mix.

In 2012, IRENA was requested by its Members to explore pathways towards the achievement of this aspirational RE target. In response, the Agency has designed a transparent, inclusive and open process to develop a global Renewable Energy Roadmap (REMAP 2030). It is envisaged that REMAP 2030, to be annually updated, will be a valuable tool to support Members' renewable energy planning and international cooperation activities. It will also serve as a global compass to coordinate and synthesise RE activities within the context of the SE4ALL initiative.

Country and stakeholder engagement will be crucial to create this innovative global Roadmap.

REMAP 2030 is designed as an iterative three-step process, built around and reliant upon full Member engagement. The three steps are: a *feasibility study* to explore the level of challenge associated with the SE4ALL renewable energy objective; a *gap analysis* to assess the gap between national renewable energy plans and 2030 projections and the SE4ALL target; and a number of *sectoral-regional analyses* to identify, evaluate, and prioritise region-specific and interregional sectoral actions.

In 2012, IRENA conducted preliminary studies to determine initial results for each of these three steps. In 2013, IRENA will rely upon close cooperation with Members throughout the process to identify realistic pathways to double the RE share by 2030, encouraging the nomination of national experts to contribute actively to the Roadmap process.

A doubling of the renewables share is achievable but will require action in all regions.

Feasibility study:

The three primary aims of this study, based on an extension of existing energy demand projections for 2030, were: 1) to explore the level of challenge of the SE4ALL objectives compared to existing scenarios for 2030; 2) to evaluate regional implications associated with a global doubling of the renewables share; and 3) to assess the interaction between the renewables objectives and the other two SE4ALL objectives of energy efficiency improvements and universal access to modern energy services. The initial results, shared with IRENA Members and other key stakeholders in two REMAP workshops in September and November 2012, suggest that, whilst considering both the universal access and energy efficiency objectives, there is still a nine percentage point gap between existing renewable energy plans and a 30% target, or a 15% gap if a doubling of the renewable energy share is to be achieved. Substantial increases in both renewable energy power generation and renewable end-use applications are required to fill this gap, and need to be implemented across the world. All sectors and regions will need to increase and join efforts to achieve the SE4ALL objective.

A global assessment of countries' RE plans is needed to evaluate the gap.

Gap analysis:

The second step of the REMAP process calls for an assessment of the disparity between the third SE4ALL target and existing national RE plans and projections. Some data on these plans are available from the existing literature, but they lack consistency and uniformity. To initiate this data collection process, IRENA invited the largest economies in each region to provide data on their national RE plans and projections. This pilot project provided valuable insights into the regional differences between RE targets and national concerns affecting them and laid the foundation for a global gap analysis.

In 2013, all countries are invited to provide their overall energy supply and demand projections until 2030, emphasising renewable energy policies and targets in place and under consideration. The data will include an energy balance sheet and a list of key technology options, including their expected contributions by 2030. This information will help to validate and improve the estimates from the existing literature and will provide a useful resource for countries developing, reviewing or updating their own RE plans.

The preliminary sectoral analysis shows that the SE4ALL RE target could be met and even surpassed.

Sectoral-Regional Analysis:

The third and final analytical step of the REMAP process will focus on prioritising RE technology options to fill the gap between the pathways to achieving the SE4ALL objectives and the national RE plans and projections. Preliminary conclusions are that – at the global level – about half of the renewable energy potential to fill the gap is in the power sector, and the other half in the end-use sectors buildings, transport and industry. Our global analysis suggests that full implementation of the technology options identified between now and 2030 would, depending on global energy demand, be able to achieve and even surpass the SE4ALL target for renewables.

Technology options are available but require prioritisation at a regional and sectoral level.

An assessment of technology options need to take place at a regional level in order to identify priority action items in the sectors relevant to the different regions. The potential of both renewable power generation and renewables applications in the end-use sectors differ largely across regions, and even across countries. Regional prioritisation requires consideration of a large number of specific regional conditions, including economic and social issues, and collaboration with national RE experts is crucial for this prioritisation process.

At a global level, IRENA's preliminary sectoral approach has identified the following initial action areas:

Biomass accounts for almost 80% of all renewable energy consumption today, and will continue to play a crucial role.

- Currently, biomass accounts for almost 80% of all renewable energy consumption. Increasing the efficiency and sustainability of traditional uses of biomass will free up biomass resources to be used sustainably in other ways. Simultaneously, this will reduce the overall share of renewables in the energy mix. Since the role of biomass will continue to grow as biomass-based renewable applications in end-use sectors (e.g. transport, buildings and industry) are expanded, all regions should examine biomass' potential role and costs more carefully.

New grid solutions will be required to double RE shares in power generation.

- The share of renewables in the electricity sector will have to double to achieve the SE4ALL objective. Furthermore, an increased share of renewables in the electricity sector will also create opportunities to bring renewables into end-use sectors as industrial processes and transport are electrified, and a growing number of households worldwide are using electrical appliances in their households. Transforming the electricity sector will require upgrades and modernised extensions of old grid systems and, at the same time, will provide opportunities for new innovative solutions to be implemented (e.g. energy storage systems, smart grids, monitoring of energy flows and harmonised regulation).

Nearly a third of the global renewables potential lies in heat applications in end-use sectors.

- Acceleration of renewable heat applications in the buildings and industry sector is essential. Heat demand in these two end-use sectors accounts for almost one-third of global energy use. Significant potential exists in cement, iron and steel making, and in the petro-chemical industry as well as in non-energy uses where ongoing efforts to implement renewables solutions are lagging behind for different reasons. There is also a large potential for renewables for heating and cooling in buildings where a host of RE technologies (e.g. solar water heating, biogas and geo-, aero- and aqua-thermal heat pumps) can provide affordable and reliable heat. It will be crucial to tap all the renewable heat options to achieve the SE4ALL target.

A long-term vision and timely implementation will be imperative to achieve the SE4ALL objectives.

Results from these three initial action areas show that a long-term vision and timely implementation will be imperative to achieve the SE4ALL objectives. Prospects and costs are still uncertain for a number of RE technologies as they depend on global fossil fuel trends, RE technological developments and their rate of uptake. Timely action can avoid a lock in of non-renewable options and create a longer-term competitive advantage, although the early phase-out of existing capital stock requires brave forward-looking decisions and visionary investment policies. Some promising output examples include: high-speed trains, interregional electricity or biomass trade, district heating and cooling systems, sun-oriented roof surfaces and industrial commodity production facilities located near suitable renewable resources.

Energy decisions made today will largely determine the energy mix in 2030.

Global engagement in REMAP 2030 is urgent precisely at this point in time because the long lead time between capital stock build-up and its impact on the energy system means that energy decisions made today will largely determine the energy mix in 2030.

IRENA invites all Members and other stakeholders to actively participate in REMAP 2030.

REMAP 2030 can succeed if—and only if—it is fully owned, developed and refined by Members with the support of IRENA. Therefore, it is crucial that countries become engaged in creating this global Roadmap, learning from each other's experiences, using opportunities in their national systems to connect with technology developments across the globe, engaging in regional initiatives and improving national renewable energy plans through dialogue involving national RE experts. Together, this Roadmap and its associated process provide a forum for such a global dialogue.

In 2013, IRENA will continue to facilitate the Roadmap process upon which it has embarked by developing and expanding the tools to evaluate the level of challenge, to assess the gap between the SE4ALL target and national renewable energy plans, and to prioritise the sectoral action items to achieve the third SE4ALL objective: doubling the share of renewable energy in the global energy mix by 2030.

1. The SE4ALL Initiative and REMAP 2030

1.1 SE4ALL: The UN Secretary-General's "Sustainable Energy for All" Initiative

The General Assembly of the United Nations, in its Resolution 65/151¹ adopted on 20 December 2010, declared 2012 the International Year of Sustainable Energy for All (SE4ALL), "*Concerned that over three billion people in developing countries rely on traditional biomass for cooking and heating, that one and a half billion people are without electricity and that, even when energy services are available, millions of poor people are unable to pay for them.*"

In the same resolution, the UN General Assembly reaffirmed its "*support for the implementation of national policies and strategies to combine, as appropriate, the increased use of new and renewable energy sources and low-emission technologies, the more efficient use of energy, greater reliance on advanced energy technologies, including cleaner fossil fuel technologies, and the sustainable use of traditional energy resources, as well as the promotion of access to modern, reliable, affordable and sustainable energy services ...*" and requested "*the Secretary-General, in consultation with relevant agencies within the United Nations system and UN-Energy... to organize and coordinate activities to be undertaken during the Year*".

In support of this resolution, the UN Secretary-General Ban Ki-moon launched the SE4ALL Initiative² in November 2011. The aim of the initiative is to achieve three global interlinked energy policy objectives by 2030:

1. Ensuring universal access to modern energy services;
2. Doubling the global rate of improvement in energy efficiency; and
3. Doubling the share of renewable energy in the global energy mix.

To guide the initiative and decide how to achieve the global objectives, the UN Secretary-General established the SE4ALL High-Level Group, including representatives from private and public sectors, civil society and international organisations. The IRENA Director-General, Adnan Z. Amin, was invited to join the SE4ALL High-Level Group.

The SE4ALL initiative involved a number of public and private organisations at both national and international levels as members of either the High-Level Group³, the Technical Group⁴ or as Partners⁵. Involved organisations included most of the international institutions active in the energy field, such as the International Energy Agency

¹ www.un.org/ga/search/view_doc.asp?symbol=A/RES/65/151.

² www.un.org/wcm/webdav/site/sustainableenergyforall/shared/Documents/SG_Sustainable_Energy_for_All_vision_final_clean.pdf.

³ High-Level Group Members: (*Governmental organisations*) Dept. of Energy, United States; European Commission; Ministry of Energy, Brazil; Ministry of Renewable Energy, India; Russian Energy Agency; (*International organisations*) IRENA; International Union for Conservation of Nature; New Partnership for Africa's Development; Organisation of the Petroleum Exporting Countries (OPEC); Principles for Responsible Investment; UN Global Compact; UN Development Programme (UNDP); UN Industrial Development Organisation (UNIDO); UN Environment Programme (UNEP); UN Foundation; World Business Council for Sustainable Development; (*Banks*) Bank of America; Brazilian Development Bank; China Development Bank; National Bank of Public Works and Services, SNC (Banobras); the World Bank; (*Private companies*) Accenture; Bloomberg New Energy Finance; Dangote Group; Duke Energy; Eletrobras; Eskom; Masdar; Renault-Nissan Alliance; Riverstone Holdings; Siemens; Statoil; Suntech Power Holdings; Vestas Wind Systems.

⁴ Technical Group Members: Agency for Development Cooperation, Norway; Caribbean Community Climate Change Center; Energy Commission of Ghana; Uruguay representative; Energy and Resources Institute; Global Green Growth Institute; IEA, IIASA; Columbia University; University of California, Berkeley; Deutsche Bank; the World Bank.

⁵ Partners: African Development Bank, Alliance for Rural Electrification, Energy for All, FAO, Inter-American Development Bank, Practical Action, REEEP, REN21, UN Energy, UN Foundation, Zayed Future Energy Prize.

(IEA), the International Institute for Applied Systems Analysis (IIASA), The Energy and Resources Institute (TERI), the Global Green Growth Institute (GGGI), the Renewable Energy Policy Network for the 21st Century (REN21), the United Nations Environment Programme (UNEP), the United Nations Development Programme (UNDP) and the World Bank.

SE4ALL Guiding Documents

The SE4ALL High-Level Group has produced two guiding documents: *A Framework for Action* (January 2012)⁶ and *A Global Action Agenda* (April 2012)⁷, the latter presented at the third Clean Energy Ministerial (CEM3) on 25–26 April 2012 in London.

The *Framework for Action* called for commitments from the public and private sector and civil society to achieve the three SE4ALL objectives and provided “a first step toward new partnerships between public and private stakeholders to exploit the opportunities offered by the steadily falling costs of renewable technologies, the investment in more sustainable and efficient energy systems in developed countries, and the new investment in energy infrastructure in emerging and developing economies”. In support of this report, the SE4ALL Technical Group also produced two technical documents: one technical report on the first SE4ALL objective of universal access to modern energy services and another on the second and third SE4ALL objectives of doubling the rate of energy efficiency growth and doubling the renewable energy (RE) share in the global energy mix.

The *Global Action Agenda* identified “major Action Areas in which public and private stakeholders can mobilize commitments to concrete actions, and lead the sustainable growth, develop new businesses and jobs, help eradicate energy poverty and increase global prosperity”. The *Global Action Agenda* identifies seven “sectoral” areas: modern cooking appliances and fuels; distributed electricity solutions; grid infrastructure and supply efficiency; large-scale renewable power; industrial and agricultural processes; transportation; and buildings and appliances; as well as four “enabling” areas: energy planning and policies; business model and technology innovation; finance and risk management; and capacity building and knowledge sharing.

A further document, the *Global Tracking Report*, is currently being prepared to define methods to track progress, create a basis for periodic tracking and provide an overview of the current status with respect to the three SE4ALL objectives. The lead agencies for this report are the International Energy Agency (IEA) and the World Bank. For the renewable energy objective, IRENA is working together with the IEA, the Renewable Energy Policy Network for the 21st Century (REN21), the United Nations Environment Programme (UNEP) and the World Bank to establish the SE4ALL **baseline** (i.e. current status and reference databases) and appropriate **indicators** to measure progress toward the SE4ALL targets. The *Global Tracking Report* is expected to be published in the first quarter of 2013.

Recent Developments of the SE4ALL Initiative

Following the great interest generated by the SE4ALL initiative, a new phase was introduced in September 2012 to better coordinate efforts. An enlarged Advisory Board, co-chaired by the UN Secretary-General and the President of the World Bank, Dr. Jim Yong Kim, will provide strategic guidance to the initiative. An Executive Committee, chaired by the Chairman of the Bank of America Mr. Charles Holliday, will guide the implementation process. A Special Representative for Sustainable Energy for All, who was appointed by the UN Secretary-General in the person of Dr. Kandeh Yumkella, will be the Chief Executive Officer of the SE4ALL Secretariat with responsibility to support and coordinate efforts among the many partners engaged in SE4ALL-relevant initiatives. Finally, separate hubs to support each of the three SE4ALL objectives are being considered as part

⁶ www.un.org/wcm/webdav/site/sustainableenergyforall/shared/Documents/SE%20for%20All%20-%20Framework%20for%20Action%20FINAL.pdf

⁷ www.un.org/wcm/webdav/site/sustainableenergyforall/shared/Documents/SEFA-Action%20Agenda-Final.pdf

of the SE4ALL Secretariat. As a key participant in this process, IRENA will continue to play an active role as the renewables hub in SE4ALL, consistent with its mandate to act as the focal point/global hub for renewable energy cooperation.

1.2 REMAP 2030: A Roadmap to Double the Renewable Energy Share by 2030

As part of its 2012 Work Programme and in the context of the SE4ALL initiative, IRENA has initiated the development of a “Roadmap” that examines the elements necessary to achieve the SE4ALL renewable energy objective while taking into consideration the interconnections between this objective and the other two SE4ALL objectives on improved energy efficiency and universal access to modern energy services.

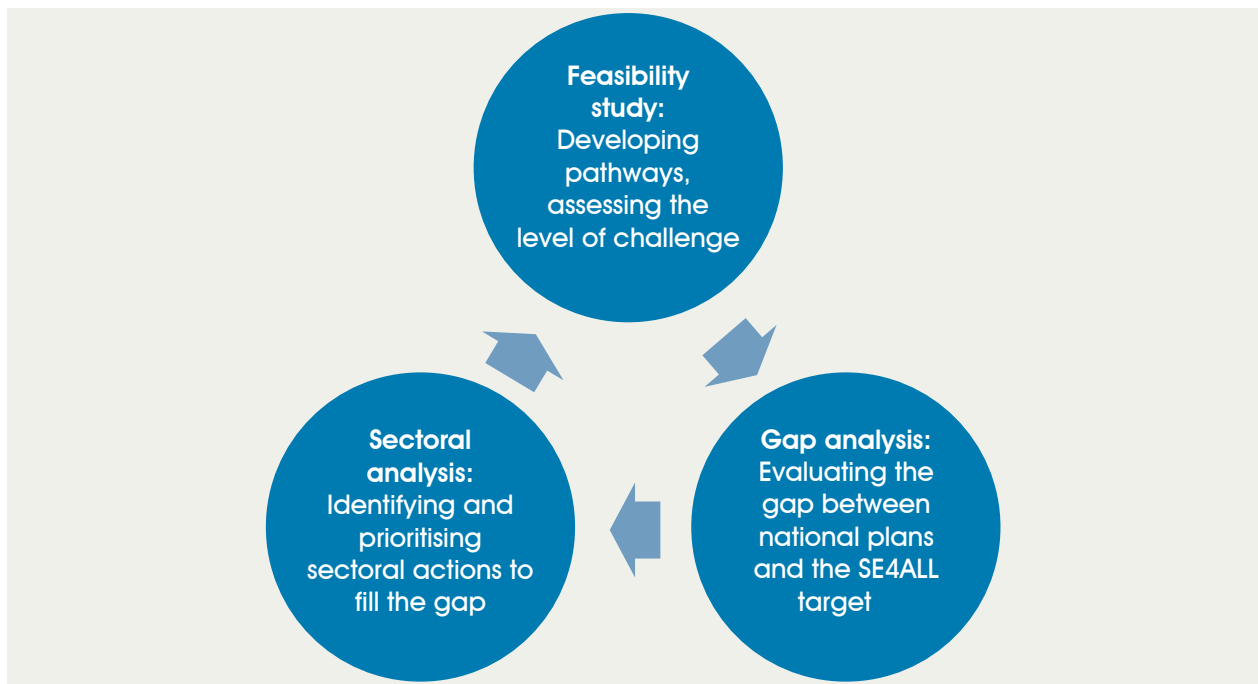
At the third IRENA Council (Abu Dhabi, June 2012), Council members endorsed the SE4ALL objective of *doubling the share of renewable energy in the global energy mix* as an aspirational target for the IRENA Roadmap activities and the Agency’s effort to develop a Roadmap to *identify, characterise and implement viable pathways* to achieve this objective.

In IRENA’s 2013 Work Programme, it is envisaged that REMAP 2030 will continue to:

- Explore how an accelerated deployment of renewable technologies in different energy sectors (e.g. power generation, transport, industry, buildings) and world regions can contribute to meeting the global SE4ALL renewables target; and
- Analyse the implications of different pathways at the regional and national level and the economic impact of the transition to a more renewables-based energy system.

In order to identify realistic pathways to doubling the share of renewable energy by 2030, IRENA plans to carry out this effort in close cooperation with its Members by involving volunteer countries to provide data on their national energy projections and plans for renewable energy (RE) deployment, as well as to nominate experts to contribute actively to the Roadmap process.

At the successful completion of this process, REMAP 2030 will identify priority action areas to accelerate RE uptake in different regions and sectors in order to achieve the SE4ALL renewables target. By periodically updating them to incorporate new developments and achievements, these action areas should serve as a guide for IRENA’s programmatic activities, as well as a global compass to coordinate, guide and synthesise RE activities within the overall SE4ALL initiative.

Figure 1 - The Proposed REMAP 2030 Process

The proposed IRENA Roadmap process consists of three iterative steps (Figure 1):

1. A *feasibility study* of the SE4ALL renewable energy objective to assess the level of challenge presented by this target and to explore possible pathways to address it at both the global and regional level;
2. A *gap analysis* based on Members' contributions (i.e. current national plans for renewable energy deployment) to assess the quantitative gap between regional/national energy strategies and the SE4ALL target; and
3. A *sectoral/regional analysis* to identify and prioritise region-specific and interregional key sectoral action items to fill the gap between the current situation and the SE4ALL renewables target.

The individual steps of the Roadmap process are described in more detail in the following sections, and preliminary results are presented in Chapter 3, 4 and 5 of this report.

The overall approach was presented and discussed with Members at two workshops: one convened in Malta on 5 September 2012 and the other in Abu Dhabi on 14 November 2012 (as a side event of the fourth IRENA Council meeting). After the first workshop in Malta, the growing interest of Members in REMAP 2030 led to the convening of the second workshop. While only five Members attended the first workshop, some 28 countries registered for the second workshop, of which 16 were actually in attendance while six others were briefed individually during the IRENA Council meeting preceding that workshop.

In both workshops, IRENA encouraged a direct, active involvement of countries in the REMAP process with the aim of making the Roadmap a valuable, shared tool for countries' energy policies rather than just an Agency exercise.

As a result, a number of Members agreed to nominate national experts to contribute the Roadmap process. While IRENA focal points remain the primary conduit for communication, national experts will serve as an additional bridge to further engage regional and national stakeholders.

In addition to country input into the Roadmap, several ongoing IRENA activities are expected to flow into the REMAP 2030 process as key components. Simultaneously, the Roadmap will become an agency-wide framework within which more detailed studies at a global, regional or national level can be carried out.

2. The REMAP Process: A Collaborative Effort

2.1 Feasibility Study: Developing Pathways and Assessing the Level of Challenge

The aim of the feasibility study is to assess the level of challenge and regional implications associated with doubling the RE share in the global energy mix by 2030, as well as to investigate the interaction between the RE target and the other two SE4ALL objectives (i.e. universal access to modern energy services, doubling the energy efficiency improvement rate). The results of this assessment are used as first estimate benchmark pathways to double the RE share in the global energy mix by 2030.

In 2012, IRENA developed two alternate pathways: one predominantly features renewable power generation options to achieve the SE4ALL target; the other predominantly features renewables options in the end-use sectors of transport, buildings and industry. The starting point for the development of these pathways is the New Policies Scenario (NPS) produced by the International Energy Agency (IEA) and described in the World Energy Outlook 2012. Subsequently, IRENA extended the IEA NPS to achieve universal access to modern energy services and energy efficiency improvements in line with the first two SE4ALL objectives. This extended version of the IEA NPS, called Access and Efficiency Scenario, became the basis for developing pathways to achieve the third SE4ALL objective for renewables.

The two pathways have been verified by comparing them to other global, regional and national studies. The results are not prescriptive; rather they serve as first estimate benchmarks to compare regional opportunities to global actions required to achieve all three SE4ALL objectives. Design and preliminary results of the feasibility study (presented in Chapter 3) have been shared with country experts during the REMAP workshops and with other organisations involved in the SE4ALL initiative.

In preparation for the feasibility study and the Roadmap process, IRENA carried out a number of additional activities to:

- Review the most appropriate indicators to measure the renewables share, track progress toward the third SE4All target and to establish a reference baseline (i.e. this review has been carried out to support the SE4ALL *Global Tracking Report*);
- Review the current renewables share in the global energy mix;
- Analyse the traditional biomass role, which is mostly used in developing countries to meet heating and cooking energy services and accounts for more than half of the current renewable share in the global energy mix; and
- Analyse major energy projections and scenarios to the year 2030.

In 2013, IRENA will repeat this feasibility study using the latest data on RE activities, as well as the data gathered in Steps 2 and 3 of the REMAP process.

2.2 Gap Analysis: Involving Members to Assess the Gap

The second step in the proposed REMAP 2030 process is the gap analysis aimed at assessing the gap between current energy projections and plans for RE deployment at the regional and national level, and the benchmark pathways developed in Step 1 of the REMAP process. The gap analysis will not only provide an accurate assessment of the challenge ahead but will also become a valuable resource for countries interested

in developing, reviewing or updating their national RE plans. Data needs and availability were discussed in the two REMAP workshops in September and November 2012.

In 2013, IRENA will approach its Members and other countries for energy demand projections and RE plans. If available, IRENA will also collect data from studies to assess the economic implications (e.g. investment, GDP impact, economic development and employment) of the shift toward more renewables-based energy systems, at both the regional and national level.

The collection of national data and information for the gap analysis presents an initial opportunity for Members to actively contribute the REMAP process.

2.3 Sectoral-Regional Analysis: Identifying Sectoral Action Items for Different World Regions

The third step of the REMAP process is a sectoral-regional analysis - carried out in collaboration with national renewable energy experts - to identify, evaluate and prioritise sectoral *action items* for implementation in different regions to fill the gap between the current trends and the global SE4ALL targets.

In 2012, IRENA conducted a preliminary assessment of sectoral RE technology options at a global level, considering both the size of the potential and the level of experience associated with each of these options (see Chapter 5). For 2013, IRENA aims to develop a methodology that will support the prioritisation of sectoral action items within each specific regional context. Based on inputs from REMAP workshop participants, a tentative list of possible criteria for prioritisation is provided below:

- Availability of natural resources;
- Availability and deployment of cost-effective renewable technologies;
- National productive capacity for renewable technologies;
- Impact of possible breakthroughs in energy technology;
- Impact on universal access to modern energy and energy efficiency;
- Need for investment and project financing;
- Economic effects of the transition to renewables (e.g. impact on GDP and employment);
- Impact on the international trading of energy commodities and technologies;
- Benefits for energy security;
- Benefits in terms of environmental impact and climate change; and
- Governmental policies to implement the action items.

Appreciative of the considerable effort it will take to analyse all these topics, IRENA is planning a step-by-step approach based on available resources and relying on Members' guidance and active contributions, as proposed in section 2.4. The analysis will progress as follows:

- First, the gaps between current energy projections and the SE4ALL global renewable target will be identified based on the regional aggregations used in major energy statistics and projection studies, as well as the outcomes of the previous gap analyses for each world region.
- The analysis of regional sectors level will then produce a list of sectoral opportunities (i.e. "action items") to increase the use of renewable energy and technologies and thus fill the gap.
- Then these action items will be characterised and prioritised in terms of their potential contribution to filling this gap and their investment costs and needs. In this phase, the action items will also be checked against selected benchmarks (e.g. availability of natural resources and cost-effective

technologies, impact on the other two SE4ALL objectives, benefits in terms of environmental impact and climate change).

- Subsequently, priority action items will be analysed to explore topics (e.g. their economic implications for international energy and technology trading, the impact on GDP and employment and the benefits for energy security), which all deserve specific analysis and tools.

This sectoral-regional approach offers a number of advantages as it:

- Facilitates the tailoring of sectoral action items to the respective regional energy systems, resources and attributes;
- Allows for cross-cutting regional/sectoral recommendations (neither exclusive nor prescriptive, without allocation of specific country targets) that are generally applicable to countries with similar energy systems;
- Permits the engagement of a wide range of stakeholders, including the private sector and civil society through the vehicle of dedicated sectoral workshops;
- Provides insights into potential RE applications that would not be evident from the global and national perspectives alone;
- Complements and elaborates the sectoral action areas as defined in the Action Agenda of the SE4ALL High-Level Group;
- Meets the criteria for current data aggregation in major energy statistics and projections, thus allowing for easy data mining and comparisons; and
- Paves the way to future disaggregation at the national level in response to country demand.

2.4 Involvement of Members

The REMAP Roadmap process is designed to encourage active participation and country input during each phase of its development.

The *feasibility study*, which provides a first estimate benchmark of the possible regional activities required to achieve the global SE4ALL renewables objective (i.e. the third objective), is based on a straightforward extension of existing scenarios. No new models have been deployed. Consequently, the results of the feasibility study can easily be shared with Members and other stakeholders, updated and checked for consistency and rigor against other global and regional roadmap activities.

The second step, the *gap analysis*, is also based on country inputs. Members are invited to nominate a national representative to collect data on national energy plans for renewable deployments, as well as national energy projections (if any) to the year 2030, using a form prepared by IRENA. It should be noted that these data are not available in the current energy statistics. Some organisations, such as REN21, are already collecting such data based on national policy plans, but they are difficult to compare and aggregate without further information regarding the energy projections underlying some of them.

Third, for the *sectoral-regional analysis* of action items, IRENA aims for an active, in-kind contribution from Members. For each region, IRENA looks forward to one or more volunteer Members nominating national experts

(e.g. typically senior energy analysts) from relevant national organisations, who would assume responsibility, in close cooperation with IRENA staff, for the national and regional contributions to the analysis, including:

- Collecting regional data;
- Analysing energy sectors, together with IRENA staff;
- Identifying and characterising possible sectoral action items;
- Participating in workshops;
- Contributing to joint working sessions; and
- Coordinating relevant national and regional activities.

IRENA aims to build a team of 10-15 senior energy analysts with global reach who are ready to work in close cooperation with IRENA staff to develop the Roadmap according to a work programme to be proposed by IRENA, jointly discussed and agreed upon.

To cover all the world's regions, IRENA is prepared to extend assistance to those regions and countries that would otherwise not be in a position to participate in this initiative or are currently not IRENA Members or Signatories.

3. Progress Results: Feasibility Study for REMAP 2030

As mentioned previously, in preparation for this Roadmap process, IRENA carried out a feasibility study of the third SE4ALL objective to double the share of renewable energy in the global energy mix by 2030, as well as a number of activities to:

- Establish a reference baseline and database and to analyse statistical issues;
- Review the most appropriate indicators to measure the renewables share, track progress toward the target and evaluate the current renewables share in the global energy mix;
- Analyse the role of traditional uses of biomass; and
- Analyse major energy projections and scenarios to the year 2030.

Sections 3.1 and 3.2 discuss the methodological background, statistical challenges and available indicators to measure the share of renewables in the global energy mix. Section 3.3 discusses the role of traditional biomass and how universal access to modern energy services will impact the achievement of the SE4ALL objectives for renewables. Section 3.4 compares current major global and regional scenarios to the year 2030. Finally, Section 3.5 provides preliminary results of IRENA's feasibility study, including:

- The impact of universal access to modern energy services and the doubling of the energy efficiency growth rate on the third SE4ALL renewable energy target;
- Technology pathways to double the renewable energy share by 2030; and
- Key factors that warrant policy makers' attention.

3.1 Baseline, Reference Database and Statistical Issues

There are only a limited number of primary data sources for global energy use. The IEA database contains comprehensive and accurate data for OECD countries and also covers about 75 non-OECD countries. However, the quality of these data varies from country to country. Data from smaller developing countries are not individually reported in IEA statistics and are based on extrapolations of country data provided by the UN Statistics Division. The UN database contains data for almost all countries but is more heterogeneous than the IEA database. Finally, WHO collects primary data on energy use but mainly at the household level.

Given the need to develop a comprehensive and comparable analysis at a global level, the IEA energy statistics are used as the starting point for this feasibility study in line with the recommendations of the SE4ALL *Global Tracking Report*. The latest available data (2010) are used as a baseline, thus providing a 20-year period to achieve the three SE4ALL goals.

However, there are a number of areas of statistical concern that may have a growing impact on tracking the renewable share over time. Current statistics do not accurately reflect or capture the impact of:

- Traditional biomass;
- Small, distributed, grid-connected power generation (e.g. small-scale PV or wind);
- Off-grid and mini-grid power generation;
- Direct production of solar heat (e.g. solar water heaters, solar dryers);
- Differences between renewable (biogenic), waste-based fuels and other waste resources;
- The reduction of transmission and distribution losses due to distributed electricity production;
- The renewable ambient heat that heat pumps capture/transfer using small amounts of electricity; and
- Interregional integration of electricity or biomass trade.

Of these statistical challenges, the statistical conventions for distinguishing between the use of “modern” and “traditional” biomass is particularly difficult. For example, in the IEA scenarios, the bioenergy used in residential applications in OECD countries is accounted for as modern biomass, while the same biomass applications used in non-OECD countries are accounted for as traditional biomass. Obviously, this is an over-simplification because, even in OECD countries, there is an informal use of wood fuels in low-efficiency appliances, which is very difficult to measure with any degree of precision. The draft *Global Tracking Report* suggests that improving energy statistics to distinguish between traditional and modern use of biomass could take significant time and effort. This has important implications for the Roadmap.

Some of these issues will be addressed by ongoing IRENA efforts and analyses (e.g. IRENA’s scenarios and strategies). In its 2013 Work Programme, IRENA included a number of activities to address some of these statistical challenges. On biomass, IRENA will contribute to a global effort to assess the availability and costs of biomass resources. Furthermore, building on its role in the SE4ALL *Global Tracking Report*, IRENA proposed a number of detailed consultations with relevant institutions to identify potential improvements in data collection and measurement of the use of biomass and distributed renewable generation. These consultations will generate a set of recommendations to improve existing methods to measure the share of renewable energy more accurately and to support REMAP 2030 activities.

3.2 Indicators for Measuring the Renewable Energy Share

The selection of appropriate indicators to measure the renewable energy share in the global energy mix and progress toward the SE4ALL target is the first step to develop the Roadmap.

The RE share in the global energy mix can be measured with respect to the Total Primary Energy Demand (TPED) or to the Total Final Energy Consumption (TFEC):

- TPED refers to primary energy (i.e. the form of energy that first appears in the energy balance, before conversion processes and related losses); e.g. crude oil, coal, natural gas, biomass;
- TFEC refers to secondary energy (i.e. the form of energy after the conversion processes and related losses; the form in which energy is made available for final consumption); e.g. electricity, heat, biofuels, gasoline and diesel, but also coal, natural gas and biomass if they are used for heating or other direct uses.

Since most renewable energy sources (e.g. solar, wind and hydroelectricity, solar heat, biofuels) are available as secondary energy, it is clear that measuring the RE share in the TPED tends to underestimate today’s role of renewables in the energy mix because the RE contribution to TPED has to be converted into primary energy equivalents⁸ using a conventional efficiency. Therefore, the RE share in the TPED is highly dependent on the

⁸ Actually, different organisations use different methods to estimate the RE share in the TPED:

- In the *Physical Energy Content* method used by the IEA and EUROSTAT, renewable electricity (e.g. wind, PV and hydro power) and biofuels are counted in TPED as they appear in the form of secondary energy (i.e. using a 100% efficiency to convert them into primary energy equivalents) while geothermal, CSP electricity and nuclear electricity are counted using average process efficiencies (e.g. 10-33%) to convert them into primary energy equivalents;
- In the *Direct Equivalent* method used by the IPCC, all non-combustible energy sources (e.g. renewables, nuclear) are converted into primary energy equivalents as they appear in the TFEC (i.e. using a 100% efficiency to convert them into primary energy equivalents); and
- In the *Substitution* method used by the US Energy Information Administration (EIA), renewable electricity and heat are converted into primary energy using the average efficiency of fossil fuel power plants.

accounting method used to convert renewable commodities into primary energy equivalents. An accounting method using high efficiency to convert renewables into primary energy will reduce the RE share in TPED.

As a consequence, the RE share in TFEC is more suited to represent the role of renewables in providing final energy services, as compared with fossil energy sources. The use of this indicator is recommended in the *Framework for Action* and in the draft *Global Tracking Report*. However, if the RE share in TFEC is used as an indicator, the contribution of individual renewable technologies to the total renewable electricity and heat production has to be allocated to each technology based on production proportions. Since decentralised renewable power generation has lower load losses than centralised, mostly fossil fuel-based power generation, the proportional allocation of energy losses to all energy sources penalises the share of renewables somewhat.

It should also be noted that, according to energy statistics definitions, the TFEC differs from the Total Final Consumption (TFC)⁹ in that it excludes non-energy uses of fossil fuels or biomass as a feedstock to industry, notably to the chemical industry for plastics or bio-plastics production. Therefore, if the RE share in TFEC is used as an indicator, the role of biomass for non-energy use is not taken into account. Whether this can penalise the RE share depends on the relative role that fossil fuels and biomass feedstock will play in the chemical industry.

The impact of using different indicators to estimate current and 2030 renewable energy share in the global energy mix is given in Table 1, where indicators apply to the IEA 2010 energy balances and the IEA NPS as described in the IEA World Energy Outlook 2012¹⁰.

Table 1 - Share of Renewable Energy in the Global Energy Mix using Different Indicators (Based on IEA WEO 2012)

Indicators	IEA Balance 2010		IEA NPS 2030	
	%	EJ	%	EJ
RE share in TPED - substitution	~17	91	~22	154
RE share in TPED - phys en. cont.	~13	69	~17	116
RE share in TPED dir. equivalent	~13	68	~17	113
RE share in TFEC	~18	60	~21	92
RE share in TFC	~17	60	~20	92

Based on the 2010 IEA Energy Balances and depending on the specific indicators used, doubling the 2010 renewable energy share would result in a 2030 renewables percentage ranging between 26-36%. Considering that the High-Level Group mentioned in its *Framework for Action* a target of around 30% by 2030 and the TFEC methodology proposed by the *Global Tracking Report* would result in a 2030 target of 36%, REMAP 2030 will explore pathways to reach a 2030 renewables share between 30-36%.

Furthermore, to explore the implications of doubling the RE share at both primary and final energy levels, IRENA proposed to use in its Roadmap both the RE share in TPED (substitution method) and the RE share in TFEC.

⁹ It should be noted that neither TFC nor TEFC represents so-called *useful energy*—that is, the energy actually used for final energy services, such as the net energy used to move a car or for space heating, after the energy losses associated with the end-use device (e.g. car or boiler). Useful energy is indeed difficult to measure and is not considered in energy statistics.

¹⁰ The IEA New Policies Scenario takes into account energy policies and measures, and technology deployment either in place, ongoing or planned worldwide to mitigate energy-related emissions and climate change.

Wherever appropriate, IRENA will also use the RE share in TFC to show the opportunities for biomass to replace fossil fuels as a feedstock for chemical products.

Further indicators are under consideration to track the evolution of the RE market in terms of policy targets, technology costs, investment, economic implications and regional diversity.

3.3 The Role of Traditional Biomass

According to the IEA energy statistics, renewable energy currently accounts for about 17% of the world total primary energy demand (TPED, substitution method), including almost 14% biomass and 3% other renewable energy sources. However, almost 70% of this biomass consists of *traditional uses of biomass* (e.g. animal manure, woody biomass, charcoal) as a fuel for inefficient open fires and stoves for cooking and heating purposes (Figure 2a). This figure is a result of the IEA approach, which assumes that all biomass in residential applications in non-OECD countries is “traditional biomass”, as discussed in Section 3.1. Different approaches lead to different figures: for example, REN21 estimates that only about 50% of global biomass use is traditional biomass. One of IRENA’s activities for 2013 is to improve the accuracy on biomass use.

In the meantime, current energy projections to 2030 suggest that the share of traditional biomass will not decline significantly. Even the most ambitious energy scenarios aimed at drastically reducing energy-related emissions and climate change (e.g. IEA’s World Energy Outlook 450 scenario) rely on a significant, continued role for traditional biomass (Figure 2b).

In contrast, the first two objectives of the SE4ALL initiative aim to provide universal access to modern energy services (e.g. electricity, modern and more efficient heating and cooking devices) and to significantly increase the overall efficiency in energy use. Both these objectives involve a gradual phase-out of inefficient uses of traditional biomass and their associated environmental concerns, such as deforestation and pollution. This has two important consequences for the SE4ALL target. On one hand, the higher efficiency of modern renewables would lead to a reduced energy (and biomass) demand for heating and cooking in developing regions, thus reducing the RE share in the global energy mix. On the other hand, increased efficiency would free up biomass resources to be used in other applications, most notably in the manufacturing and agricultural sectors.

In any case, doubling the current RE share, which today includes a significant proportion of traditional biomass, while simultaneously phasing out inefficient uses of traditional biomass would imply an increase in the share of modern renewables (currently about 8%) by a factor of four in less than 20 years (Figure 2b). This is, indeed, a very ambitious target, which would require a significant transformation of the global energy system.

Figure 2a -The Share of Renewable Energy and Traditional Biomass in the Global Energy Mix (Based on IEA WEO 2012).

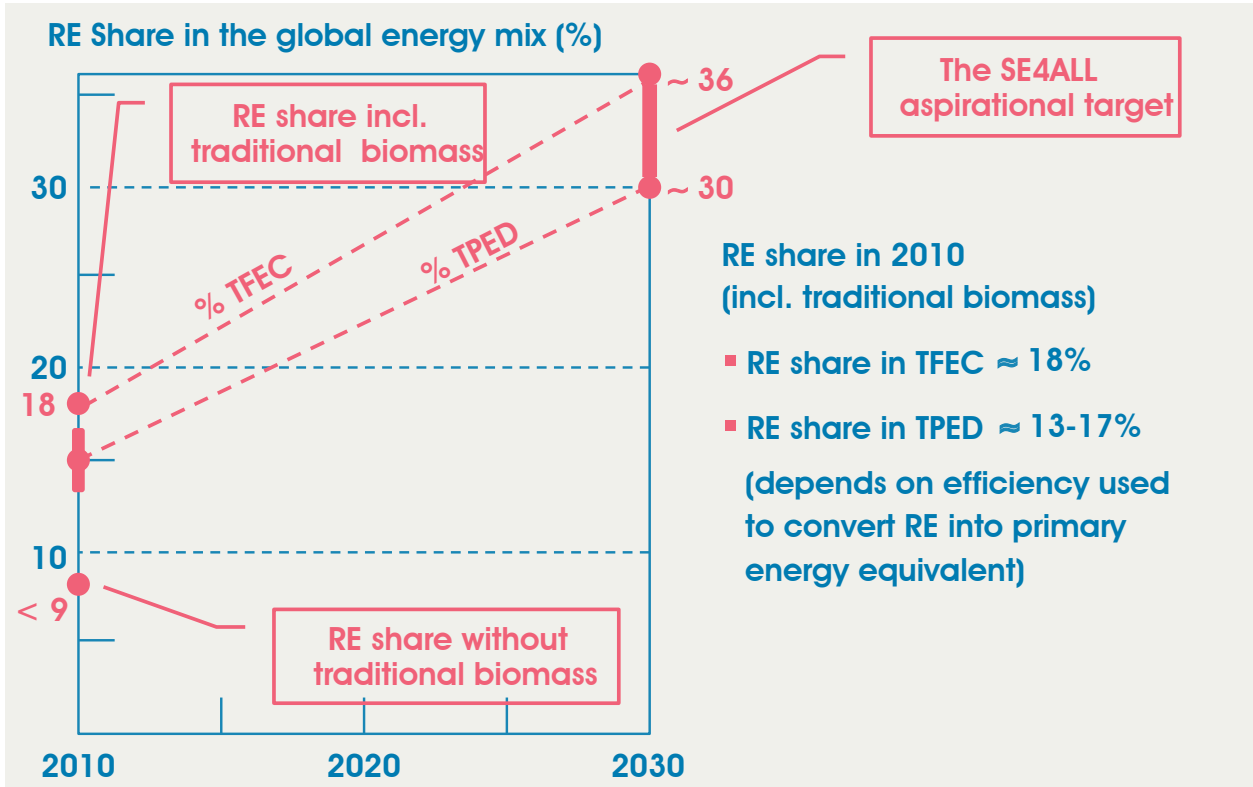
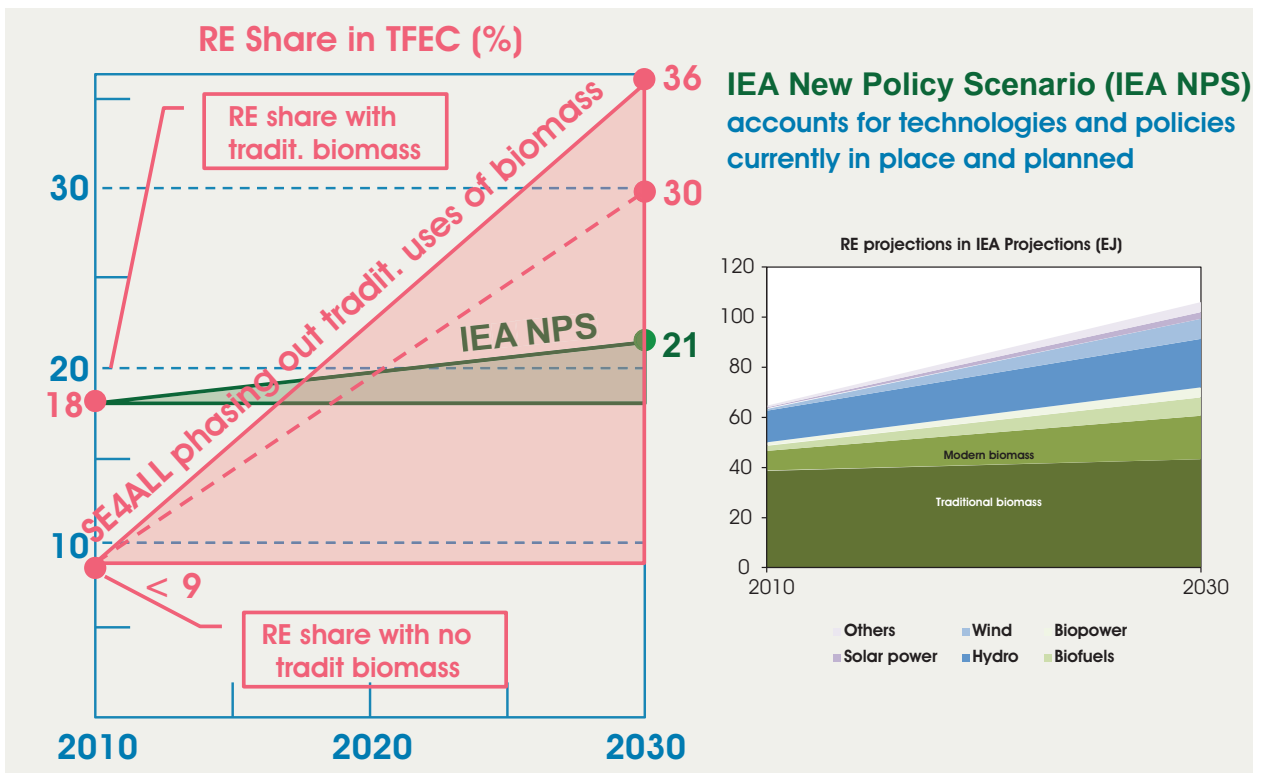


Figure 2b - Doubling the Renewables Share in TFEC without the Contribution of Traditional Biomass (Based on IEA WEO 2012).



3.4 Review of Current Energy Projections to 2030 and Beyond

Several international and national organisations, such as the IEA, the US Energy Information Administration (EIA), the International Institute for Applied Systems Analysis (IIASA), the European Union, and Non-Governmental Organisations (NGOs) like Greenpeace and the World Wide Fund For Nature (WWF), as well as major oil companies, such as BP, Exxon and Shell, develop and publish projections for global energy demand and supply.

Most of these scenarios are developed with a special context in mind and, except for the SE4ALL scenario developed by IIASA's Global Energy Assessment (GEA), none of these scenarios explores a future in which all three SE4ALL objectives are achieved. A short summary of major projections for 2030 energy demand and supply, highlighting the renewable energy share, is given in Table 2.

Table 2 - Energy Demand Projections and Renewable Share in Major Energy Scenarios to 2030

Organisation	Scenario	TPED (EJ)	Renewables (%)	TFEC (EJ)	Renewables (%)
IEA Statistics (2010)	2010 Energy Balances	533	13%	324	18%
IEA ¹¹ (2012)	NPS 2030	687	17%	425	21%
	450ppm 2030	605	23%	384	27%
	EWS 2030			380	22%
IEA ¹² (2012)	2D	600			
EIA ¹³ (2011)	Reference	684	13.9%		
	High oil case	733	13.6%		
	Low oil case	655	13.9%		
IPCC ¹⁴ (2011)	ReMind	590	32%		
	MINICAM	608	24%		
	MESAP/PlaNet	474	39%		
GEA (2012) ¹⁵	Supply – conventional	549	20%	434	29.5%
	Efficiency – advanced, no CCS & Nuclear	449	30%	351	32.7%
	Mix – advanced	548	19.7%	389	24.2%

¹¹ IEA (2012): World Energy Outlook 2012. TPED is based on the physical energy content method, which assumes 33% efficiency for nuclear, 100% efficiency for renewable energy resources like hydro, wind and solar PV, 50% for CSP and 10% for geothermal.

¹² IEA (2012): Energy Technology Perspectives 2012: Pathways to a Clean Energy System.

¹³ EIA (2011): International Energy Outlook 2011. TPED is based on the substitution method.

¹⁴ IPCC (2011): Renewable Energy Sources and Climate Change Mitigation. In all scenarios, the direct equivalent method is used to measure primary energy demand.

¹⁵ GEA (2012): Towards a Sustainable Future. TPED is based on the direct equivalent method, assuming 100% efficiency for both renewables and nuclear.

Table 2 (continued) - Energy Demand Projections and Renewable Share in Major Energy Scenarios to 2030

Organisation	Scenario	TPED (EJ)	Renewables (%)	TFEC (EJ)	Renewables (%)
ExxonMobile ¹⁶ (2011)		618	14%	478	24%
BP ¹⁷ (2012)		683	14%		
Shell ¹⁸ (2008)	Scramble	734	23.7%		
	Blueprint	692	20%		
Greenpeace/EREC/ GWEC (2012) ¹⁹	Revolution			340	45%
WWF, Ecofys/ OMA (2012) ²⁰				319	42%

Table 2 shows the primary energy demand today and in 2030, according to the *IEA New Policies Scenario (NPS)*, which is based on policies currently in place and assumes timely implementation of policies that are now under consideration. In such a scenario, primary energy demand will rise by 29% by 2030. Fossil fuels will remain by far the dominant source of energy. All forms of renewable energy would grow faster than fossil energy starting from a much lower base. Clearly this scenario is not in line with the objective of doubling the renewable energy share by 2030.

The *450 Scenario*, also produced by the IEA, foresees a higher share of renewables and increased energy efficiency but is rather optimistic on the prospects of CO₂ Capture and Storage (CCS) technology, assuming around 35% of CCS in coal-fired power generation by 2030. CCS is especially relevant for coal-based power generation, but it is not yet deployed at any commercial level and involves very significant increases in electricity generation costs. In contrast, it is possible to foresee scenarios in which renewable power generation is used instead of CCS technologies to reduce global CO₂ emissions to below levels, thus precluding catastrophic climate change. The emissions trajectory associated with the 450 Scenario is consistent with the *2 °C Scenario (2DS)* developed in the context of IEA's Energy Technology Perspectives 2012. In the 2DS scenario, renewables roughly make up around 50% of electricity generation in 2030 and their share of total average world electricity generation increases to 57% by 2050.

The IEA has also developed a special *Efficient World Scenario (EWS)* in its 2012 World Energy Outlook. This scenario uses the NPS as its basis but assumes increased energy efficiency in all end-use sectors. The result of

¹⁶ ExxonMobil (2012): 2012 The Outlook for Energy: A View to 2040. The data are based on interpolations between the data points for 2025 and 2040.

¹⁷ BP (2012): BP Energy Outlook 2030. The primary energy values of nuclear and hydroelectric power generation, as well as electricity from renewable sources, have been derived by calculating the equivalent amount of fossil fuel required to generate the same volume of electricity in a thermal power station, assuming a conversion efficiency of 38% (i.e. the average for OECD thermal power generation).

¹⁸ Shell (2008): Shell Energy Scenarios to 2050.

¹⁹ Greenpeace International, EREC, GWEC (2012): Energy [r]evolution: A Sustainable World Energy Outlook 2050.

²⁰ WWF, Ecofys, OMA (2011): The Energy Report, 100% Renewable Energy by 2050.

this scenario is that final energy consumption decreases by 45 EJ. The share of renewables is slightly increased in comparison to the NPS.

The US Energy Information Administration (EIA) has higher projections for total primary energy demand than the IEA, but this is mainly due to the different accounting methods used. Because the EIA assumes efficiencies of around 38% for renewable energy and nuclear power generation, the total primary energy demand for these sources is also higher.

There are a number of other scenarios that have explored possible pathways for renewable energy, especially in the context of climate change and global oil consumption. The Intergovernmental Panel on Climate Change (IPCC) has reviewed a number of scenarios and their projections for renewables deployment in 2030. Of the 164 scenarios reviewed, more than half of them projected a contribution from renewables in excess of 17% share of primary energy supply in 2030, which is far less than is required to achieve the SE4ALL objective. The scenarios with the highest renewable energy shares reached approximately 43% in 2030.

More recently, the *IIASA Global Energy Assessment* (GEA) developed a number of future energy scenarios. These were based on high, low or medium demand followed by options for conventional versus advanced transport systems, including a number of options for CCS, nuclear and renewable energy resources. The three scenarios included in Table 2 represent a high-demand scenario with conventional transport systems (i.e. supply-conventional), a low-demand scenario with advanced transport systems and excluding CCS and nuclear (i.e. efficiency-advanced, no CCS and nuclear) and a medium-demand scenario with an advanced transport systems (i.e. mix-advanced). These scenarios project RE shares between 24-33%. IIASA has also developed a special SE4ALL scenario, but the data for this scenario are not yet in the public domain.

Among major oil companies, significant differences also exist in terms of the prospective future contributions of renewables. BP has the most optimistic scenario for renewables and is roughly in line with the IEA NPS scenario. BP's forward-looking analysis published in 2012 projects that primary energy use will grow by nearly 40% over the next twenty years (compared to 29% in the NPS), with 93% of the growth in non-OECD countries, which will rapidly increase their share of global energy demand from the current over 50% to about 66%. Between 2010-2030, the contribution of renewables (i.e. solar, wind, geothermal and biofuels) is projected to increase from 16% to in 2010 to 20% in 2030 (including traditional biomass), with biofuel use growing to nearly 8 EJ in 2030.

The ExxonMobil projections for global energy demand are 24% higher than in 2010 (i.e. a considerably lower demand growth compared to NPS), based on the assumptions that energy demand growth will slow down as economies mature, efficiency gains will accelerate and population growth will moderate. According to this scenario, oil, gas and coal will continue to be the most used fuels, making up about 80% of the total primary energy demand in 2040; wind and solar contributions will grow about ten-fold by 2040; hydro power by 25%; with no significant growth for biomass.

Among the two Shell scenarios, Blueprint is comparable to previous scenarios in terms of basic assumptions and scope. In the Blueprint scenario, primary energy demand will grow to around 730 EJ by 2030 (i.e. a 37% growth over 2010 projections). This includes around 35 EJ biomass, with 20 EJ of biofuels (about half second-generation biofuels), and 35 EJ of wind and other renewables (in primary energy terms). The major part of energy demand growth will continue to be met by fossil fuels, notably gas and coal.

Finally, there are scenarios developed by Greenpeace/EREC/GWEC and WWF/Ecofys/OMA. These scenarios assume a radical change in the energy infrastructure and project significantly lower energy consumption compared to the other scenarios. For example, Greenpeace's advanced scenario assumes a phase-out of nuclear

energy, full exploitation of energy efficiency measures using currently available best practice technologies, and all cost-effective renewable energy sources for heat, electricity generation and the production of biofuels. The biomass potential is based on considerations of sustainability and has been further reduced to consider any unknowns.

Comparing the different scenarios suggests that a distinction should be made between aspirational scenarios (e.g. Greenpeace, WWF and some IASA and IPCC scenarios), which involve radical and rapid transitions to renewables and more efficient uses of energy and those other scenarios, which factor in the considerable inertia of current energy systems.

Apart from aspirational scenarios, data from Table 2 show that an approximate 10% uncertainty factor exists in demand projections for 2030, and that even ambitious scenarios aimed to drastically mitigate emissions and climate change leave significant gaps if compared to the SE4ALL objectives. For example, in the IEA 450 scenario, the renewable energy share in TPED increases from today's 13% to 23% in 2030, while the share in TFEC increases from today's 18% to 27% in 2030. In addition, the energy efficiency improvement rate is expected to increase from today's 1.6%¹⁶ to 2.5% by 2030 (but does not double), and, while the number of people without access to electricity and modern cooking and heating services will decline, it will remain significant.

It should be noted that the year in which each projection was developed may also have a significant impact on its calculations. Lower demand projections in more recent scenarios may reflect the current economic crisis. This may also explain why Shell's biofuel projection is much more optimistic than the BP projection: the biofuel outlook has deteriorated in the last couple of years.

An in-depth comparison of available scenarios at the sectoral level is currently in progress.

Using the IEA NPS as a Starting Point

Based on the review of existing scenarios and the availability of IEA energy statistics, the feasibility study uses the IEA's New Policies Scenario (NPS) as its starting point. This projection assumes that energy demand will grow by 29% by 2030 with considerably higher final energy demand than the IEA Efficient World Scenario (EWS), the IEA 450ppm scenario, and other scenarios developed by the Global Energy Assessment (GEA, Greenpeace and WWF/Ecofys/OMA).

Table 3 shows the power generation mix today and the NPS projection for 2030. As a comparison, data are also included for the IEA 450 scenario where deep CO₂ emission cuts are foreseen, assuming a massive uptake of CCS technology and growth in the renewable energy share. In the NPS scenario, the share of renewable energy in power generation grows from 20% in 2010 to 29% in 2030 while the 450 Scenario foresees growth to nearly 42%.

¹⁶ "Energy intensity improvements" is used as a proxy for energy efficiency improvements. These results are based on IEA energy statistics 2012 and World Bank GDP data (in PPP) between 1971 and 2008. Similarly, a 40-year period (from 1990 to 2030) is assumed to calculate the energy intensity improvements in 2030.

Table 3 - Power Generation Today and Scenarios for 2030 (Based on IEA WEO, 2012)

Power generation	2010 (EJ)	NPS 2030 (EJ)	450ppm 2030 (EJ)	2010 (%)	NPS 2030 (%)	450ppm 2030
						(%)
Total generation	77.1	121.6	107.4	100.0	100.0	100.0
Coal	31.3	41.6	19.7	40.6	34.2	18.4
Oil	3.6	2.2	1.5	4.7	1.8	1.4
Gas	17.1	27.8	22.7	22.2	22.9	21.1
Nuclear	9.9	14.8	18.8	12.9	12.2	17.5
Hydro	12.4	19.2	20.9	16.0	15.8	19.5
Bioenergy	1.2	4.2	5.5	1.5	3.5	5.1
Wind	1.2	7.9	11.9	1.6	6.5	11.1
Geothermal	0.2	0.9	1.2	0.3	0.7	1.2
Solar PV	0.1	2.4	3.5	0.1	2.0	3.3
CSP	0.0	0.5	1.4	0.0	0.4	1.3
Marine	0.0	0.1	0.1	0.0	0.1	0.1
<i>Renewable share</i>				<i>19.7</i>	<i>29.0</i>	<i>41.6</i>

3.5 Feasibility Study of the Third SE4ALL Objective: Assessing the Level of Challenge

The IRENA feasibility study of the third SE4ALL objective aims to:

- Explore alternative pathways to double the RE share in the global energy mix by 2030;
- Assess the impact of the universal access and energy efficiency objectives on the renewable energy objective;
- Assess the level of challenge associated with achieving the renewable energy objective; and
- Assess regional and sectoral contributions to, and implications of, different pathways to achieve the renewable energy target.

As mentioned earlier, the IEA 2010 Energy Balances and the IEA New Policies Scenario (NPS) have been used to determine the current and future energy demand and renewable energy production in the light of current and planned policies. Subsequently, the IEA NPS has been extended to explore how to achieve all three SE4ALL objectives and analyse their mutual interaction and implications:

- The **Access Scenario (AS)** explores options to achieve the universal access to modern energy services, building on IEA NPS;
- The second **Access and Efficiency Scenario (AES)** builds on the previous AS to achieve both universal access and a doubling of the energy efficiency growth rate by increasing electrification in all end-use sectors, based on renewable energy sources;
- The third **Renewables, Access and Efficiency Scenario (RAES)** builds on the AES and explores different combinations of renewable technology options to double the RE share by 2030. Two different pathways are proposed to achieve the renewable energy target: one is based on increasing the renewables share in end-use sectors; the other relies on an increased use of renewables in power generation.

While this simple addition of effects and the global assumptions used in the feasibility study do not capture the complexity of the energy market transition that is needed to achieve the SE4ALL targets (e.g. the steps to get there, the regional dimension, the impact on energy trading, the economic implications), this approach provides helpful information on the level of challenges involved in the SE4ALL objectives and their mutual interaction, as well as sharing initial information on regional differentiation.

The key results for the three scenarios—AS, AES and RAES—are summarised in Figures 3, which shows the renewable energy share in TFC for AS, AES and RAES and compares it with the renewable share in 2010 and in the IEA NPS 2030. Similarly, Figures 4 and 5 provide the renewable share in TFEC and TPED (substitution method), respectively. The results of Figure 3 and 4 differ, because the share of renewables in TFC also includes energy consumption for non-energy use (including renewables for chemical feedstocks). The results for Figure 5 differ from Figures 3 and 4, because the share of renewables is presented in primary instead of final energy terms. Annex A provides the numerical data behind these figures.

Figure 3 - RE Share in Total Final Consumption in Different Scenarios and Pathways.

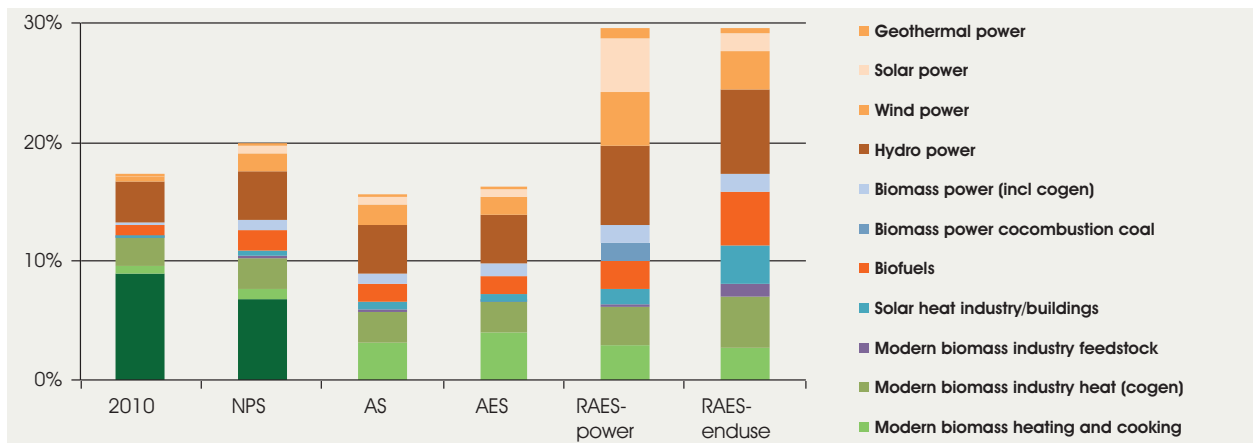


Figure 4 - RE Share in Total Final Energy Consumption in Different Scenarios and Pathways

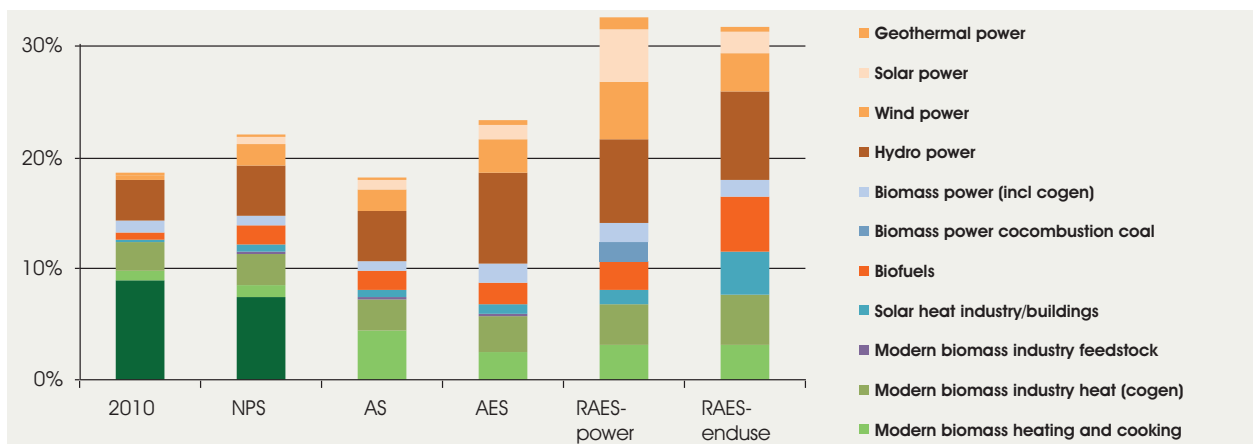
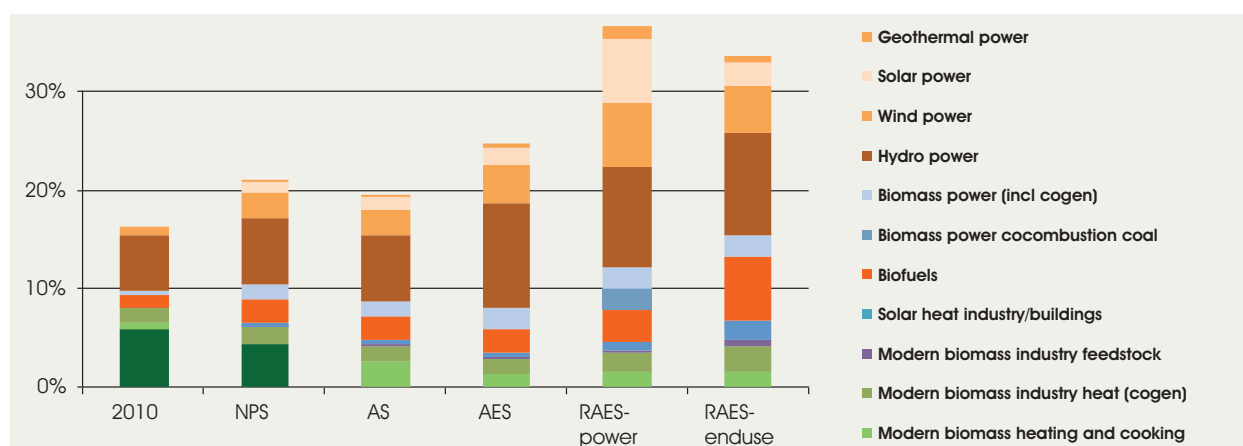


Figure 5 - RE Share in Total Primary Energy Demand (Substitution method) in Different Scenarios and Pathways.



Key assumptions and findings for each scenario are as follows:

The first **Access Scenario (AS)** builds on the IEA New Policies Scenario (NPS) and assumes an additional deployment of modern renewable technologies to provide access to electricity to about 1.3 billion people and modern heating/cooking facilities to some 2.7 billion who currently have none¹⁷. Of course, the impact of this transformation on the renewable share depends on the role of RE sources and technologies in providing universal access to modern energy. If only renewable-based power generation were used for electricity access (i.e. an additional 77 GW of RE power generation would be required on top of the additional 1,478 GW of RE power generation assumed in the NPS) and only renewables-based cooking facilities were used to replace traditional biomass, the RE share in total final consumption would decline from 19% in the NPS 2030 to 17% in the AS 2030 (or from 21% to 18% in TFEC). This is basically due to the higher efficiency of modern renewable technologies (even modern biomass-based technologies), which would drastically reduce RE consumption in comparison to the current use of traditional biomass. Obviously, if not only renewables were used to provide universal access to modern energy, the RE share in total final consumption could decline even further (under the IEA “Energy for All” scenario, the 2030 renewable share would decline to 16% of TFC and 17% of TFEC).

Similarly, the renewable share in TPED (substitution method) would decline from 22% in NPS 2030 to 20% in AS 2030 if only renewables were used to provide universal access, but even more (i.e. 19%) under the assumptions used in IEA’s “Energy for All” scenario (Figure 5).

Comparing NPS 2030 to AS 2030, it should be noted that the use of traditional biomass (i.e. around 8% in NPS 2030, Figure 1) is replaced by 4% modern biomass for heating and cooking. Therefore, the key AS finding is that providing universal access to modern energy services will reduce the RE share in the global energy mix due to the phase-out of traditional biomass. The level of this reduction depends on which technologies and energy sources are used to replace traditional biomass.

The second **Access and Efficiency Scenario (AES)** builds on the AS and explores the contribution that increased electrification based on renewable power (i.e. increased use of renewable power generation) can

¹⁷ According to the IEA NPS, the number of people without access to electricity will decline from today’s 1.3 billion to about one billion by 2030 while the number of people without modern cooking and heating facilities will remain level at around 2.7 billion between now and 2030.

make to energy efficiency. It should be noted that AES does not assume efficiency improvements in power generation and in end-use sectors compared to AS.

Figures 3, 4 and 5 show the impact of increased electrification in the transport sector (e.g. electric vehicles), the building sector (e.g. heat pumps) and the industry sector (e.g. heat pumps and innovative electricity-based process technologies). In the AES, it is assumed that electricity displaces gasoline and diesel consumption in the transport sector, fossil fuels in industry, and both fossil fuels and biomass in the buildings sector. As a consequence, the RE share in the total final consumption increases from 17% in AS to 18% in AES 2030 (and 18% to 20% in TFEC). Similarly, the share of renewables in TPED (substitution method) increases from 20% in AS to 22% in AES 2030.

The main AES finding is that an increased electrification contributes significantly to the achievement of the SE4ALL renewable energy target. The level of additional renewable power capacity to be installed worldwide for this to happen is on the order of 4,203 GW. This is 1,525 GW more than in the IEA NPS and would require around 2,000 GW of additional RE capacity to be built between now and 2030. In comparison, only around 100 GW of RE power generation were added in the year 2011.

The third scenario, **Renewables, Access and Efficiency Scenario (RAES)**, builds on AES and explores how to achieve the aspirational target of doubling the RE share in the global energy mix using several renewable technology options to displace additional amounts of fossil fuels in power generation and end-use sectors compared to AES.

The two pathways within the RAES each represent a different end of the spectrum in terms of the scale at which various RE technology options have been considered. The aim of these pathways is to provide a first estimate benchmark for the global and regional efforts to achieve the SE4ALL renewables objective. The RAES-power favours efforts in the electricity sector to double the share of renewables globally, while the RAES-end-use favours efforts in the end-use sectors. In other words, the RAES-power combines the higher-end assumptions for RE power generation with the lower-end assumptions about RE use in the end-use sector and vice versa for the end-use sector pathways.

Except for regional constraints and existing regional conditions in terms of resource availability, the pathways are based on global assumptions that are identical for all world regions. In other words, it is assumed that each world region puts equal efforts in place to achieve a doubling. For the power sector, it is assumed that all regions will increase their renewable power generation capacity for each individual RE technology by the same percentage. For example, in RAES-power, it is assumed that wind power capacity in all regions will double, while in the RAES-end-use, an additional capacity of 30% is assumed. For the end-use sectors, it is assumed that all regions will increase deployment levels at the same rate. For example, the RAES-power assumes a 4% replacement of fossil-fuel based heat requirements with RE resources in the industry and buildings sector for all regions, while the RAES-end-use assumes 20% replacement of fossil-fuel based heat requirements for all regions. The overview of these assumptions can be found in Table 4. This means that the results of RAES do not assume specific allocation of efforts to different regions, but that all regions are assumed to take similar measures to achieve the global target.

This list of options is a preliminary selection based on IRENA's analysis of the most promising renewable technologies (i.e. IRENA Technology Briefs) and the technology database developed in Chapter 5. A more detailed discussion is needed on how this list can be expanded or amended and on the technology option priorities.

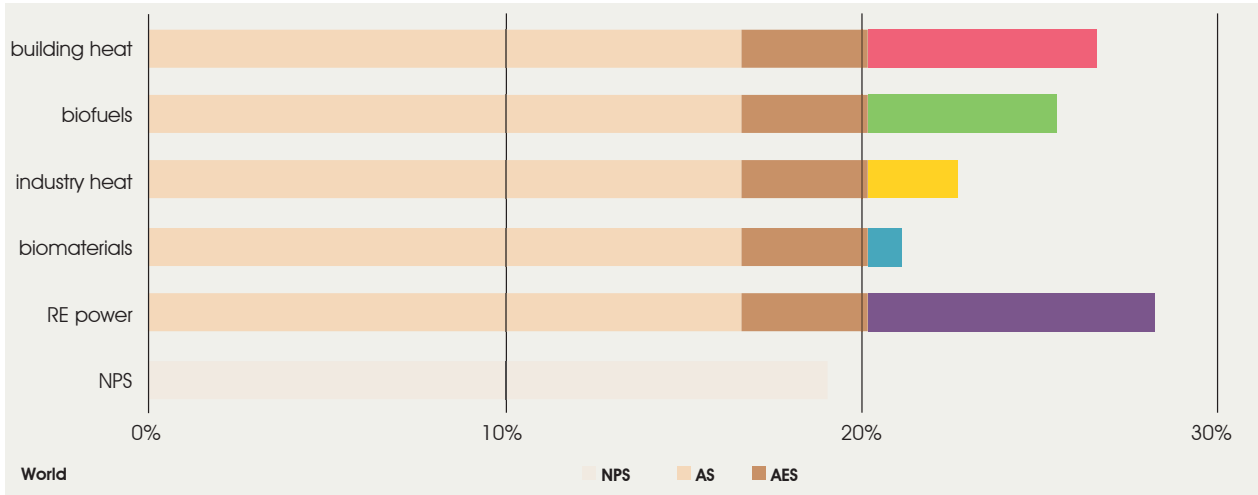
Table 4 - Overview of Global Assumptions used to Develop Two Alternative Pathways to Achieve the SE4ALL Objectives.

RE option	RAES-power	RAES-end-use	Absolute values (2030)
Hydro	AES+10%	AES	2200-2350 GW
Biomass (incl. co-gen)	AES+20%	AES	240-260 GW
Wind	AES+100%	AES+25%	1300-1800 GW
Geothermal	AES+250%	AES+50%	60-120 GW
Solar PV	AES+250%	AES+50%	850-1800 GW
CSP	AES+800%	AES+100%	70-300 GW
Marine	AES+300%	AES+100%	6-11 GW
Biomass co-firing	15% of coal-fired power generation	0% of coal-fired power generation	0-245 GW
Solar heat in industry	2% of heat demand	12% of heat demand	1-10 EJ
Biomass heat in industry	2% of heat demand	8% of heat demand	1.4-5.6 EJ
Solar heat in buildings	4% of heat demand	20% of heat demand	0.6-5.7 EJ
Bio-based chemical feedstock	5% of fossil-fuel based feedstock	20% of fossil-fuel based feedstock	1.6-4.6 EJ
Biofuels	50% (Brazil), 20% (EU, OECD Americas, Asia, Latin America), and 10% (Russia, Japan, Middle East, Africa) of transport fuel consumption	50% (Brazil), 15% (EU, OECD Americas, Latin America), and 5% (rest of world) of transport fuel consumption	10-19 EJ

The findings for these two pathways is that even a *significant growth* in renewable power generation alone will not be sufficient to achieve the SE4ALL objective for the RE share in the global energy mix, and that **combined interventions in both power generation and end-use sectors will be needed**. While even RE options in the end-use sectors have an insufficient individual impact, **collectively they can enable the achievement of the SE4ALL renewables objective** if combined with a significant increase of renewables in power generation. Under these conditions, the 30% RE share in the global energy mix that is marginally achieved if the RE share is measured with respect to the total final consumption (Figure 3) can be slightly exceeded if the RE share is measured with respect to total final energy consumption (Figure 4). And finally, **the RE goal can even be exceeded if measured on the basis of total primary energy demand** (Figure 5).

Figure 6 provides an overview of the incremental contribution that each technology option can make in RAES to achieve the third SE4ALL objective, considering the lower and upper limits explored in the different pathways, comparing them with NPS, AS and AES. Important contributions are provided by the use of RE in building heating and cooling, by the use of biofuels in transport and by RE power generation (including biomass co-firing in coal-fired power stations). Smaller but still significant contributions are provided by the use of renewables to meet industrial heat demand, including options with growing importance (e.g. renewables-based water desalination) and the use of biomass in the chemical industry (i.e. bio-plastics) instead of fossil fuels.

Figure 6 - Contribution of Different Technology Options to Increase the RE Share in Total Final Consumption, compared to NPS, AS and AES Scenarios.



This analysis also includes a preliminary exploration of the regional level impact, based on global assumptions. Figure 7 illustrates the RE share in total primary energy demand (substitution method) for different world regions. The results show that achieving universal access to modern energy services would significantly reduce the RE share in Africa but would have little impact on the RE share in the European Union and the Middle East. On the other hand, while a high growth rate of bio-based plastics would have virtually no impact on the RE share in Africa, it *would* impact the RE share in the European Union and the Middle East. Similarly, replacing 20% of fossil fuel use in the residential sector in the Middle East could increase the RE share in TPED by 6% (i.e. three times higher than current levels) while the absolute RE share increase in Africa would be much lower due to the already high RE share and the lower shares of fossil fuel use in the residential sector.

These regional differences are an obvious consequence of differing natural endowments and starting points for individual regions and countries¹⁸ and show that the challenges associated with the achievement of the third SE4ALL objective vary considerably across regions and countries. The global assumptions considered in the present IRENA analysis need to be adapted to the regional and national level to capture these dimensions of the challenge.

¹⁸ The current share of renewable energy in TFEC is close to zero in the Middle East; it is 58% in Africa due to the extensive use of traditional biomass and 42% in Brazil due to the deployment of biofuels and renewable power (i.e. substantial availability of hydropower and sugarcane for biofuel production).

Figure 7 - Contribution of Different Technology Options to the Increase of the RE Share in Total Final Primary Energy Demand, compared to NPS, AS and AES Scenarios in various World Regions

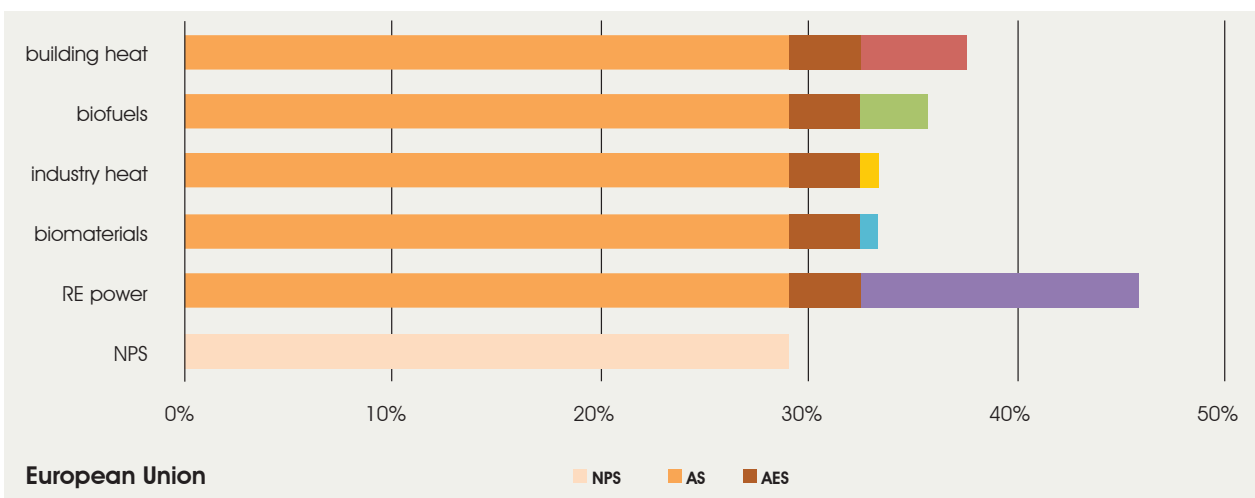
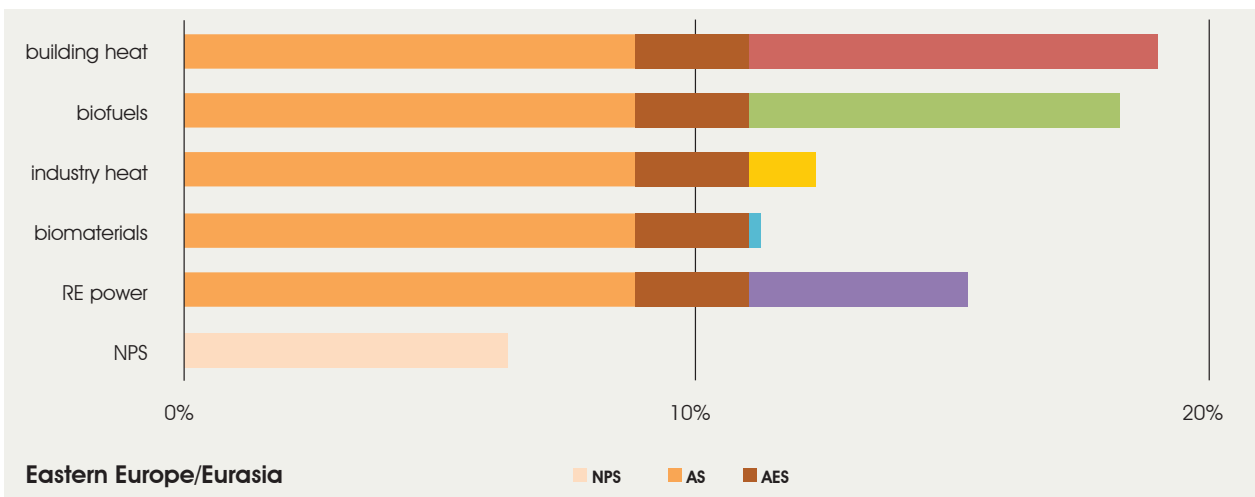
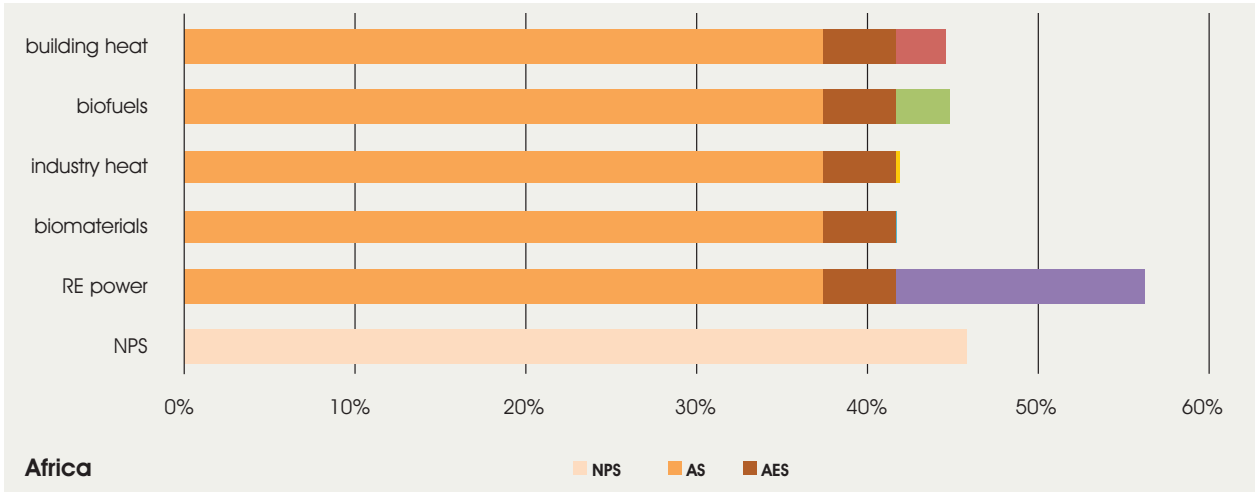
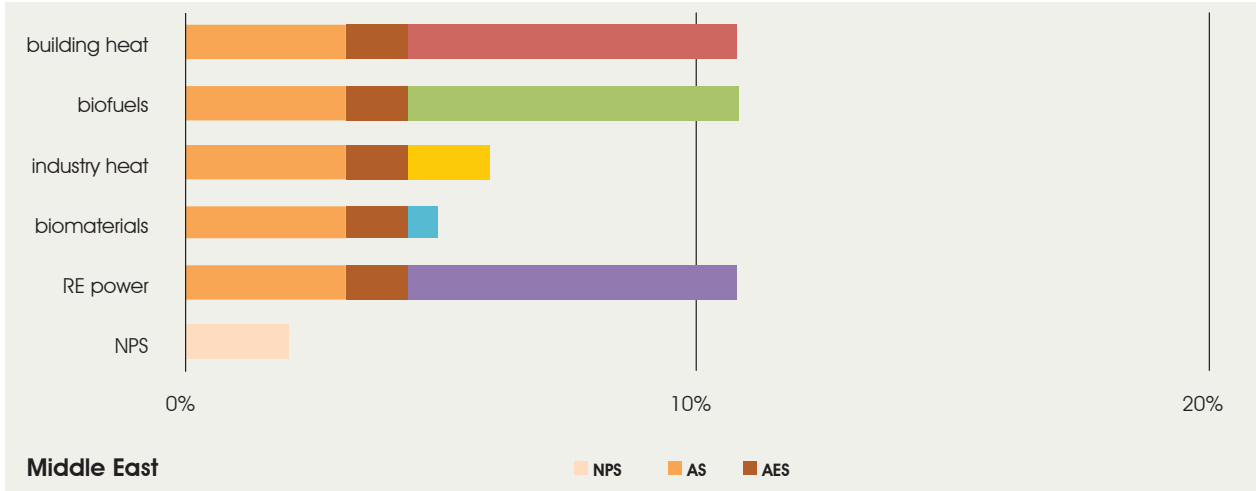


Figure 7 - Contribution of Different Technology Options to the Increase of the RE Share in Total Final Primary Energy Demand, compared to NPS, AS and AES Scenarios in various World Regions (continued)



Main Outcomes of the Feasibility Study

The main conclusion of the IRENA analysis is that **the SE4ALL objective for renewable energy, as it is currently defined, is technically achievable**. However, it poses unprecedented challenges in terms of development and deployment of renewable technologies and capacities within a relatively short time frame; in particular, if it is linked with the gradual reduction of traditional biomass uses in developing regions of the world.

The deployment of modern renewable technologies needed to achieve the third SE4ALL objective goes well beyond even the most ambitious scenarios to mitigate emissions and climate change, which still account for a significant and ongoing use of traditional biomass.

Therefore, increasing the renewable share in power generation alone will not be sufficient to achieve the SE4ALL renewable objective. Combined interventions in both power generation and end-use sectors will be needed. While even renewable energy options in the end-use sectors have an insufficient individual impact, *collectively* they can enable the achievement of this objective but only if combined with a significant increase of renewables in power generation. Under these assumptions, a 30% RE share of the global energy mix can be feasibly, if marginally, achieved.

4. Progress Results: Identifying the Gap

The “gap analysis”, the second step of the REMAP process, involves developing an accurate assessment of the gap between the SE4ALL renewable energy objective and national renewable energy plans and projections currently in place. In the latest *Global Status Report* of REN21, 116 countries set specific targets: 84 for electricity, 13 for transport and 20 for heat. Furthermore, ten countries set specific targets to use renewable energy for rural electrification programmes. In contrast, in 2011 REN21 reported that 95 countries had set specific targets, of which 65 were for renewable energy power generation, eight for renewable heat, three for transport and five for rural electrification.¹⁹ This means that the number of countries with specific national renewable energy targets has increased at all levels, but that still more than half of the world does not have specific targets for RE deployment for electricity, heat, or transport purposes.

Furthermore, these plans differ in terms of their respective target year (i.e. ranging from 2015 to 2050), scope (i.e. primary energy, final energy, electricity or heat demand), sector (i.e. electricity, transport or other end-uses) and target (i.e. in percentage of total generation or in GW). There are often only limited data in the open literature on the background projections upon which these targets are based. For example, 55 countries formulated RE targets as a share of final energy or primary energy demand. The results associated with these targets are highly dependent on the assumptions used to calculate final or primary energy demand in the target year.

The aim of the gap analysis is to collect data on national renewable energy plans and projections in a uniform, transparent and simple format. This will allow IRENA to compare and accurately determine the gap between national renewable energy plans and projections and the global SE4ALL targets and will create a valuable depository for Members to make international comparisons, as well as serving as a unique resource for countries in their process of formulating, updating or revising their national RE plans.

As a starting point for data collection, IRENA invited the largest economies in each world region to present their data on national RE plans and projections. Five countries—Germany, Japan, Saudi Arabia, the United Arab Emirates and the United States of America—identified national RE experts to present data on their national RE plans and projections²⁰. These countries provided data on intermediate and final targets for renewable power and heat, as well as energy demand projections. Some countries also provided a range of RE targets and projections based on different assumptions and policy options.

Furthermore, these five countries provided available information on the social, macro-economic and political impacts of their RE projections. This included information on costs, impacts on direct and indirect employment and on the import and export of fossil energy sources, and environmental implications (e.g. reductions in CO₂, NO_x and SO₂ emissions).

Subsequently, IRENA discussed the possibility for collecting national renewable energy plans and projections in a second workshop, which took place in November 2013. This time 16 countries attended, and another six countries were individually briefed. Again, the response from these countries on identifying and nominating national experts to provide and verify data on national renewable energy plans and projections was mostly positive. Several countries volunteered to help test the REMAP data sheets developed for this specific purpose.

¹⁹ REN21 (2012): *Renewables 2012 - Global Status Report*; REN21 (2011): *Renewables 2011 - Global Status Report*.

²⁰ This workshop took place on 5 September 2012 in Malta. These countries' presentations can be found at www.irena.org.

5. Progress Results: Sectoral Analysis and Action Items

The objective of the third activity—the sectoral analysis—is to explore each end-use sector individually at a regional level by:

- Identifying and characterising specific actions and technologies with respect to their potential contributions towards achieving the third SE4ALL target; and
- Developing a mechanism to prioritise sectoral action items based on characteristics like their incremental costs in comparison to current conventional solutions, their levels of maturity, levels of experience within the region, macro-economic impacts, etc.

The starting point for the sectoral analysis is the gap between the pathways to achieve the SE4ALL objectives and the national RE plans and projections. Assuming the IEA NPS as an accurate reflection of national renewable energy plans for 2030, this gap is between 52-63 EJ—equivalent to the total energy consumption of the United States for the entire year 2010.

This chapter illustrates the preliminary results of the sectoral analysis at a global level. In general, energy technology options—particularly novel and emerging renewable technologies—are subject to considerable differences and uncertainties in terms of their performance, potential and costs across the world's regions and countries. Although expected to decline over time, significant differences still exist between regions, depending on their geographical location, natural resource endowments, climate, labour costs, general economic conditions, etc. Particularly novel technologies are affected by uncertainties. At present, the analysis looks at the global potential of each technology and refers to current international costs. Therefore, results are intended to inform decision-making processes and strategies rather than to provide specific inputs and targets for national policies.

However, IRENA contends that the finalisation of this kind of strategic assessment is urgent precisely at this point in time because the long lead time between capital stock build-up and its impact on the energy system means that decisions made in this current decade will largely determine the energy mix in 2030. The main goal is, therefore, to identify the most promising and economic areas of action based on latest market developments and to accurately evaluate practical deployment opportunities and implications for the transition to renewable energy.

Once this analysis is finalised at the regional level, it will offer a set of policy options and action items to fill the gap between current national plans for renewable energy and the third SE4ALL objective.

In principle, the potential of the technology options proposed below exceeds the size of the gap to be filled at a global level and thus makes meeting the third SE4ALL objective feasible. However, this does not mean that all of the technology options explored at the global level are relevant to a regional levels or that the options explored are exhaustive.

5.1 Technology Options and Potential in the Energy Transformation Sector

The energy transformation sector includes the electricity sector, as well as a number of industries that convert primary fossil resources into fuels (e.g. coal mines, oil refineries). This illustrative example focuses only on the electricity sector since IRENA's feasibility study showed that accelerated RE deployment in this sector will be crucial to achieving the SE4ALL targets.

In order to achieve all three SE4ALL targets, RAES-end-use and RAES-power assumed RE power generation of 37% and 52% or between 16,500-23,000 TWh, respectively. Preliminary results of the power generation sector

analysis at the global level show that there is, indeed, potential to further accelerate the uptake of renewable energy in the power sector with respect to current energy projections. However, this would require substantial investments and immediate actions.

Figure 8 shows the potential of different renewable power generation technologies for 2030. The upper limits are based on the evaluation of a number of different global technology roadmaps from both industry associations and international organisations.

The technical potential for **hydropower** is estimated to be around 14,576 TWh or 3,721 GW²¹, but the IEA 450ppm scenario only projects that 1,742 GW will be installed by 2030. The RAES-power and RAES-end-use pathways require around 2,200 GW to achieve the SE4ALL targets, which assume an additional 500 GW of hydropower capacity to be built in addition to the IEA projections.

Projections for **wind** seem to vary widely. The BLUE scenario of the IEA's Energy Technology Perspectives²² projects 2,500 TWh while the Global Wind Energy Council (GWEC)/Greenpeace²³ projects wind power production between 4,251-6,678 TWh (i.e. 1,617-2,541 GW, respectively). In comparison, the RAES-end-use and RAES-power scenarios project 3,800-5,400 TWh respectively to achieve the SE4ALL targets.

The projections for **solar PV** seem to vary as widely as wind. The European Photovoltaic Industry Association (EPIA) projects between 1,950 and 2,500 TWh, and the IEA roadmap on solar PV²⁴ foresees levels between 200-900 GW. In comparison, the RAES-power and RAES-end-use scenarios assume 1,800 and 1,100 GW, respectively.

The role and potential of **biomass** in 2030 is uncertain. Current estimates suggest a total global potential of 100 EJ, considering the availability of little-to-no land for energy crops, the inclusion of agricultural residues (< 30EJ), low-input agriculture, limited expansion of cropland area and a high level of environmental protection.²⁵ However, this potential is not evenly distributed. For example, biomass co-firing in coal-fired power stations does not result in any major technical problems up to 20%. However, investments in transportation and storage facilities would be required if the coal-fired power station is not located adjacent to major transport corridors or along coastal routes. Furthermore, biomass for power generation competes with a number of other uses (e.g. bio-based products, biofuels and biogas production). The IEA NPS and 450ppm scenarios project between 208-264 GW of biomass-based power generation, while the RAES pathways each require between 250-400 GW.

Geothermal power is a mature technology and IEA NPS and 450ppm scenario projections for 2030 range between 38-51 GWe. The IEA technology roadmap on geothermal assumes around 50 GWe with 350 TWh/yr produced. In comparison, RAES-power and RAES-end-use pathways require between 75-120 GW, considerably higher than the capacity projected by the IEA. On the other hand, resource estimates for geothermal electrical

²¹ IEA (2012): Technology Roadmap – Hydropower

²² IEA (2009): Technology Roadmap – Wind energy.

²³ GWEC/Greenpeace (2012): Global wind energy outlook 2012.

²⁴ IEA (2010): Technology Roadmap – Solar Photovoltaics Energy.

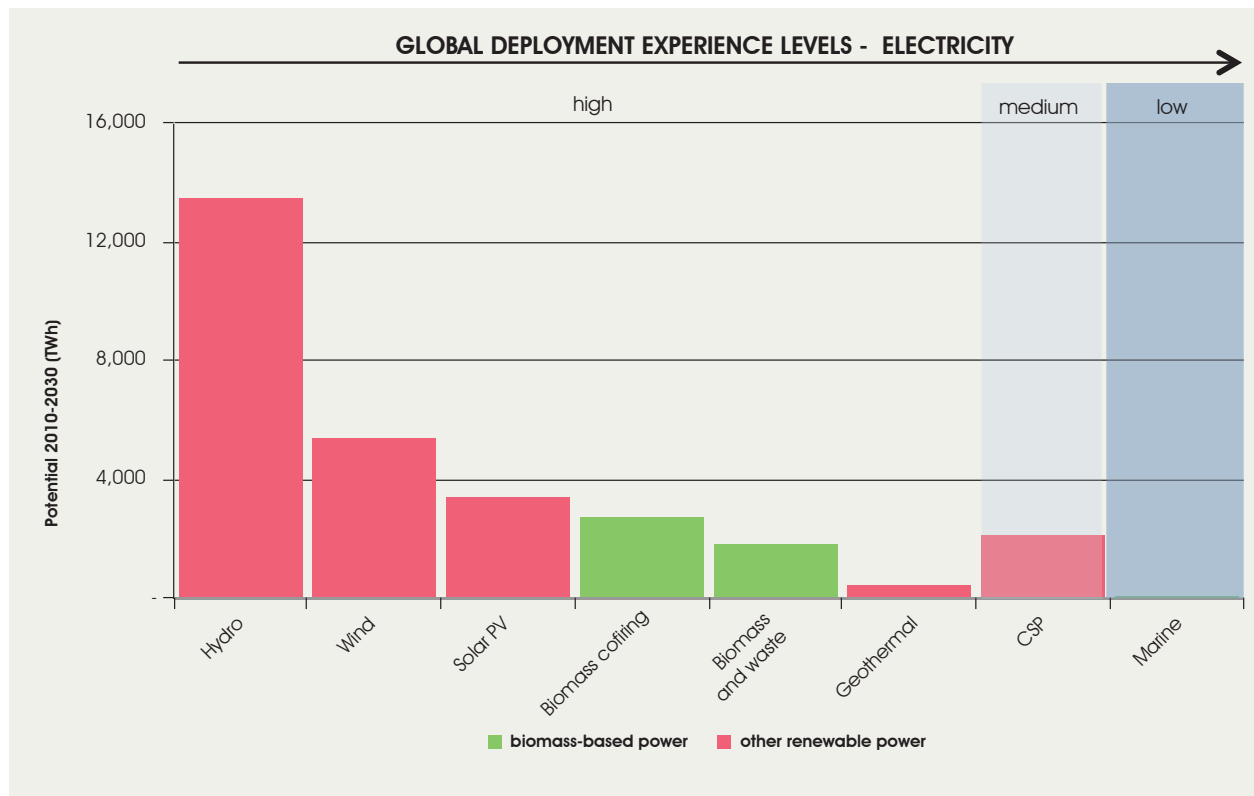
²⁵ UKERC (2011): Energy from biomass: the size of the global resource. An assessment of the evidence that biomass can make a major contribution to future global energy supply.

power are between 1,250-12,500 TWh/year, and several countries have stepped up their plans for geothermal power capacity with Japan planning around 4 GW in 2030 and Kenya up to 5 GW.

Finally, future projections for concentrated **solar power (CSP)** vary widely. The IEA roadmap on CSP suggests an installed capacity of 337 GW²⁶ by 2030. The RAES pathways require CSP capacity between 70-300 GW.

In general, the analysis suggests that up to 50% of power generation could be based on renewable energy by 2030, up from around 20% today. This implies around 60 EJ of renewable electricity and equals around 150 EJ of primary energy equivalents (Figure 8). The options are sub-divided according to their current global deployment levels, according to the renewable energy source (i.e. biomass-based or other forms of renewable electricity) and according to their potential between now and 2030. The categories for global deployment levels are indicative; the aim is to differentiate between RE technology options that are currently being used and RE technologies, especially those with high potential, that have received little attention to date.

Figure 8 - Renewable Energy Technology Options in the Electricity Sector.



Examining the range of RE options in the electricity sector suggests that hydro, wind, solar PV and biomass, followed by CSP, could contribute significantly to renewable power generation on a global scale. The role of geothermal and marine power on the 2030 horizon will be limited on a global scale and confined to regions and countries where these options can play a vital role.

The results also suggest that regional analysis is crucial. Although the potential for renewable energy power generation is substantial at a global level, renewable resources are not equally divided across regions. Therefore,

²⁶ IEA (2010): Technology Roadmap – Concentrating Solar Power

it is extremely important to consider the role of interregional trade of both electricity and biomass as a renewable resource. Furthermore, it is important to consider the role that renewable power generation can play in providing universal access to electricity in those regions that do not have any access to grids yet.

Smart Grids and Energy Storage

An important concern is the need for electricity storage and smart grids to support higher penetration levels of renewables in the electricity sector, including improvements in assessing and predicting the availability of renewable energy sources. These enabling technologies offer additional benefits, notably the promise of higher reliability and overall electricity system efficiency.

Smart grid technologies are already making significant contributions to electricity grids in Puerto Rico, Jamaica, Denmark, Singapore and elsewhere. They can play a role on any electricity grid, from isolated islands to very large integrated systems. However, these technologies also introduce a number of technical and non-technical risks. They are currently undergoing continual refinement and improvement but in many cases lack a clear performance history. Considering that there is currently only limited experience to draw on, it is important to consider the development and deployment of smart grids as one of the action items of this Roadmap.

5.2 Technology Options and Potentials in the Industry Sector

Current penetration levels of renewables in the manufacturing sector are less than 8% (excluding renewable power generation) and would need to be increased to around 12% in RAES-power and 19% in RAES-end-use scenarios. If renewable-based electricity and heat production used in the industry sector are included, the share of renewables in the manufacturing sector should increase from 18% in NPS to around 36% in both RAES-power and RAES-end-use scenarios. This section provides an overview of RE options in the different industrial sub-sectors.

Figure 9 - Overview of Renewable Energy Technology Options in Industry

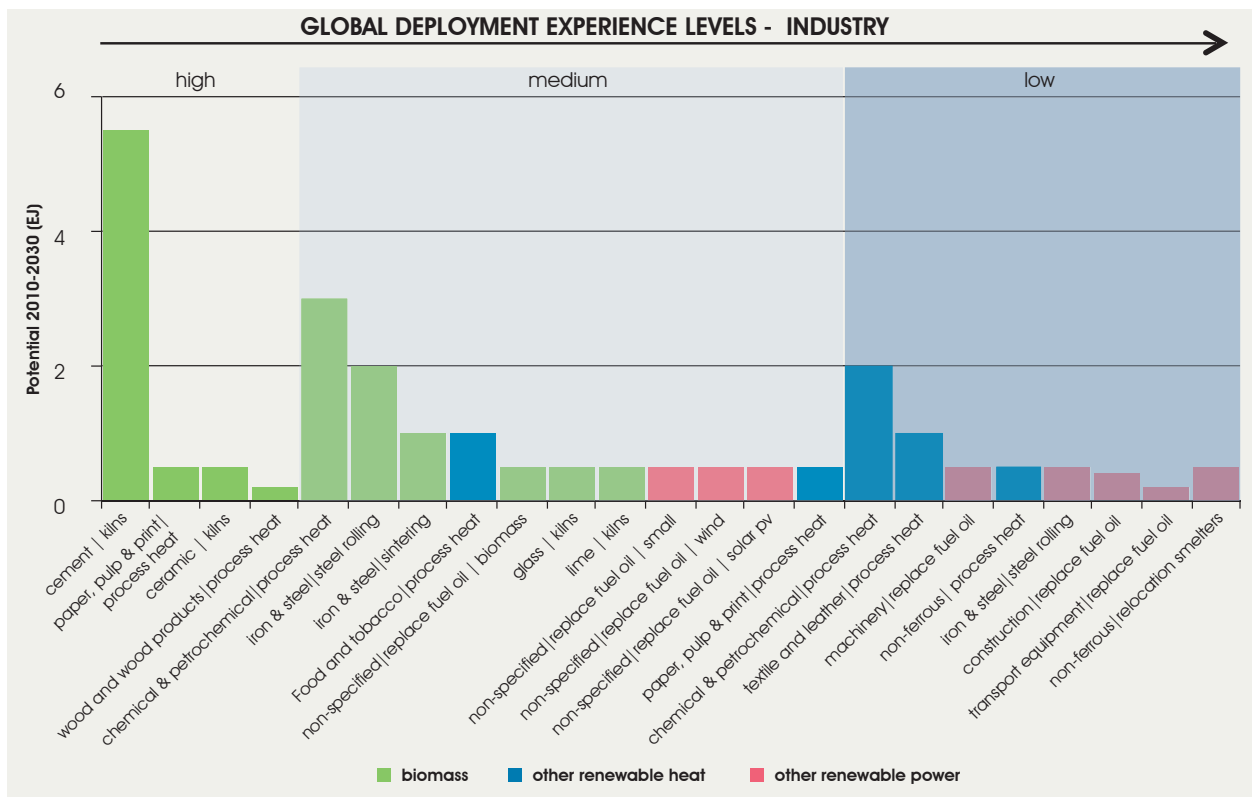


Figure 9 provides a global overview of the different renewable energy technology options in the industry sector. Again, the options are sub-divided according to their current global deployment levels and their renewable energy source (i.e. biomass, renewable heat, renewable power) and their potential between now and 2030.

The results show that, at the global level, only a small number of industrial sub-sectors have renewable energy options with a high potential. These sub-sectors include the cement sector (i.e. mostly biomass), the chemical and petrochemical sector (i.e. biomass and renewable heat) and iron and steel (i.e. biomass²⁷ and renewable power). Specific examples of sectoral action items are the use of biomass in cement kilns, charcoal substitution for coke in the steel sector and CSP for industrial heat applications in sunny climates. At the same time, there are quite a number of smaller industrial sub-sectors that have the potential to replace the use of fuel oil with renewable energy options or to replace space and process heat by solar heaters and heat pumps.

All in all, this overview suggests that RE options in the manufacturing sector could provide up to 20 EJ. However, about half of the renewable energy options in the industry sector use biomass in one way or another. Although the biomass potential is large—much larger, in fact, than is required to achieve the RAES pathways—it is important to consider the impacts that biomass use in the industrial sector might have on biomass consumption in the buildings, transport and electricity sector.

The bottom-up analysis also suggests that there are many renewable heat and energy options that are underexplored and that additional activities would be required to increase the share and use of solar water

²⁷ Suopajarvi & Fabritius (2012): Effects of Biomass Use in Integrated Steel Plant – Gate-to-gate Life Cycle Inventory Method. ISIJ International, Vol. 52 (2012), No. 5, pp. 779–787.

heating systems, heat pumps, on-site renewable power generation and other renewable applications in the industrial sector. Again, this is an important area for future action.

5.3 Technology Options and Potentials for the Transportation Sector

The transport sector can be divided into road vehicles (i.e. cars, trucks, buses, bicycles and tricycles), light rail/metro/trams for urban public transportation, railroads, aviation and shipping. The latter three are explicitly tracked in the IEA Energy Balances. In terms of energy use, road vehicles dominate with 73%. Road transportation energy use is split between diesel and gasoline (i.e. 30 EJ and 39 EJ, respectively), with an additional use of around 1 EJ of natural gas and 2 EJ of biofuels.

Figure 10 - Overview of Renewable Energy Technology Options in the Transport Sector

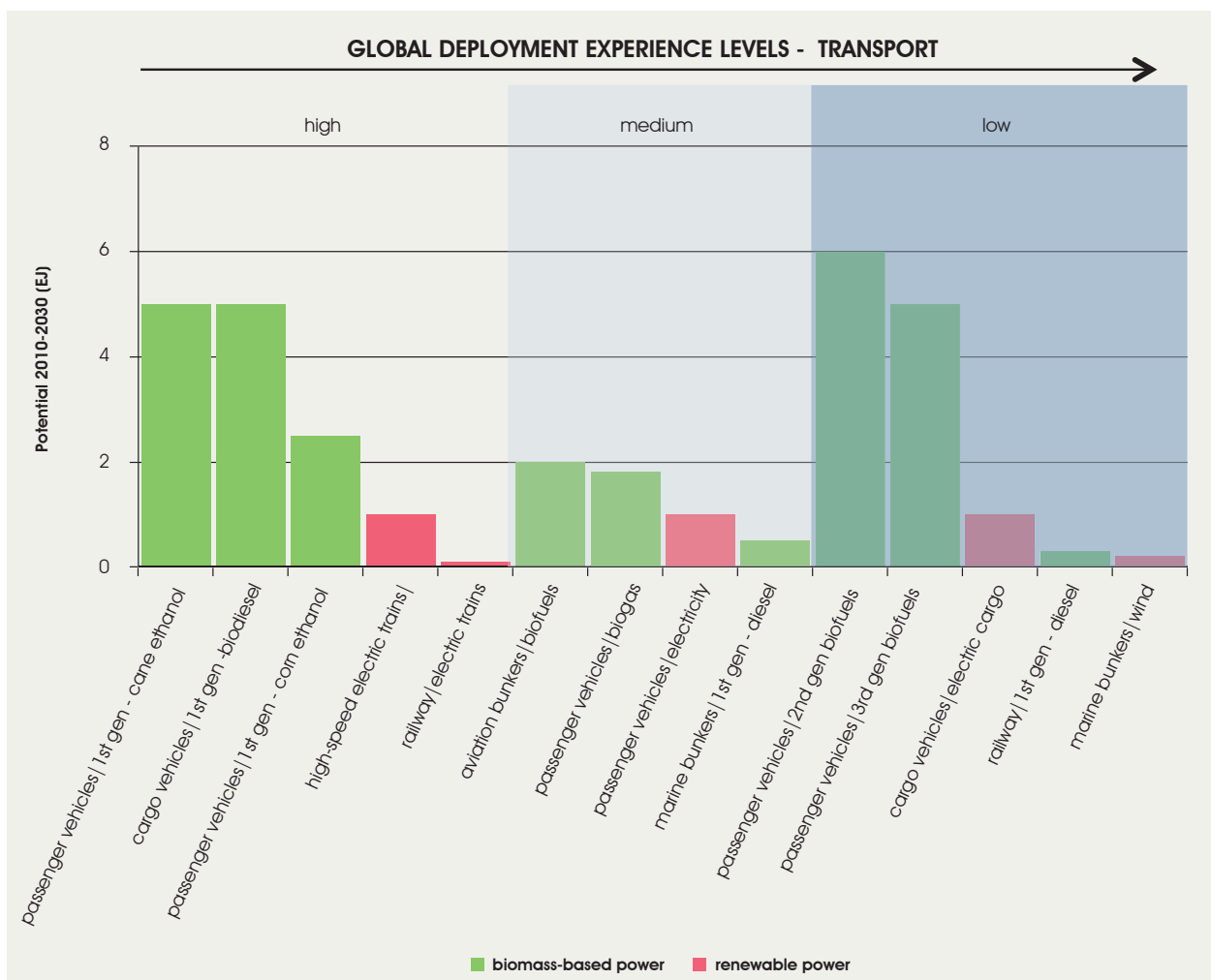


Figure 10 provides a global overview of the different renewable energy technology options in the transport sector. Again, a similar categorisation is used to differentiate biomass and renewable electricity options. The level of global deployment experience per option is indicative.

The results show that the most significant potential lies in the use of biomass for fuel, in particular in road transport. However, as Section 3.4 showed, biofuel projections vary widely, even among oil companies, and the actual size of the potential depends largely on political choices made across the globe. In 2008, the Shell Scramble scenario projected more than 20 EJ of biofuels in 2030 with about half coming from second-generation biofuels, while its Blueprints scenario projects that first-generation biofuels would grow to nearly 11 EJ and second-generation biofuels to around 1.5 EJ.²⁸

On the other hand, BP projects only 8 EJ with almost no second-generation biofuels. IEA's projections range between 4-11% for transport fuels, depending on the scenario, but with only limited data on the share of first-versus second-generation biofuels. In any case, with a projected doubling of demand, a share of around 9% would require a five-fold rise in the production volume to 600 billion litres (13 EJ) per year. Such growth would imply a tripling of first-generation ethanol production (i.e. to more than 300 billion litres/6 EJ per year) and a growth of second-generation production to nearly the same amount, or an even quicker expansion of first-generation biofuels. In other words, the potential for both first-generation biofuels, as well as for those technologies that have not yet been deployed at scale (e.g. second- and third-generation biofuels) is highly uncertain.

Compressed natural gas is an important fuel for road vehicles in some countries and biogas can supplement natural gas in this application. In the aviation sector, synthetic biofuels are already in use while natural oils have been used for test flights²⁹ and biofuels are an option for marine bunkering. However, the costs for these applications make the potential limited in the near- to medium-term.

Electrification is a possibility for road transport. Pike Research projects 1.7% EV market share worldwide by 2017 (which would imply around 1.3 million cars sold)³⁰, but projections beyond that hinge on assumptions regarding transport infrastructure changes and battery technology improvements. More significant energy savings and renewable energy shares are possible if cargo or trucks are loaded on trains for long distance transportation and if high-speed trains replace short haul aviation. However, the trend towards modal shift in most countries has registered a slight decline in the rail freight share in favour of road transportation, although the length of high-speed rail (HSR) tracks worldwide is undergoing extensive growth to meet increasing demand³¹. In sum, the impact of modal shift will probably be modest between now and 2030 but could gain importance on a longer time horizon.

The results of this preliminary analysis show that there is a considerable potential for biofuels and biogas to penetrate the transport sector beyond what would be required in the RAES pathways. However, the use and expansion of biomass has to be carefully negotiated with other uses. Further action is required to understand the biomass supply curves at a regional level and to create a better understanding of current biomass uses in each

²⁸ Kramer & Haigh (2009): No Quick Switch to Low-Carbon Energy, *Nature*, 462, 568-569.

²⁹ Lane, J. (2012): Aviation and Military Biofuels: New Thinking on Finance, Fuels.

³⁰ Pike Research (2012): Pike Pulse Report: Electric Vehicle Batteries.

³¹ IEA/UIC (2012): Railway Handbook 2012: Energy use and CO₂ emissions; World Watch Institute (2011): High-Speed Rail Networks Expand.

of the different end-use sectors. Furthermore, changes in the electrical system, in particular charging stations, would be one of the main requirements to allow for a larger system penetration by electric modes of transport.

5.4 Technology Options and Potentials for the Residential and Commercial Sectors

The buildings sector accounts for around 36% of total final energy consumption or 121 EJ. The commercial and public services sector accounted for 15.2 EJ of thermal energy in 2010. A variety of uses exist. Space and water heating, as well as cooking services, dominate energy use. In the residential sector, it is estimated that, overall, around 25 EJ is used for heating, 30 EJ for cooking and 13 EJ for hot water generation. Purchased electricity consumption is around 35 EJ, although the share of electricity consumption is expected to grow from around 28% to 37% in the IEA NPS³².

In colder climates (e.g. North America, Europe, Russia, northern China), building heating dominates and accounts typically for 50–60% of household final energy use. Hot water consumption is more widely spread and counts for around 20 GJ/household/year where available. However, in tropical climates where there is no significant need for space or water heating, cooling requirements and cooking energy use dominates. Exxon/Mobil projections foresee a continued shift in the sector from traditional biomass towards electricity and natural gas, estimating that electricity will provide 40% of the world's residential/commercial energy demand by 2040.

Finally, around 20 EJ of biomass is used for cooking, mostly inefficient, **traditional biomass use** in developing countries (i.e. mainly in Africa and Asia). This traditional biomass use is expected to decline substantially in the future because of efforts to enhance access to modern energy as discussed in Section 3.3. This shift has important implications for the RE options in the buildings sector in these two regions.

Another challenge in the buildings sector is inertia in the building stock. Two-thirds of the buildings that will be in use in 2030 already exist today. The percentage is even higher in high-latitude cold areas where heating demand is concentrated. Key RE technologies that can be used for heating and cooling are biomass boilers, solar thermal systems and heat pumps. These technologies currently have a low uptake but, due to their potential, could be increased significantly and rapidly in the coming years.

³² IEA (2012): World Energy Outlook 2012.

Figure 11 - Overview of Renewable Energy Technology Options in the Building Sector

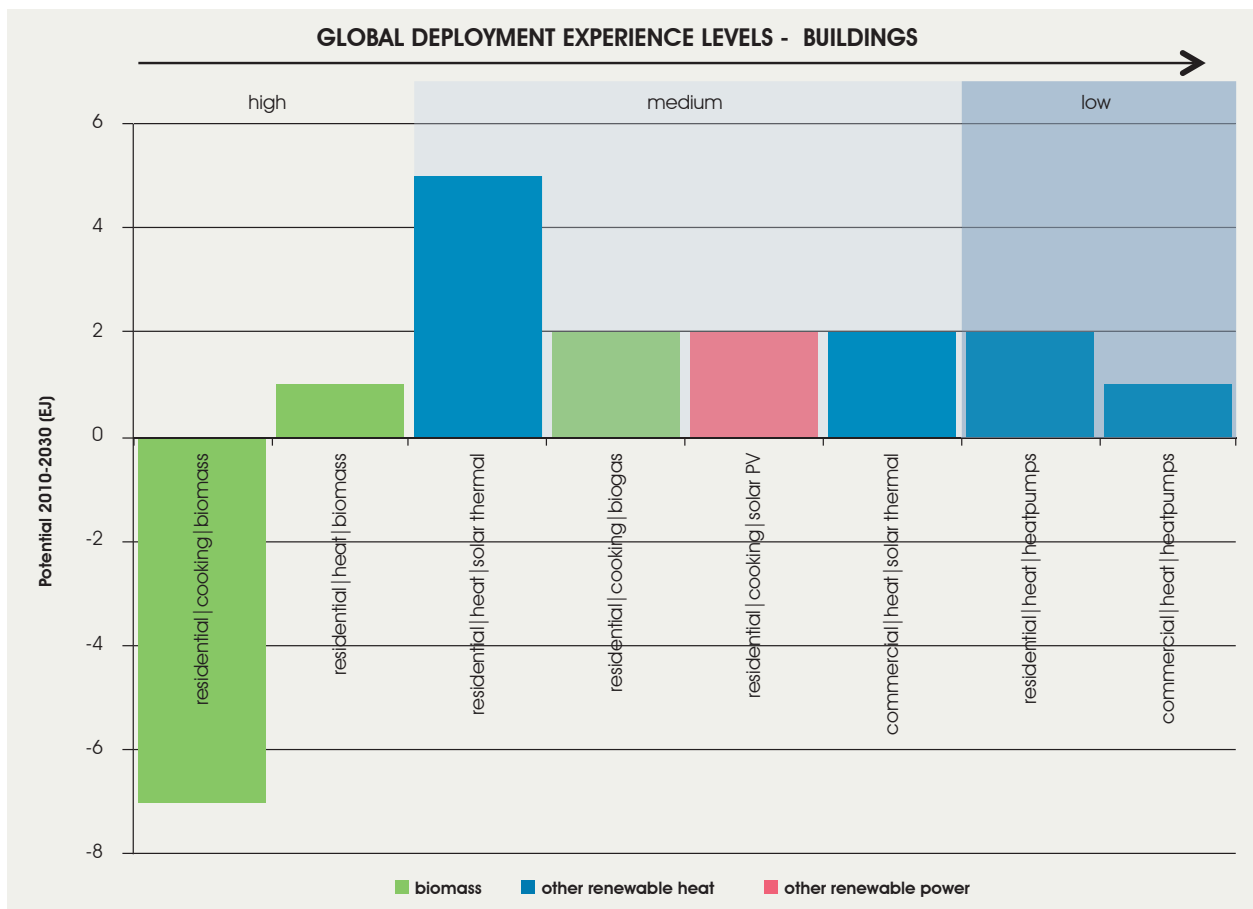


Figure 11 provides an overview of the different renewable energy technology options in the building sector with a similar categorisation as the other sectors.

The first observation is that there is a large potential to increase **biomass** resources by increasing the efficiency with which biomass is used for cooking and heating purposes in many regions of Africa and Asia. The potential to decrease traditional biomass use through efficient use exceeds the potential to increase biomass boiler use for space and water heating in both domestic and non-domestic markets. These boilers are already applied successfully in some European countries, but their widespread adoption suffers from relatively high upfront costs. Where local residues are available, the cost can be low but imported biomass pellets cost more than US\$ 20 per GJ.

Solar water heating systems also have a high potential. This option is not commonly used for space heating in cold climates, but they are increasingly popular in sunny regions like the Middle East, North Africa and southern Europe but also in China. In many regions, their lifetime average annual costs are lower than for electric and gas

heaters. Globally, 245 GW thermal capacity was in place by the end of 2011, yielding around 0.8 EJ useful heat per year. The solar water heating market is projected to grow more than ten-fold by 2030.³³

Solar cooling is another promising application for solar thermal systems since solar irradiation coincides with peak cooling demand. However, the market is still small: only about 750 solar cooling systems were installed in 2011 worldwide, including installations with small/household capacity (<20kW) and commercial capacity. IEA roadmap projections suggest that up to 0.5 EJ of solar cooling could be provided by 2030.

Finally, **geothermal** systems are popular in central and northern Europe for space heating. Globally, around 51 GW of geothermal heating capacity is in place, yielding around 0.4 EJ of heat per year³⁴. In 2011 the IPCC estimated around 3.2 EJ of ground source heat pumps by 2030. Air-to-air heat pump systems have gained ground as their efficiency has improved, even at low ambient temperatures. For all these systems, the shift towards renewable resources for seasonal heating or cooling can be supported by seasonal storage of heat and cold. Typically, below-ground aquifer storages are used for longer periods.

In conclusion, heating and cooling requirements in the building sector provide a considerable potential to increase the share of renewables, and a number of options have been explored. Overall biomass use in this sector will decline, releasing biomass resources for other types of energy use.

5.5 Preliminary Conclusions

This global sectoral analysis has shown that a wide range of technology options is available in both the electricity and other end-use sectors. At a global level, about 110 EJ of renewable power generation is possible but only 35 EJ is projected to be in use by 2030. This means that an additional 75 EJ is available for exploitation and that a renewable share of up to 50% seems possible. The rest of the potential is in the end-use sectors where deployment and uptake of renewable technologies seems to be significantly slower, but the potential is equally high (i.e. around 70 EJ). Although the potential for renewables in the end-use sectors is spread more widely, collectively - and combined with the power sector - they enable a total potential of 180 EJ. In other words, if all RE options were implemented, a 40% share of renewable energy in Total Final Energy Consumption, as projected by the IEA NPS, would be technically feasible by 2030. (See Table 2 for energy demand projections for 2030, and Tables 4 and 5 for an overview of renewable energy potential).

In terms of resources, biomass accounts for around 40% of the total potential. Indeed, biomass is used in all energy sectors (i.e. power generation, energy transformation, industry, transportation, residential, commercial and non-energy use). Thus, the growth of biomass use from around 40 EJ in 2012 to 100 EJ in 2030 (or 130 EJ if biofuels are counted in terms of primary biomass input) must be seen as a critical factor to achieve the SE4ALL renewables objective, particularly in the light of the limited biomass development due to agricultural productivity, the need to avoid major land-use changes, and the possible impacts on food prices, biodiversity and sustainable use of water resources. Biomass resource availability, and the sustainability of its use, needs to be investigated in more detail.

³³ IEA (2012): Technology Roadmap – Solar heating and cooling.

³⁴ Bundesverband Geothermie (2010): Geothermische Energie, nr. 67.

Table 5 - Indicative Renewable Energy Potential by Sector in Final Energy Equivalents, 2030

Key technology options	[EJ/yr]
Transformation sector power	110
Transformation sector other ^a	10
Industry sector ^a	20
Transportation ^a	25
Buildings ^a	15
<i>Total potential</i>	<i>180</i>

^aExcludes options to increase the share of renewable energy power in the end-use sectors.

Table 6 - Indicative Renewable Energy Solutions by Supply Category in Final Energy Equivalents, 2030

	[EJ/yr]
Biofuels	25
Biomass (power)	20
Hydro (power)	50
Wind (power)	20
Solar (power)	20
Other renewables (power)	2
Biomass (thermal & feedstock)	25
Geothermal (thermal)	3
Solar (thermal)	15
<i>Total potential</i>	<i>180</i>

This global sectoral analysis also shows that a long-term vision and timely implementation are essential for renewable technologies. Such timely implementation can avoid the lock-in of non-renewable options and the early (and expensive) retirement of existing capital stock. Short-term objectives may result in a significant mis-allocation of resources. For example, biomass co-firing in coal-fired power plants may help meet short-term renewable objectives but it falls short of a long-term, fully renewable-based power supply. On the other hand, premature implementation of renewable technologies can face higher investment costs and risks, at either the private or public level.

From a global perspective, there are a number of key action areas:

1. Much higher shares of renewables in the electricity sector will be required. Although the actual share may differ by region and country, action needs to be initiated to prepare for higher RE levels in this sector. Enabling technologies (e.g. smart grids, underground and subsea power lines, electricity storage) need further development.
2. The uptake of renewables for heat consumption has been slow and needs to be accelerated to achieve the SE4ALL objectives. For industrial applications, where successful replicable case studies are sometimes lacking or energy issues might not be the core concern, specific regional and sectoral support is required to facilitate a transition to much higher shares of renewable heat. In the building

sector, a transition towards the use of renewable heat should be planned with both new buildings and retrofit in mind.

3. Biomass emerges as a key option for many end-use sectors and is projected to account for nearly one-third of all renewable energy in 2030. However, the bioenergy potential is uncertain. A better understanding of its potential will be forthcoming through improved dialogue between experts from the energy, agriculture, forestry and food sectors.

6. Operationalising REMAP 2030

As outlined in Chapter 2, the REMAP process is designed to allow for open, transparent and inclusive engagement of IRENA Members and other relevant stakeholders. In 2013, IRENA hopes to operationalise this process further and develop REMAP into an evolving Roadmap to help guide its overall programmatic activities, updating and refining it in close collaboration with governments, technical experts and involved stakeholders.

To support IRENA's role as the renewable energy "hub" within the SE4ALL initiative, REMAP 2030 could become an important compass to guide and synthesise the growing number of individual and collective activities being carried out globally under the SE4ALL umbrella. To address all these topics, the IRENA Roadmap process is expected to require significant resources in the years to come, in addition to the contributions from Members and other stakeholders.

6.1 Stakeholder Engagement in the Feasibility Study

The feasibility study presented in this introductory report offers a first estimate benchmark for the activities required at a global level to achieve the SE4ALL objectives and the possible implications of these global efforts at the regional level. The decisions regarding baseline year, database use and indicator choice for this study have been made in close cooperation with other international organisations engaged in the development of the *Global Tracking Report* for the renewable energy objective of the SE4ALL initiative. Furthermore, the global assumptions regarding universal access to modern energy services, increased electrification and renewable energy options have been informed by other existing scenarios and roadmaps or have been developed on the basis of the IEA's Energy Technology Systems Analysis Programme (ETSAP) and IRENA's Technology Briefs.

In 2013, IRENA intends to update this feasibility study, incorporating relevant activities that have taken place in 2011 and 2012. Furthermore, the feasibility study needs to be improved to consider in greater detail the regional and national dimensions of the challenge, which varies considerably from setting to setting. Stakeholder engagement, including peer review of the Technology Briefs, assessment of the basic assumptions of the feasibility study and verification of the results, will provide an important means to ensure consistency with global scenarios and projections developed by other global or regional organisations.

6.2 Stakeholder Engagement in the Gap Analysis

A gap analysis will be a crucial step to accurately determine the level of challenge associated with doubling the share of renewables globally. In 2013, IRENA intends to request its Members to nominate a national representative to provide and verify data on national renewable energy plans and projections. National representatives would be requested to provide and/or verify energy demand projections for end-use sectors between 2010 and 2030 and provide possible ranges for the share of different RE technologies in the electricity and end-use sectors in 2030. In many cases, it is possible that the national representative will be someone different than IRENA's national focal point.

To support this process, IRENA is developing an easy-to-use spread sheet containing relevant data available in the public domain. A number of countries have already offered to act as test cases to ensure that these spread sheets are user-friendly, compatible with country reporting in other international activities, and that they are compatible with available information in both large and small countries. IRENA intends to collect data in

an annual cycle with data sheets sent out in the first quarter of each year. Subsequently, country data will be integrated into REMAP 2030 and a draft report sent out for review in the third quarter of each year.

From the national representatives, it is expected that they have pertinent knowledge and access to data on projections for both energy production and demand over the period 2010-2030, as well as insights and expertise on the technical, economic and political feasibility of different pathways for renewable energy deployment in the electricity and end-use sector, as well as how these different sectors and renewable energy technologies interact. While these national representatives are not expected to carry out any new analyses, they should be able to provide existing material and key recent studies to be considered in the context of the Roadmap.

For those countries that do not have accurate data on their current status or future projections for energy demand and renewable energy potential, REMAP will use the proposed plans for an IRENA network of data focal points and data training sessions to support, facilitate and improve capabilities for such data collection and analysis.

6.3 Stakeholder Engagement in the Sectoral-Regional Analysis

Chapter 5 provided an example of a preliminary sectoral analysis at the global level. Members' experts who deal with plans to increase RE are invited to consider these results, explore how specific technology options can contribute their national RE plans and propose additional options relevant to their countries. They are encouraged to provide feedback, *inter alia*, on the overall approach, the relevance of the identified options for their own countries, technology solutions that may have been overlooked and the accuracy of cost estimates.

In 2013, REMAP 2030 intends to develop more detailed sectoral analyses at a regional level, including a more substantiated methodology to identify, evaluate and prioritise RE options. Such a methodology should consider not only the potential and costs associated with different options but also examine specific regional implementation conditions.

At the second REMAP workshop in November 2012, participants suggested that the methodology include parameters like capital costs of new renewable installations, the affordability of modern energy services, the bankability of projects, the cost distribution among national governments, international donors and companies, and the interaction between renewables with specific sectors of the economy (e.g. tourism). Possible discrepancies between regional options and the phasing-out of traditional biomass should also be considered. Finally, specific action items, timelines, milestones and verification mechanisms should be included in each of the selected options to evaluate progress and incorporate lessons learned.

As mentioned in Section 2.4, IRENA advocates an active, in-kind contribution from its Members for sectoral-regional analysis of action items. For each world region, IRENA looks to its Members to nominate national experts (i.e. senior energy analysts) from relevant national organisations who will assume responsibility for the national and regional contributions to the analysis.

In total, IRENA aims to build a global team of 10 to 15 senior energy analysts who are ready to work in close cooperation with its staff to build the Roadmap, according to a work programme to be proposed by IRENA, jointly discussed and agreed upon.

To cover all regions, IRENA will use regional aggregations to supplement those regions and countries that are not in the position to be part of this initiative. Furthermore, it is envisioned that special interest groups will be organised to address interregional matters (e.g. electricity or biomass trade) or specific conditions affecting the range of RE options (e.g. islands or small countries). Through IRENA's future workshops on regional and technology roadmaps, some important action items may be identified.

7. Conclusions

1. A doubling of the renewables share is achievable and requires action in all regions. The magnitude of the challenge will depend on progress made on energy efficiency and universal access. Increasing the efficiency of traditional uses of biomass will free up resources, but reduce the overall share of renewables compared to current levels. On the other hand, increased energy efficiency will reduce the absolute growth required to achieve a doubling of the renewables share.
2. Due to the inertia in the energy system and the long lead time required for development of new projects and investments in RE technologies, immediate action is required at a global scale. However, the challenges will differ substantially among the different countries and regions. A global doubling does not imply a doubling for each individual country.
3. IRENA's global Renewable Energy Roadmap—REMAP 2030 - can provide a global framework for renewable energy activities in the context of SE4ALL, and can become a valuable tool for IRENA Members, allowing them to participate in setting a global agenda assessing the actions taking place in different regions around the world and integrating them into a single framework.
4. The support for REMAP 2030 has grown significantly in a short period of time. Through a number of workshops, IRENA has discussed and refined the REMAP process and elicited support from at least 18 countries around the world.
5. The REMAP process will consist of three steps:
 - a. A **feasibility study** will evaluate the level of challenge and develop associated pathways as first estimate benchmarks for global and regional action. IRENA's preliminary analysis revealed that action in all regions will be required to achieve the SE4ALL objective for renewable energy.
 - b. A **gap analysis** is required to compare national renewable energy plans and projections with the actions required to achieve the three SE4ALL objectives. For 2013, IRENA Members are invited to nominate national experts to provide data on national renewable energy plans and projections for 2030.
 - c. A **sectoral-regional analysis** will fill the gap with sectoral action items specified at a interregional and regional level. In 2012, a preliminary global sectoral analysis was conducted and for 2013 IRENA invites Members to assign national experts to actively contribute and carry out these sectoral analyses at a regional level.
6. Future “action areas” revealed by IRENA's global preliminary sectoral analysis include:
 - a. Accelerated investments in renewable power generation. The share of renewables in the electricity sector will have to double to achieve the SE4ALL objective. Transforming the electricity sector will require upgrades of old grid systems and, at the same time, provide opportunities for new solutions to be implemented.
 - b. Acceleration of renewable heat applications in the buildings and industry sector. Heat demand in these two end-use sectors account for almost one-third of global energy use. It will be crucial to tap the whole range of renewable heat options to achieve the SE4ALL target.
 - c. Biomass availability and cost assessments. Currently, biomass accounts for almost 80% of all renewables and its role will continue to grow as biomass-based renewable applications in end-use sectors (e.g. transport, buildings and industry) are expanded.

7. In 2013, IRENA will facilitate the Roadmap process by developing tools to evaluate the level of challenge and progress towards achieving the third SE4ALL objective, collecting required information for consecutive gap analyses and developing and providing tools to prioritise and rank the sectoral action items at a regional level.
8. The most important and far-reaching conclusion is that the REMAP 2030 project can succeed *only* if it is fully owned and developed by IRENA Members.

8. Further References to IRENA Documents

The results of the REMAP 2030 project are supported and guided by a number of documents that have been prepared based on IRENA's Roadmap activities in 2012:

IRENA (2011) Scenarios and Strategies for Africa

IRENA (2012) Workshop proceedings: "Renewables for a New Product Mix in 2050", Brussels, 19 April 2012

IRENA (2012) Workshop proceedings: "Renewables for Resilient Cities: A Roadmap to 2050", Bonn, 12 May 2012

IRENA (2012) Workshop proceedings: "Renewables for Small, Growing Cities in Africa: A Roadmap to 2050". Naples, 2 September 2012

IRENA (2012) Workshop proceedings: "Doubling the Share of Renewables: A Roadmap to 2030", St. Julians, 5 September 2012

IRENA (2012) Workshop proceedings: "IRENA's Global Renewable Energy Roadmap (REMAP 2030)", Abu Dhabi, 14 November 2012

IRENA (2012) Workshop proceedings: "Renewables Deployment in Small- and Medium-sized Enterprises in the Manufacturing Sector in South Asia", New Delhi, 21-22 November 2012

IRENA/IEA-ETSAP (2013) Technology brief: Biomass Co-combustion

IRENA/IEA-ETSAP (2013) Technology brief: Bioethylene

IRENA/IEA-ETSAP (2013) Technology brief: Biomethanol

IRENA/IEA-ETSAP (2013) Technology brief: Biofuels

IRENA/IEA-ETSAP (2013) Technology brief: Desalination using Renewables

IRENA/IEA-ETSAP (2013) Technology brief: Electricity Storage

IRENA/IEA-ETSAP (2013) Technology brief: Heat Pumps

IRENA/IEA-ETSAP (2013) Technology brief: Solar Heating and Cooling for Industry

IRENA/IEA-ETSAP (2013) Technology brief: Solar Heating and Cooling for the Buildings Sector

Annex A: Data

Data for Figure 3: Share of renewable energy options in Total Final Consumption (TFC)

	2010	NPS	AS	AES	RAES - power	RAES - end use
Traditional biomass heating and cooking	9%	7%	0%	0%	0%	0%
Modern biomass heating and cooking	1%	1%	3%	4%	3%	3%
Modern biomass industry heat (co-gen)	2%	3%	3%	3%	3%	4%
Modern biomass industry feedstock	0%	0%	0%	0%	0%	1%
Solar heat industry/buildings	0%	1%	1%	1%	1%	3%
Biofuels	1%	2%	2%	2%	2%	4%
Biomass power co-combustion coal	0%	0%	0%	0%	1%	0%
Biomass power (incl cogeneration)	0%	1%	1%	1%	1%	1%
Hydro power	3%	4%	4%	4%	7%	7%
Wind power	0%	2%	2%	2%	5%	3%
Solar power	0%	1%	1%	1%	4%	2%
Geothermal power	0%	0%	0%	0%	1%	0%

Data for Figure 4: Share of renewable energy options in Total Final Energy Consumption (TFEC)

	2010	NPS	AS	AES	RAES- power	RAES - end use
Traditional biomass heating and cooking	10%	7%	0%	0%	0%	0%
Modern biomass heating and cooking	1%	1%	4%	3%	3%	3%
Modern biomass industry heat (cogeneration)	3%	3%	3%	3%	4%	5%
Modern biomass industry feedstock	0%	0%	0%	0%	0%	0%
Solar heat industry/buildings	0%	1%	1%	1%	1%	4%
Biofuels	1%	2%	2%	2%	3%	5%
Biomass power co-combustion coal	0%	0%	0%	0%	2%	0%
Biomass power (incl co-generation)	1%	1%	1%	2%	2%	2%
Hydro power	4%	5%	5%	8%	8%	8%
Wind power	0%	2%	2%	3%	5%	3%
Solar power	0%	1%	1%	1%	5%	2%
Geothermal power	0%	0%	0%	0%	1%	0%

Data for Figure 5: Share of renewable energy options in Total Primary Energy Demand – substitution method (TPED)

	2010	NPS	AS	AES	RAES- power	RAES- end use
Traditional biomass heating and cooking	6%	4%	0%	0%	0%	0%
Modern biomass heating and cooking	0%	0%	3%	1%	2%	2%
Modern biomass industry heat (co-generation)	1%	2%	2%	2%	2%	2%
Modern biomass industry feedstock	0%	0%	0%	0%	0%	1%
Solar heat industry/buildings	0%	0%	0%	0%	1%	2%
Biofuels	1%	2%	2%	2%	3%	6%
Biomass power co-combustion coal	0%	0%	0%	0%	2%	0%
Biomass power (incl co-generation)	1%	1%	2%	2%	2%	2%
Hydro power	6%	7%	7%	11%	10%	10%
Wind power	1%	3%	3%	4%	7%	5%
Solar power	0%	1%	1%	2%	6%	2%
Geothermal power	0%	0%	0%	0%	1%	1%

Annex B: List of Acronyms

AES	Access and Efficiency Scenario
AS	Access Scenario
CSP	Concentrated Solar Power
CCS	CO ₂ Capture and Storage
EIA	Energy Information Administration (USA)
EJ	Exajoule
EPIA	European Photovoltaic Industry Association
EREC	European Renewable Energy Council
ETSAP	Energy Technology Systems Analysis Programme (IEA)
EWS	Efficient World Scenario
FAO	Food and Agriculture Organization
GEA	Global Energy Assessment
GW	Gigawatt
GWEC	Global Wind Energy Council
HSR	High-Speed Rail
IEA	International Energy Agency
IIASA	International Institute of Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
NGO	Non-Governmental Organisation
NPS	New Policies Scenario (IEA)
OPEC	Organization of Petroleum Exporting Countries
OMA	Office for Metropolitan Architecture (Netherlands)
RE	Renewable Energy
REEEP	Renewable Energy and Energy Efficiency Partnership
REN21	Renewable Energy Policy Network for the 21st Century
RAES	Renewables, Access and Efficiency Scenario
TFC	Total Final Consumption
TFEC	Total Final Energy Consumption

TPED	Total Primary Energy Demand
TWh	Tera Watt hour
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization



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