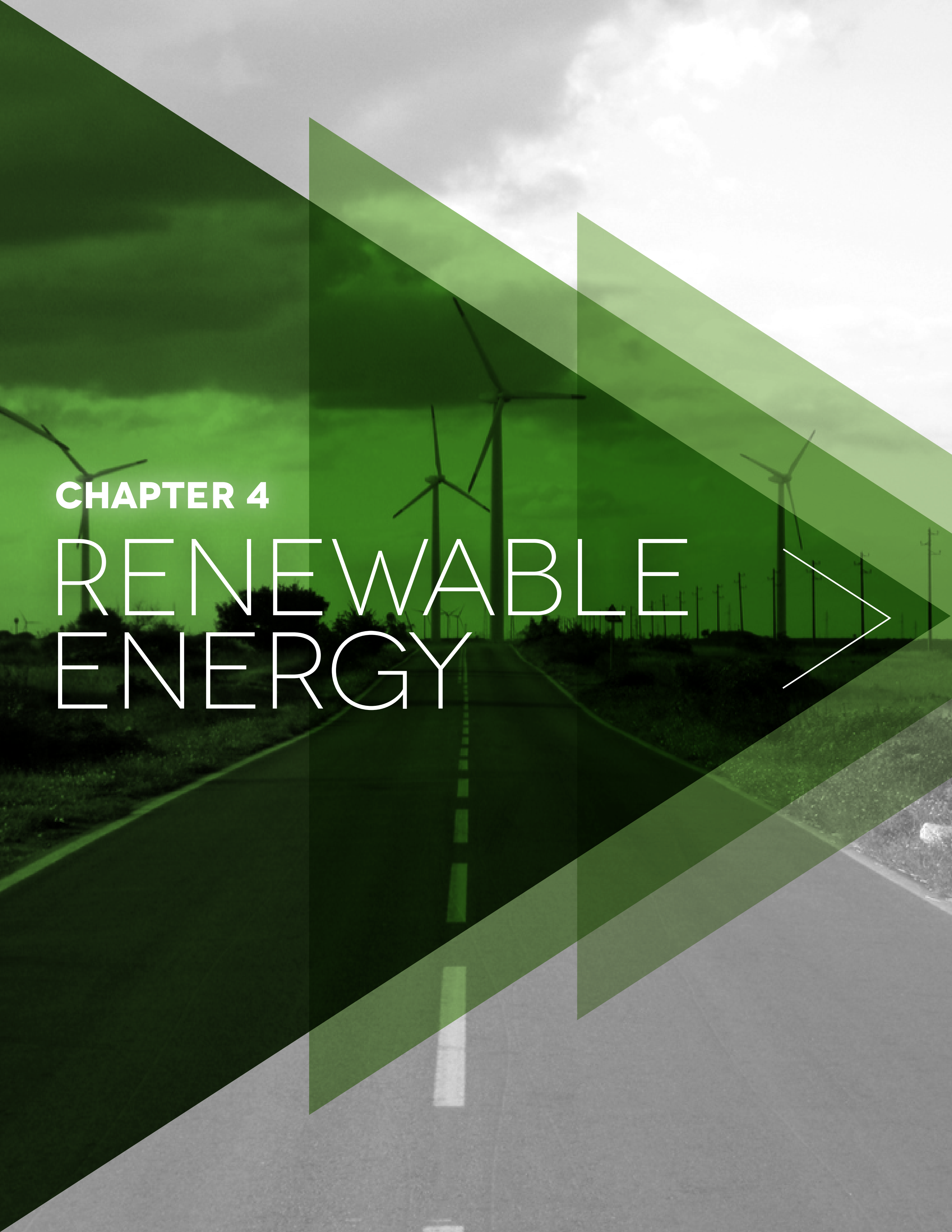
CHAPTER 4

RENEWABLE ENERGY



CHAPTER 4: RENEWABLE ENERGY

One of the three objectives of the UN Secretary General under the Sustainable Energy for All (SE4ALL) initiative is to double the share of renewable energy in the global energy mix by 2030, with an emphasis on promoting sustainable forms of renewable energy.

This chapter proposes a methodology for establishing a starting point against which future global progress can be measured and provides an indicator framework for tracking that progress. The chapter also describes global trends in renewable energy and discusses market growth, barriers, high-impact opportunities, as well as future scenarios and the scale of the challenge.

SECTION 1: METHODOLOGICAL CHALLENGES IN DEFINING AND MEASURING RENEWABLE ENERGY

There are various definitional and methodological challenges in measuring and tracking the share of renewable energy in the global energy mix:

- Defining renewable energy, taking into account sustainability considerations
- Data availability, collection, and management issues
- Determining what convention to use for measuring the share of renewables in the global energy mix
- Measuring other relevant indicators

Defining renewable energy

While there is a broad consensus among international organizations, government institutions, and regional commissions on what constitutes renewable energy, these groups employ legal or formal definitions that vary slightly in the types of resources and sustainability considerations included.

The International Renewable Energy Agency (IRENA) has a statutory definition, ratified by 108 members (107 states and the European Union) as of February 2013: "renewable energy includes all forms of energy produced from renewable sources in a sustainable manner, including bioenergy, geothermal energy, hydropower, ocean energy, solar energy and wind energy."

The International Energy Agency (IEA) defines renewable energy resources as those "derived from natural processes" and "replenished at a faster rate than they are consumed" (IEA 2002, OECD, IEA and Eurostat, 2005). The IEA definition of renewable energy includes the following sources: "electricity and heat derived from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources" (IEA 2002).

These definitions vary in the type of sources included and in whether sustainability considerations are explicitly incorporated. These differences illustrate the fact that there is no common or global definition of renewable energy.

For the purposes of the SE4ALL tracking framework, it is recommended that the definition of renewable energy specify the range of sources to be included, embrace the notion of natural replenishment, and espouse sustainability. But data are not currently available to distinguish whether renewable energy – notably biomass – has been sustainably produced. Until adequate data become available, it is thus recommended that renewable energy be defined and tracked without the application of specific sustainability criteria. The SE4ALL initiative will support the strengthening of methodologies for tracking sustainability across all renewable energy sources.

Ensuring sustainability

It is clear that the SE4ALL initiative should encourage renewable energy where this contributes to overall sustainable development, taking into account all three pillars of sustainability—environmental, economic, and social. In general, the renewable technologies score high in terms of sustainability criteria, but energy production from these sources inevitably has both positive and negative environmental, economic, and social impacts, which must be carefully managed. These considerations are most pronounced in the case of bioenergy and hydropower, but are also relevant to the widespread deployment of other technologies. Assessment methodologies and best practice guidelines that can be used to manage these impacts are often available at the national level. But there are no internationally accepted sustainability criteria covering the major technologies, and it is therefore very difficult to distinguish between sustainable and less-sustainable deployment.

Bioenergy

Bioenergy is a very complex field; concerns associated with the sustainability of its production and use require a case-by-case assessment, considering feedstock, location, production methods, land use, conversion pathways, infrastructure, and so on. These concerns span all types of bioenergy, from traditional uses of biomass in the residential sector to bioenergy used in the transport sector and power generation, across the three pillars of sustainability. For example, the greenhouse gas (GHG) balance needs to be carefully evaluated on a case-by-case basis with proper assessment of the full life cycle of GHG emissions, from land use conversion to end use. There are some unresolved methodological issues, such as how to account for the indirect impacts of bioenergy production on land use (that is, indirect land use change, ILUC). Potential economic and social impacts, including on food security, must also be carefully considered. Substantial progress has been made in identifying the key sustainability issues and creating methodologies for impact assessment, notably through the work of UN Energy [1] and the Global Bioenergy Partnership (GBEP).[2] The GBEP has established international consensus around sustainability indicators for bioenergy. While the inclusion of sustainability considerations for bioenergy is still under development in the legal and regulatory regimes of many countries, improved frameworks are beginning to emerge.

Bioenergy provides around 14 percent of global energy consumption. Some 70 percent of this biomass energy is believed to be consumed in developing countries for cooking and heating with open fires and very inefficient stoves, the traditional uses of biomass. It is widely recognized that these uses, including the inefficient production and use of charcoal, lead to deforestation and are closely linked to indoor air pollution (Goldemberg 2004).

But biomass can also be used to produce household-level energy more efficiently via improved cooking and heating appliances. It can also be used to produce heat efficiently for commercial and industrial needs, as well as electricity and transport fuels. Ambitious renewable energy scenarios rely heavily on these "modern" forms of bioenergy use to meet their goals, but some also recognize that traditional uses of biomass will continue to be an important energy source for many people for some time to come. Indeed, it is not possible to distinguish, using available data, the extent to which bioenergy is used by modern or traditional conversion methods, at least as far as the residential sector is concerned. For example, in some IEA analysis it is assumed that the use of bioenergy in the residential sector of non-OECD (Organisation for Economic Co-operation and Development) countries is made up of "traditional biomass," whereas in the OECD countries it counts as modern bioenergy. This is obviously a simplification given the fact that informal use of wood fuels in low-efficiency appliances also occurs in many OECD countries.[3] Clearer criteria are needed. For example, should the use of biomass in an improved stove be counted as "sustainable" use? In addition, data on household use of biomass for fuel is difficult to establish with any precision, with different methodologies and estimates providing a range of differing results. Within the monitoring process associated with the SE4ALL initiative, it would clearly be desirable to distinguish between "sustainable" and "unsustainable" bioenergy use. While the GBEP framework of sustainability indicators would provide a good basis for making this distinction, no internationally accepted standards based on these indicators have yet been developed. Given the additional difficulties of collecting appropriate information in the field, such distinctions are not feasible at this stage.

1 UN Energy Bioenergy Decision Support Tool at http://www.bioenergydecisiontool.org.
2 http://www.globalbioenergy.org.
3 Note that it is possible to estimate traditional biomass use based on data from national household surveys. But this approach require assumptions on a set of issues; for example, these surveys report on what is the primary fuel being used by households but do not provide volume or quantity or the actual total level of fuel household consumption. Thus, the proportion of primary fuel could vary widely depending on the number and extent of consumption of other fuels used. Also, the actual household consumption needs to be assumed.

Since it is not currently possible to distinguish consistently between the sustainable and less-sustainable ways of using bioenergy (including traditional biomass) the SE4ALL initiative will track all types of bioenergy uses. But progress toward the target should be monitored in as disaggregated a manner as the data allow so that trends can be assessed.

Hydropower

There is a degree of international consensus around sustainability considerations for hydropower. For example, the IEA Hydropower Agreement published guidelines on "Hydropower and the Environment" in 2000, which were updated in 2010 (IEA 2000; 2010). The World Commission on Dams also produced a "Decision Making Framework" to guide planners in protecting people from the negative impacts of water and energy projects. Brazil has produced a detailed manual for river basin inventory studies and management. In 2010 the International Hydropower Association published the "IHA Sustainability Assessment Protocol" based on a multistakeholder development process involving representatives from social and environmental nongovernmental organizations (NGOs), governments, commercial organizations, development banks (including the World Bank), and the hydropower sector (International Hydropower Association 2010).

Other technologies

For other technologies, guidelines are established on a national or regional basis in the absence of international consensus. To encourage the highest levels of sustainability in the deployment of all renewables, a necessary first step is to establish internationally accepted indicators and protocols for the sustainability of each technology. Although it would be desirable to differentiate between sustainably and unsustainably produced renewable energy—in line with the overall aim of the initiative—this is not possible in the short term, based on existing data and protocols. The SE4ALL initiative presents a unique opportunity to improve existing methods of data collection and enhance the available knowledge base as a step toward the ability to track progress on sustainability.

Data availability, collection, and measurement

Availability

Tracking progress toward the renewable energy SE4ALL objective requires accurate, consistent data on both overall energy production and use of energy from all sources.

Many organizations and companies generate reports on global energy statistics. But only three organizations collect primary global and country-level data on energy consumption and production:

- IEA
- UN
- World Health Organization (WHO) (focusing particularly on household energy use)

Many other institutions and companies use these IEA, UN, and WHO databases, and complement them with both primary data and secondary information to create customized databases and analyses (for example, Enerdata, US-EIA, BP, and REN21; see table A1.1 in annex 1).

The IEA compiles a comprehensive and comparable set of energy data that is used as the reference source for most reporting of global energy demand and renewable energy production. The IEA database contains comprehensive and accurate data for OECD countries and also covers about 75 non-OECD countries that provide their national energy balances to the IEA. For 10 other countries, tertiary sources and estimations are used to compile the data. Data from some smaller developing countries are not individually reported in the IEA statistics and are based on extrapolations of country data provided by the UN Statistics Division.

The UN database contains long-time series data for almost all countries, but is more heterogeneous and not available until sometime after the IEA information is reported. The WHO collects primary data on energy use but mainly at the household level.

Collection and measurement

As discussed above, the major issue affecting the contribution from renewable energy to the global energy mix relates to the use of biomass for heating and cooking. In many countries this is an informal sector, and data availability and accuracy are acknowledged to be poor and subject to large errors. Different data sources and methodologies produce varying estimates. This makes it very difficult to establish the starting point and to track progress toward the goal with any precision. So there is an urgent need to improve the overall quality of data on bioenergy use, particularly in regard to heating and cooking, and to refine the definitions and classifications relating to this sector.

There are some other categories of renewable energy production that are not fully or consistently represented in the data. While these data gaps may not significantly affect the overall proportion of renewables within the current energy mix, as new technologies are more widely deployed their shares may become more significant and would need to be better monitored in any comprehensive tracking system. These categories include:

- Small, distributed grid-connected generation, such as small-scale photovoltaic (PV) or wind and solar water heating. These may not be included in statistical reports, and a correction based on installed capacity may be needed. Indeed, current practice is inconsistent across countries.
- Renewable energy production that is estimated based on installed capacities may be inaccurate, particularly because some systems may be installed but not producing energy effectively.
- Biofuels are currently measured at final, not primary, energy levels.
- Off-grid and mini-grid electricity generation, which are often not captured by energy statistics.
- Direct production of heat (for example, by solar water heaters). Contribution of direct use of solar heat is often estimated based on installed capacity of solar collectors, but there are inconsistencies in how the data is collected and reported.
- Waste fuels, where the methodologies do not consistently differentiate between renewable (biogenic) and other waste fractions.
- The treatment of heat pumps within the statistics is somewhat complex, and there are inconsistencies in how the net energy produced by the heat pump is accounted for, and whether this is classified as renewable.
- "Passive solar" energy makes a substantial contribution to energy needs, both in industrial processes (salt production, food processing, and drying) and buildings (passive solar heating and lighting). This contribution can be further optimized by careful design, reducing the need for fossil fuels. But it is difficult to explicitly identify the contribution from passive solar, and so it is usually excluded.
- Interregional integration of electricity or biomass trade.

Given the need to develop a comprehensive and comparable analysis at a global level, we recommend that the IEA energy statistics—complemented with UN data for the smaller non-OECD countries—be used as the basis for tracking progress toward the target. Furthermore, a review of the methodologies for collecting data and reporting on the sources listed above is needed to ensure that the share of energy from these sources is accurately represented in the energy statistics as their importance grows.

Primary and final energy

To track the share of renewables in the global energy mix it is necessary to define at which level of the energy balance the measurement must be taken. The choice has a material impact on the starting and target levels of deployment. Tracking can be done at the primary energy level or on the basis of final energy.[4] Each of the choices has different advantages and disadvantages.

[4] In some countries, such as the United States, the term "delivered energy" is used, which is defined as the energy value of the fuel or electricity that enters the point of use (for example, a building).

Primary energy accounting

Many energy production statistics (for example, those used by the IEA, Eurostat, and the U.S. Energy Information Administration [EIA]) are based on a physical energy content or primary energy accounting method. In these systems, energy is accounted for in the form in which it first appears. For fossil fuels and bioenergy, the energy content in the fuels before conversion is used as the measure. For nuclear and renewable energy, the primary energy content is calculated based on a number of different conventions. The comparison between the roles of renewables and other sources is obscured by assumptions about the efficiencies of the various processes in these conventions. Wherever high efficiencies are used, the share of renewables in the overall system is underrepresented in terms of the useful energy produced.

There are, in fact, three different conventions for presenting the primary energy data, which can affect the overall size of the global energy mix and of the renewable share within it. These are:[5]

- The physical energy content method (used by IEA and Eurostat)
- The partial substitution method (used by EIA)
- The direct equivalent method (used in some Intergovernmental Panel on Climate Change [IPCC] reports)

Table 4.1 provides a comparison of total world energy supply in 2010 that illustrates the differences in the proportion of renewables in the energy mix estimated using these methodologies.

The advantage of estimating primary energy is that figures are based directly on the physical measurement of the energy content in fossil fuels. The disadvantages are that for low-carbon electricity sources the primary energy content has to be calculated and the result depends on the accounting convention used. It is difficult to make a clear comparison between the contribution of renewable and nonrenewable sources because this is obscured by assumptions about efficiencies. The resulting figures tend to underrepresent the share of electricity-producing renewables.

	RE CONTRIBUTION TO WORLD PRIMARY ENERGY SUPPLY						RE CONTRIBUTION TO TOTAL WORLD FINAL ENERGY CONSUMPTION	
% renewables in global energy mix	Physical content method		Direct equivalent method		Substitution method			
	EJ	%	EJ	%	EJ	%	EJ	%
2010	69	13	68	13	91	17	60	18

TABLE 4.1 **COMPARISON OF PRIMARY AND FINAL ENERGY CONSUMPTION METHODOLOGIES**

SOURCE: SOURCE: IEA ANALYSIS. (2010)
NOTE: RE = RENEWABLE ENERGY.

Final energy accounting

The data for this methodology come from the Total Final Energy Consumption (TFEC) figures within the IEA statistics (these exclude nonenergy uses of fossil fuels such as their use as raw material for the production of plastics and chemicals). Within the TFEC figures, heat and electricity are reported directly in the form ready for consumption. Although other primary energy sources (for example, fossil fuels and bioenergy used for heating in the residential sector) are still reported in terms of their fuel content, this methodology comes closer to representing the energy in

[5] Definitions of the methods as well as more details on how to calculate primary and final energy can be found in annex 1.

the forms useful to users. To establish the contribution of each technology, the aggregated figures for electricity and commercial heat have to be allocated to the relevant technology. This can be done based on the proportions exhibited in production data, attributing the losses proportionally.

Table A1.5 in annex 1 shows the breakdown of final consumption figures for 2010 before and after allocation of electricity and heat.

The advantage of using TFEC as the basis for monitoring is that it allows a straight comparison (in GWh) of electricity-producing renewables (or nuclear sources) as well as of commercial heat—and gets closer to measuring useful energy.

The merits and disadvantages of using primary and final energy as the basis for tracking are summarized in table 4.2.

	PRIMARY ENERGY SUPPLY	FINAL ENERGY CONSUMPTION
Advantages	• Widely used. • Based on physical measurement of fuels.	• Heat and electricity in form ready for consumption. • Closer to useful energy output valued by end-users • Better balance for directly produced RE.
Disadvantages	• Different conventions for assumptions on efficiencies means that contribution of RE depends on calculation procedure. • Underrepresents directly produced RE.	• Losses need to be allocated.

TABLE 4.2 **ADVANTAGES AND DISADVANTAGES OF PRIMARY AND FINAL ENERGY CONSUMPTION METHODOLOGIES**

NOTE: RE = RENEWABLE ENERGY.

Given the decarbonization efforts under way around the globe, we can expect that more and more energy will be delivered by noncombustible energy sources. These are precisely the sources that are measured in the energy balance only once they have produced power or heat (that is, at the secondary energy level). Because the aim is to track the contribution of renewables to the global energy mix, we suggest using progress measurement at the final energy consumption level of the energy balance.

Measuring additional indicators

In addition to tracking deployment levels, it will be useful to track some supplementary indicators to improve the overall analysis of the global evolution of renewable energy markets. These could include trends in deployment diversification, policy developments, evolution of technology costs, and investment.

Deployment diversification

In order to meet the SE4ALL goals it will be important for an increasing number of countries to develop significant renewable energy portfolios. This diversification trend is already in progress; for example, the recent IEA Medium Term Renewable Energy Market Report shows an increasing number of countries reaching a 100-megawatt (MW) threshold level of installed renewable energy capacity (IEA 2012b). Tracking such diversification could be based on the:

- Number of countries exceeding threshold capacity levels for key technologies, which would identify only those countries with a larger absolute and globally significant level of production.
- Number of countries reaching threshold levels of renewable energy as a proportion of final energy consumption, which would identify countries that made significant efforts.

Renewable energy policy

It will also be useful to track the adoption of formal renewable energy targets and the introduction of fiscal, financial, and economic incentives for the purposes of future analyses and tracking of renewable energy development across countries and regions.

The IEA has a policy database that covers policies within a wide range of countries. This is now being expanded as a joint database with IRENA, and will eventually cover all the member countries of both organizations. The data will be regularly updated and validated by the responsible organizations in the countries. Other international organizations, such as REN 21 in its annual Renewables Global Status Report,[6t] also track renewable energy policies. The tracking could include:

- Number of countries with renewable energy targets
- Number of countries with specific legislation or regulations supporting the development of renewables within the electricity, heat, and transport sectors

At present, there is no common basis for the way that countries establish renewable energy targets; some are based on technology capacities, others on a percentage that is based on primary energy production, and some on final energy consumption. This makes it impossible to establish the extent to which, taken together, country targets are aligned with the overall SE4ALL goal. We recommend that countries establish goals based on final energy consumption, and that a target for 2030 be included along with intermediate targets to improve the consistency of tracking efforts.

Technology cost

Tracking the evolution of technology costs will also be essential to future analyses of the development of renewable energy markets. Many institutions, including IRENA and the IEA, are playing an important role in collecting data and reporting on costs for a range of renewable energy technologies.

Cost estimates are not always consistent due to the different conventions and assumptions applied in their calculation (for example, different cost allocation rules for combined heat and power plants may be applied, or different grid connection costs and rules).

Considering the advantages and disadvantages of different cost analyses, we suggest that a number of different cost indicators are used for the analysis, including:

- Equipment cost
- Total installed project cost, including fixed financing costs
- The levelized cost of energy (LCOE)

The cost of equipment at the factory gate and installed project costs are often available from market surveys or from other sources, such as the IRENA.

The LCOE is the price of electricity required for a project where revenues would equal costs, including making a return on the capital invested equal to the discount rate, as measured by a discounted cash flow analysis.

Investment

Tracking global trends in renewable energy investment will help to identify emerging trends and to highlight bottlenecks. It will be particularly important to track private sector investment, the role of development banks, and the extent to which public and concessional finance is leveraged with other sources of finance including asset finance, venture capital, and private equity. Bloomberg New Energy Finance (BNEF) and UNEP have been reporting data on investment on an annual basis from 2004 (BNEF, UNEP, and Frankfurt School 2012).

[6] http://www.ren21.net/gsr.

Suggested methodology for defining and measuring renewable energy

While it is not possible to fully resolve all of the methodological challenges outlined in the preceding section, the preferred approach for tackling them is summarized in table 4.3.

CHALLENGE	PROPOSED APPROACH
Definition of renewable energy	Energy from natural sources that are replenished at a faster rate than they are consumed, including hydro, bioenergy, geothermal, aerothermal, solar, wind and ocean
Sustainability of renewable energy	Develop sustainability protocols for different forms of renewable energy over time, so that sustainability considerations can be incorporated to the definition in the medium term
Primary versus final energy accounting	Track renewable energy as a share of total final energy consumption, and as a subsidiary indicator the share of renewable energy in electricity generation
Measuring additional indicators	Track complementary indicators such as deployment diversification, renewable energy policy, technology cost and diversification

TABLE 4.3 **ADDRESSING METHODOLOGICAL CHALLENGES IN GLOBAL TRACKING OF RENEWABLE ENERGY**

SOURCE: AUTHORS.

Definition of renewable energy

For the purposes of the SE4ALL tracking framework, we recommend that renewable energy be defined broadly as:

"Energy from natural sources that are replenished at a faster rate than they are consumed, including hydro, bioenergy, geothermal, aerothermal, solar, wind, and ocean."

We also propose that, in the short term, sustainability criteria not be applied so as to exclude any of these resources or associated technologies, given the difficulties of making these distinctions based on currently available data. This implies that the traditional uses of biomass would be included in the definition of renewable energy.

But since it is also important that the SE4ALL initiative emphasizes and promotes the sustainable use of renewable energy resources, we recommend that, in parallel, the SE4ALL initiative promotes or commissions a formal assessment to tackle the methodological aspects necessary for tracking sustainability in the long term. This will require the development of a consensus around sustainability indicators and criteria for each of the main technologies considered. These efforts will need to be introduced in tandem with strong capacity building at the country level, especially in less-developed economies.

Method for accounting and measuring renewable energy

For the purposes of the SE4ALL initiative, we recommend that the estimation of the proportion of the global energy mix from renewable energy be based on the TFEC data.

To improve the tracking of the contribution of renewable energy to TFEC, it will be necessary to enhance measurement and data collection to improve the issues identified previously, particularly relating to bioenergy use. We therefore propose that the SE4ALL initiative promote or commission the assessments necessary for improving measurement and data collection in those categories.

Measuring and tracking complementary indicators

In tracking the contribution of renewable energy to TFEC under the SE4ALL initiative, the analysis of complementary indicators will be necessary to understand patterns and overall market evolution at the global, regional, and country levels.

We recommend monitoring the following additional indicators:

- Deployment diversity, including threshold levels of installed capacity for key renewable energy technologies or resources and number of countries reaching threshold levels of renewable energy as a proportion of final energy consumption
- Policy development, including number of countries with a policy target and level of target in each country for an aggregated global baseline; and adoption of fiscal, financial, and economic incentives at the country level
- Technology costs for each of the renewable energy technologies considered, initially in terms of LCOE, but if suitable procedures can be developed this should be complemented by manufacturing cost data where possible
- Investment in renewable energy (by asset class, country, and region)

Baseline year

Given the availability of data, we propose that the baseline year should be established as 2010, providing a 20-year period for reaching the target.

Data sources

We recommend using the IEA data as the main source for measuring the starting point and for tracking the contribution of renewable energy to TFEC, complemented with the UN data for the case of smaller non-OECD countries.

The use of IEA statistics as a basis for tracking should also be supplemented by enhanced efforts to track direct use of renewable energy for heat, improve data on bioenergy use (particularly relating to the traditional uses of biomass), and identify small-scale and off-grid electricity generation (as well as other sources not currently measured or included in the energy statistics described earlier).

Global baseline and tracking

Immediate and short term

In the immediate and short term (that is, for establishing the starting point and for tracking progress within the next five years), the SE4ALL initiative will track TFEC of different renewable energy resources used for heating, electricity, and transport on a global basis.

These resources include: hydro (all sizes), bioenergy (all types, but including only the estimated biodegradable fraction of products or waste), geothermal, aerothermal, solar (including PV and solar thermal), wind, and ocean.

The tracking of TFEC will be conducted primarily based on the statistics already produced by the IEA. These are based on country information gathered through annual questionnaires that the IEA designed to ensure consistency of reporting variables (for example, use of the same reporting conventions and definitions, use of the international standard industrial classification, application of the same definitions for different categories, and so on). This information is supplemented with other data sources in countries that have not signed data-reporting conventions with the IEA. The IEA aggregates the country-level data and reports on an annual basis.

During the first five years, the SE4ALL initiative will seek to complete the recommended assessments for improving methodological issues and to enhance data collection to cover identified data gaps. Once the assessments are completed, these new concepts, definitions, and questions will be integrated into the procedures for collecting and reporting the energy statistics.

A parallel review of sustainability indicators and criteria for each of the main technologies will be carried out and used as the basis for developing internationally accepted standards that can be used to assess the degree to which deployment meets the highest sustainability standards.

These new procedures and the necessary country-leve-training will be introduced before the end of the fifth year after the SE4ALL initiative is launched.

The SE4ALL initiative will track four additional indicators:

- Deployment diversity
- Policy developments
- Technology costs
- Investment in renewable energy

All indicators will be tracked on a country level and aggregated globally for the purposes of reporting under the SE4ALL initiative.

Medium term

In the medium term, we recommend that the SE4ALL initiative move toward a working definition of renewable energy that includes only renewable energy produced in a sustainable manner. To do this it will be necessary to develop and promote methodologies for tracking sustainability across the use of all types of resources; improving definitions and data on bioenergy use, particularly relating to traditional vs. modern uses of biomass; organic versus inorganic fraction of waste and products; output and use of heat pumps; use of small-scale renewable energy in distributed generation; and use of renewable energy in off-grid schemes.

In addition, we recommend that countries adopt a consistent targeting approach, setting targets in terms of the proportion of energy in their energy mix based on TFEC, which would allow for the calculation of an aggregate figure that would provide a measure for the cumulative ambition for comparison with the SE4ALL goal.

Toward the fifth year of the SE4ALL implementation, these additional aspects could be incorporated into the reporting systems on an annual basis.

Country-level tracking

At this stage there is no attempt to disaggregate the increases in the share of renewable energy to the individual SE4ALL commitments (that is, the impact of particular UN SE4ALL measures is not considered). Nor does the report attempt to address the allocation of the SE4ALL objective on a regional or country level.

In the medium term it would be beneficial for country-level targets to be reformulated in line with the proposed SE4ALL methodology—that is, as the percent of renewable energy in TFEC.

Also in the medium term, the revised information-gathering systems and definitions will need to be implemented at the country level, along with the application of sustainability criteria for bioenergy and other technologies as appropriate.

A summary of the strategy for tracking is provided in table 4.4.

	IMMEDIATE	MEDIUM TERM
Global tracking	• TFEC. • Electricity (MW, GWh). • Number of countries exceeding threshold levels of installed capacity for key RE technologies and exceeding threshold levels as a proportion of final energy consumption. • Number of countries with policy targets and incentives. • Technology costs. • Investment levels.	• Improved definitions and data associated with bioenergy. • RE in distributed generation. • RE in off-grid (including micro-grids). • Harmonized approach to target setting.
Country-level tracking	• Nil.	• Development of consistent targets expressed in terms of renewable energy share of TFEC by 2030. • Support and implementation of revised information gathering systems aimed at improving coverage of the full range of renewable energy technologies in selected countries. • Piloting of the application of sustainability criteria in bioenergy in selected countries. • Developing sustainability criteria for other renewable energy technologies and piloting their application in selected countries.

TABLE 4.4 **TRACKING FRAMEWORK**

SOURCE: AUTHORS.
NOTE: GWH = GIGAWATT–HOURS; MW = MEGAWATTS; RE = RENEWABLE ENERGY; TFEC = TOTAL FINAL ENERGY CONSUMPTION.

SECTION 2. GLOBAL TRENDS IN RENEWABLE ENERGY

This section establishes the initial conditions of the share of renewable energy in global final energy consumption using the methodology described in section 1, and presents global trends including breakdowns for different regions and income groupings. It also discusses trends in renewable energy policy, technology progress, investment and, deployment diversification.

Total final energy consumption and electricity

Based on existing data sources (with their associated statistical limitations), the share of renewable energy in TFEC is estimated to be 18 percent at the starting point in 2010[7]. This implies a SE4ALL objective of 36 percent for the year 2030. For immediate tracking purposes, it is not possible to take sustainability considerations into account, so as to exclude any unsustainable forms of renewable energy; though it is recommended that these considerations be incorporated over time. As a result, the starting point of 18 percent as well as the associated target can be regarded as upper bounds.

It is estimated that traditional biomass accounts for about half of the renewable energy total (figure 4.1).[8] A further quarter of the renewable energy total relates to modern forms of bioenergy, and most of the remainder is hydropower. Other forms of renewable energy—including wind, solar, geothermal, waste, and marine—together contribute barely 1 percent of global energy consumption.

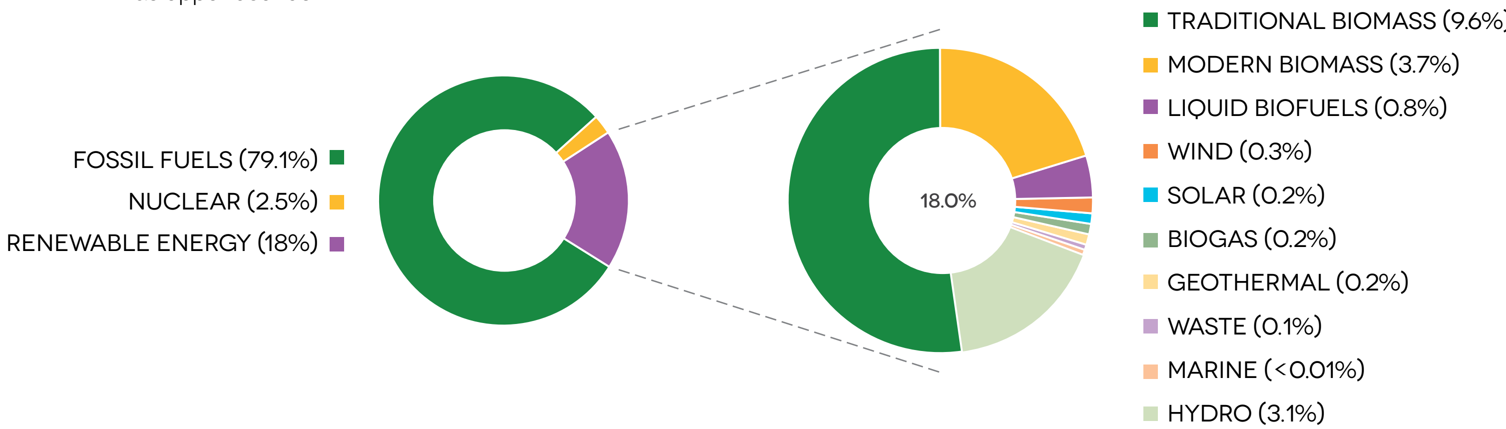


FIGURE 4.1 **GLOBAL SHARE OF RENEWABLE ENERGY IN TFEC, 2010**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D

Indeed, although the consumption of traditional biomass increased in terms of volume between 1990 and 2010, its share of TFEC declined from 10.2 percent in 1990 to 9.6 percent in 2010. This trend may be partially attributed to a slow shift toward the use of more modern energy sources at the global level. The modern biomass share of TFEC increased slightly from 3.5 in 1990 to 3.7 percent in 2010.

Nonetheless, as mentioned previously, the methodology for collecting data on biomass (both traditional and modern) must be enhanced for a more accurate disaggregation of sources and uses and a better understanding of the degree to which these sources are being utilized sustainably.

[7] During the 2012 Year of Sustainable Energy for All a provisional estimate of 15 percent was used for the share of renewable energy in the global energy mix, with an associated target of 30 percent. This was based on 2005 data and a slightly different methodological approach to that finally agreed in this report.

[8] The UN Food and Agriculture Organization defines traditional biomass as "woodfuels, agricultural by-products, and dung burned for cooking and heating purposes." In developing countries, traditional biomass is still widely harvested and used in an unsustainable and unsafe way. It is mostly traded informally and non-commercially. So-called modern biomass, by contrast, is produced in a sustainable manner from solid wastes and residues from agriculture and forestry.

3.0% VS 1.5% GROWTH

– THE COMPOUND

ANNUAL GROWTH RATE OF GLOBAL TOTAL FINAL ENERGY CONSUMPTION FROM RENEWABLE SOURCES (EXCLUDING TRADITIONAL BIOMASS) VERSUS THE GROWTH RATE OF TOTAL FINAL ENERGY CONSUMPTION OVERALL

The renewable energy sources other than traditional biomass and hydropower (including modern solid biomass, biofuels, biogas, waste, geothermal, wind, solar, and marine energy) contributed only 5.4 percent to TFEC in 2010. In the same year, the global consumption of hydropower reached a comparatively high share of 3.1 percent of TFEC.

The use of different sources has evolved at contrasting rates. While the share of traditional biomass in the global energy mix steadily declined between 1990 and 2010, increasing at a compounded annual growth rate (CAGR) of only 1.2 percent, the share of all other renewable sources (including hydro) grew at 3.0 percent CAGR, with the last five years marked by an unprecedented 4.9 percent CAGR.

The renewable energy sources other than traditional biomass and hydropower grew at an even higher annual rate, on the order of 11 percent between 1990 and 2010. Thus, the incremental increase in the share of renewable energy in TFEC during that period was to some extent driven by wind, biofuels, biogas, solar, waste, and geothermal sources (figure 4.2).

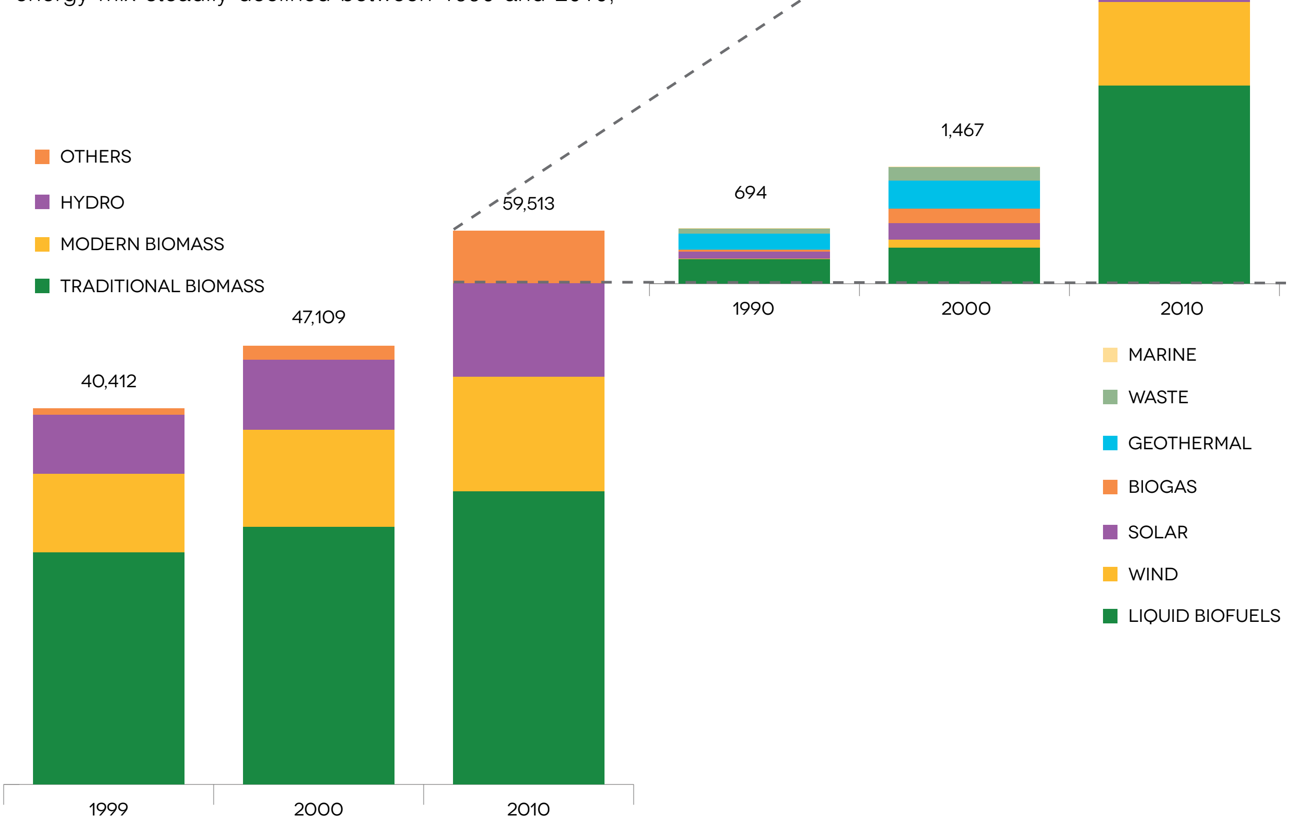


FIGURE 4.2 **EVOLUTION OF RENEWABLE FINAL ENERGY CONSUMPTION (PJ)**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.

Indeed, over the past ten years the use of renewable energy sources other than biomass and hydro almost quadrupled at the global level. Wind, biogas, and solar exhibited the most dramatic growth in both absolute and relative terms, growing at 25, 16.7, and 11.4 percent CAGR, respectively (as illustrated in figure 4.3). The impressive scale-up in the use of these sources is largely attributed to the provision of sustained policy incentives that triggered high investment volumes and remarkable reductions in technology costs.

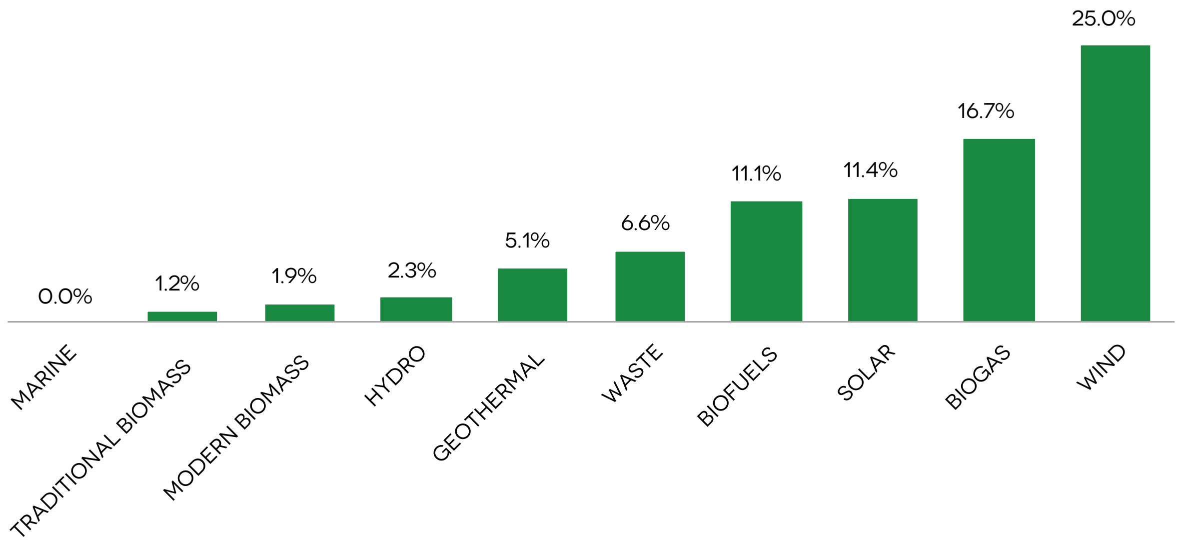


FIGURE 4.3 **COMPOUNDED ANNUAL GROWTH RATES (CAGR) OF RENEWABLE ENERGY TFEC BY SOURCE, 1990–2010**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.

Renewable energy sources are used for heating, electricity, and transport. Renewables for heating (cooking, space, and water heating) accounted for 75 percent of all renewable energy use in 2010, with biomass contributing 96 percent of this share.[9] Commercial-scale heating, in particular, increased rapidly between 1990 and 2010, although it still represented only 1 percent of total heating consumption by the end of 2010. Indeed, the use of modern renewable energy technologies for heating and cooling is still limited relative to their potential for meeting global demand.

Despite its significant share, renewable energy for heating declined 7.5 percent over the period 1990-2010. This trend may be also partially attributed to substitution of traditional for more modern sources of energy. The CAGR associated with the global use of biomass for heating between 1990 and 2010 is estimated at only 1.3 percent, while those of geothermal and solar thermal for heating reached 6.7 and 10.6 percent respectively.

The share of renewable energy in electricity production fluctuated between 1990 and 2010, decreasing from 19.5 percent in 1990 to a low of 17.5 percent in 2003, and then rebounding to 19.4 percent in 2010. The reason for the decline between 1990 and 2000, despite the absolute growth, is that electricity demand grew at a faster pace than renewable energy. Hydropower contributed 83 percent to this global share, followed by wind-based generation, which accounted for a little more than 8 percent. All other sources combined accounted for about 10 percent of total renewable-source-based electricity supply in 2010 (figure 4.4a).

25% GROWTH
– THE COMPOUND ANNUAL GROWTH
RATE OF WIND ENERGY OVER THE PERIOD 1990–2010.

While the historic share of renewable energy in electricity production was relatively flat through 2010, more recent trends suggest that it may be increasing. Renewables accounted for almost half of the estimated 208 gigawatts (GW) of new electric capacity added globally during 2011. Wind and solar photovoltaic (PV) accounted for almost 40 percent and 30 percent of new renewable capacity, respectively, followed by hydropower (nearly 25 percent). By the end of 2011, total renewable power capacity worldwide exceeded 1,360 GW, up 8 percent over 2010; renewables comprised more than 25 percent of total global power-generating capacity (estimated at 5,360 GW in 2011) and supplied an estimated 20.3 percent of global electricity. Renewable technologies are also expanding into new markets. In 2011, around 50 countries installed wind power capacity, and solar PV capacity is moving rapidly into new regions and countries. Solar hot water collectors are used

[9] Traditional biomass alone contributed approximately 70 percent to the share of renewable energy sources used for heating.

A. TECHNOLOGY BREAKDOWN BY RENEWABLE ENERGY APPLICATION (2010)

B. RENEWABLE ENERGY CONTRIBUTION TO GLOBAL TFEC IN ELECTRICITY, TRANSPORT, AND HEAT (2010)

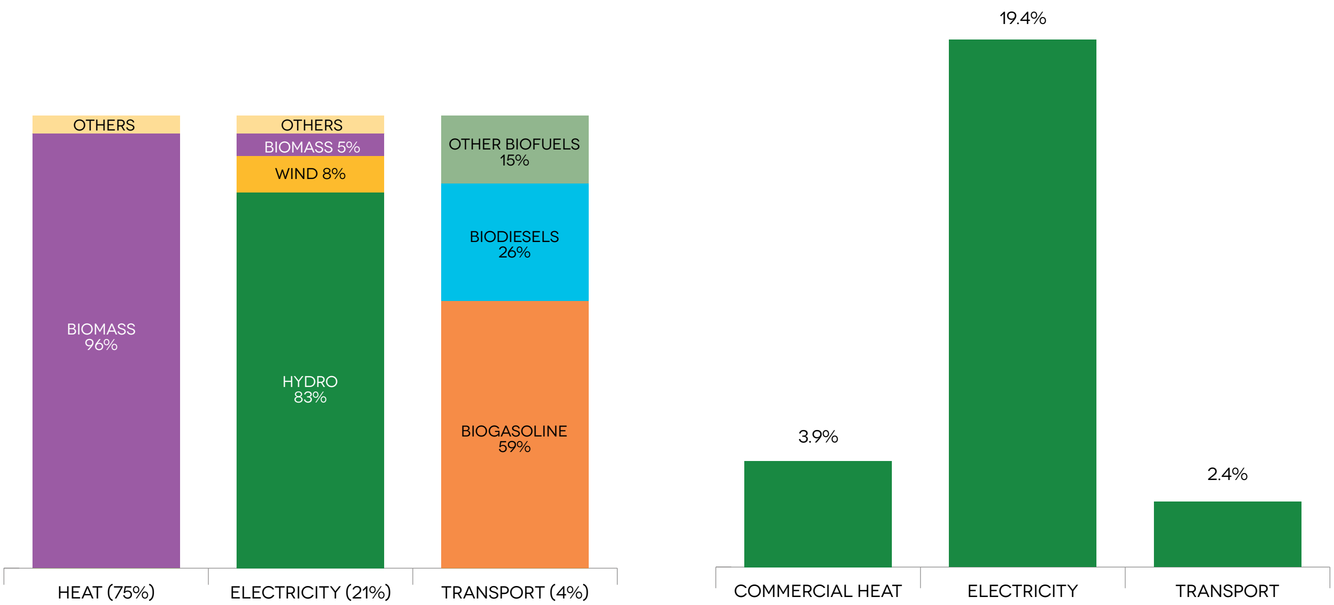


FIGURE 4.4 **RENEWABLE ENERGY APPLICATIONS**

NOTE: BIOMASS INCLUDES PRIMARY SOLID BIOFUELS AND CHARCOAL. BIOGASOLINE INCLUDES BIOETHANOL, BIOMETHANOL, BIOETBE, AND BIOMTBE AND "OTHER BIOFUELS" INCLUDES THOSE THAT CANNOT BE SPECIFIED AS EITHER BIOGASOLINE OR BIODIESEL DUE TO LACK OF DATA. COMMERCIAL HEAT REFERS TO HEAT PRODUCED FOR SALE BY COMBINED HEAT AND POWER (CHP) AND HEAT PLANTS. TFEC = TOTAL FINAL ENERGY CONSUMPTION.
SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.

by more than 200 million households, as well as in many public and commercial buildings around the world. Interest in geothermal heating and cooling is also on the rise globally, as is the use of modern biomass for energy purposes.

The contribution of renewable energy to global final consumption in commercial heat—mainly combined heat and power—and transport reached 3.9 and 2.4, respectively, in 2010 (figure 4.4b).

Renewable energy is used in the transport sector in the form of gaseous and liquid biofuels; liquid biofuels provided about 3.3 percent of global road transport fuels in 2010-11, more than any other renewable energy source in the transport sector.[10] Electricity powers trains, subways, and a small but growing number of passenger cars and motorized cycles, and there are limited but increasing initiatives that link electric transport with renewable energy.

But despite the remarkable growth of wind, biogas, solar, geothermal, and smaller renewable-source-based developments, the overall share of renewable energy in TFEC remained relatively stable between 1990 and 2010 because of the central role of traditional biomass, which accounted for about 53 percent of the renewable energy share of TFEC in 2010 (figure 4.5).

50%
OF NEWLY INSTALLED POWER GENERATION
IN 2011 CAME FROM RENEWABLE SOURCES.

Global TFEC increased from 243 to 330 exajoules (EJ) over that period, at a CAGR of 1.5 percent. Meanwhile, the consumption of renewable energy increased from 40 to about 60 petajoules (PJ), at 2 percent annually.

[10] Road transport is a subcategory of total transport shown on figure 4.4b, with the latter also including rail, pipeline, navigation, aviation, and other nonspecified transport categories. It is important to note that most biofuels are used in road transport.

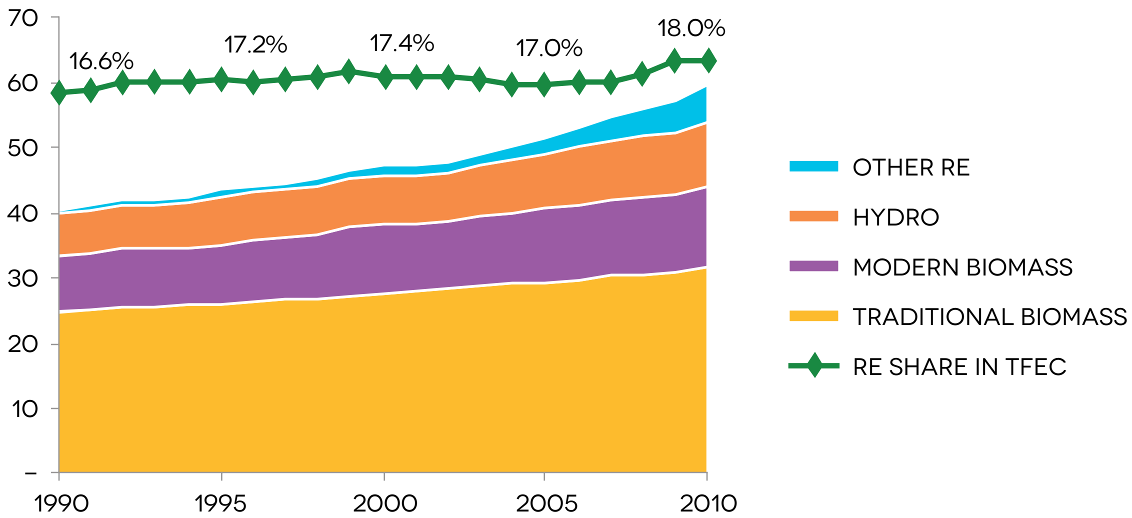


FIGURE 4.5 **GLOBAL TFEC (PJ) VS. SHARE OF RENEWABLE ENERGY (%)**

NOTE: TFEC = TOTAL FINAL ENERGY CONSUMPTION.
SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.

Global trends by region

The evolution of the share of renewable energy in regional TFECs has been influenced by a number of factors, including growth in overall energy consumption, trends in the use of traditional biomass, and growth in the production of renewable energy other than traditional biomass and hydropower per se.

The regional share of renewable energy between 1990 and 2010 increased in Europe, North America, and Sub-Saharan Africa but decreased in Latin America, Northern Africa, and most subregions of Asia (table 4.5).

The increased share of renewables in Europe has been attributed to the adoption of bold and sustained policy measures that triggered a large volume of investments primarily in renewable source-based initiatives other than hydropower, although this trend has also been influenced by a low growth in overall energy demand. In Europe renewables have directly displaced other sources of energy, most notably fossil fuels.

The share of renewables in Southern Asia and Sub-Saharan Africa is particularly high due to the use of traditional biomass, especially in the residential sector. But the share of renewables in Southern and Southeastern Asia declined significantly over the 1990–2010 period, in part owing to decreased reliance on traditional biomass for cooking and wider adoption of non-solid cooking fuels.

At the same time, the analysis of the data by income group reveals that traditional biomass is being consumed predominantly by middle-income economies, while renewable energy sources other than hydro and traditional biomass are primarily being consumed by upper-middle- and high-income countries (figure 4.6).

If we confine attention to power generation only, the regional picture for the share of renewable energy in the electricity mix looks quite different. Latin America and Caribbean emerges as the region with by far the highest share of renewable energy in the electricity generation portfolio of 56 percent, which is more than twice the level in the next highest regions – Caucuses and Central Asia, Europe, Oceania and Sub-Saharan Africa – all of them above 20 percent. Globally, 80 percent of renewable electricity generation is found evenly spread across just four regions: East Asia, Europe, Latin America and Caribbean and North America.

65% VS 20%
– THE SHARE OF GLOBAL TOTAL FINAL
ENERGY CONSUMPTION FROM RENEWABLE SOURCES CONTRIBUTED BY AFRICA AND ASIA VERSUS EUROPE AND NORTH AMERICA

REGION	SHARE OF RE IN EACH REGION			CONTRIBUTION TO GLOBAL SHARE		
	1990	2000	2010	1990	2000	2010
North America	6.0	7.1	9.0	8.1	9.8	9.7
Europe	8.1	9.4	14.1	7.6	8.2	10.0
Eastern Europe	3.0	4.2	5.4	2.9	2.3	2.4
Caucasus and Central Asia	3.1	5.2	4.4	0.5	0.4	0.3
Western Asia	8.2	5.8	4.3	1.1	0.9	0.9
Eastern Asia	22.2	19.1	15.3	23.2	20.8	19.9
Southeastern Asia	52.2	37.9	31.1	8.8	8.5	7.7
Southern Asia	50.9	43.4	34.8	18.1	17.5	16.4
Oceania	15.0	15.6	15.1	1.1	1.2	1.0
Latin America and Caribbean	32.3	28.2	29.0	10.7	10.4	10.7
Northern Africa	6.5	6.2	5.0	0.3	0.3	0.3
Sub-Saharan Africa	72.5	74.6	75.4	17.7	19.8	20.7
World	**16.6**	**17.4**	**18.0**	**100.0**	**100.0**	**100.0**

TABLE 4.5 **REGIONAL CONTRIBUTION TO THE SHARE OF RENEWABLES IN TFEC (AFTER ALLOCATION) (%)**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.

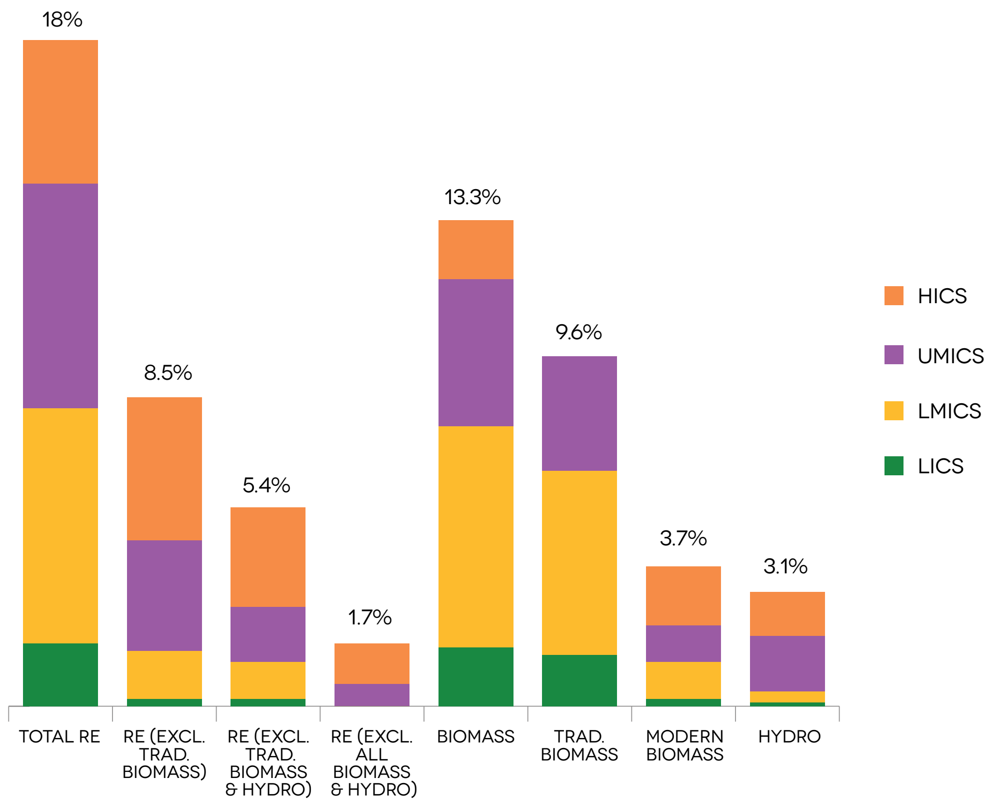


FIGURE 4.6 **CONTRIBUTIONS TO THE SHARE OF RENEWABLE ENERGY IN TFEC BY SOURCE AND INCOME GROUP, 2010**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.
NOTE: HICS = HIGH-INCOME COUNTRIES; LICS = LOW-INCOME COUNTRIES; LMICS = LOWER-MIDDLE-INCOME COUNTRIES; UMICS = UPPER-MIDDLE-INCOME COUNTRIES.

Trends in relevant indicators

Policies and dramatic technology cost reductions have driven renewable energy investment and market development in unanticipated ways. This subsection discusses general trends in renewable energy policy, technology progress, investment, and deployment diversification.

Policies to promote renewable energy development

Policy makers are increasingly aware of renewable energy's wide range of benefits, including energy security, reduced import dependency, reduction of GHG emissions, prevention of biodiversity loss, improved health, job creation, rural development, and energy access, leading to closer integration of renewable energy policy with policies in other economic sectors in some countries. Globally there are more than 5 million jobs in renewable energy industries, and the potential for job creation continues to be a main driver of renewable energy policies (REN21 2012).

To a large extent, policy incentives targeting different stages of the technology innovation and market development chain have driven the remarkable growth of renewable energy other than hydropower. Policy instruments include targets and a combination of economic, fiscal, and financial incentives.

Renewable energy targets have increasingly been adopted around the world over the past few years. Today, about 120 countries have a national target on renewable energy, more than half of which are developing countries (REN21 2012).

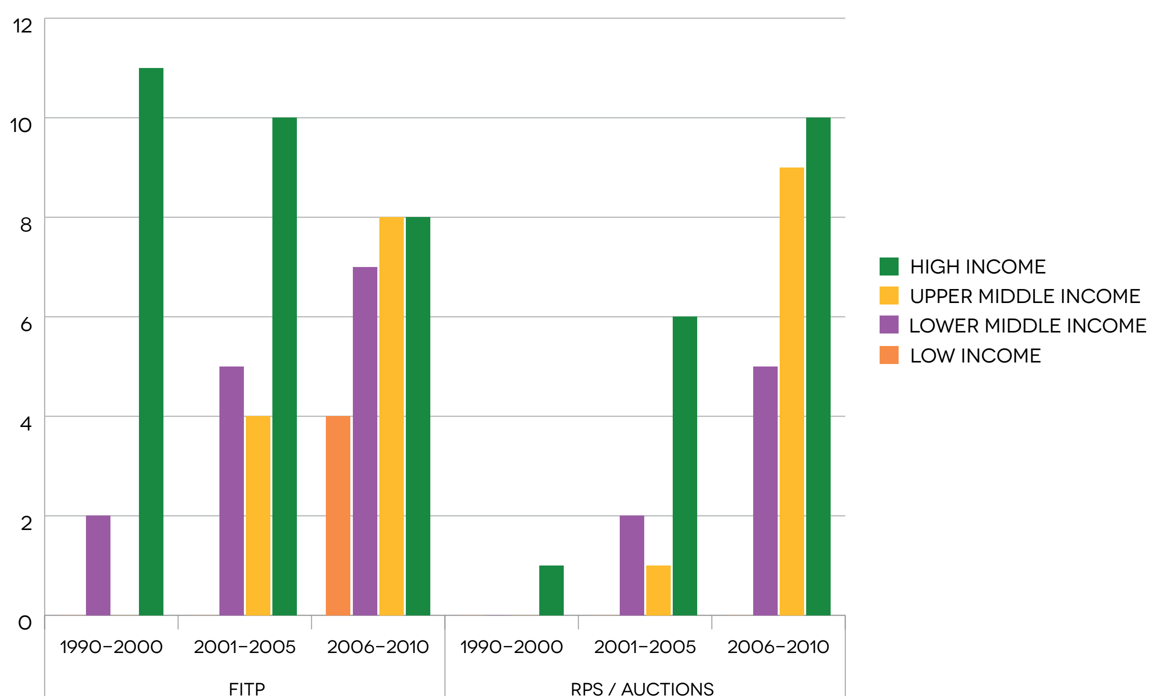


FIGURE 4.7 **NUMBER OF COUNTRIES INTRODUCING PRICE AND QUANTITY SETTING INSTRUMENTS**

SOURCE: REN21 2012.
NOTE: FITP = FEED–IN TARIFF POLICY; RPS = RENEWABLES PORTFOLIO STANDARD.

Indeed, developed and emerging economies have accumulated years of experience with the design and implementation of various types of policy instruments, including price-setting mechanisms and policies that impose a quota and introduce competitive bidding or auctions. In particular, feed-in tariff policies have been necessary to lower the range of risks associated with the introduction of capital-intensive technologies and the development of new markets.

Increasingly, low- and middle-income countries are adopting price/quantity setting instruments in combination with fiscal and financial incentives to promote different segments of the renewable energy market (figure 4.7). Even oil- and gas-exporting economies such as Saudi Arabia and the Gulf States are beginning to introduce incentives to develop renewable energy, with the intention of lowering domestic consumption of fossil fuels and developing industrial capacity for the manufacture of renewable energy equipment.

Most recently, however, policy support for renewable energy weakened in Europe due to the economic crisis and associated austerity measures. As a result, efforts have increased to improve the effectiveness and economic efficiency of policy incentives, especially in countries with a long track record of their implementation (box 4.1 discusses the issue of policy performance).

BOX 4.1 Policy effectiveness and economic efficiency

Between 1990 and 2010, many countries, especially developed and emerging economies, introduced a combination of economic, fiscal, and financial incentives to promote renewable energy development. Policy makers and regulators have gradually learned that the choice of policy mechanism, the features of policy design, the setting of tariff levels, and the compatibility of different instruments are all crucial aspects of an effective and economically efficient regime.

Indeed, policy and regulatory frameworks have been repeatedly reformed and adjusted in most countries that have introduced renewable energy policies. For example, almost all countries using feed-in tariffs to promote one or many segments of the renewable energy market— different types of technologies, project scales, or geographic areas— have successively adjusted the tariff levels to avoid high infra-marginal rents and policy costs or subsidy volumes. In this process, countries have introduced automatic adjustment mechanisms and other design features to ensure that the cost to taxpayers or consumers is acceptable while also lowering regulatory uncertainty for potential investors.

The design of auction mechanisms to competitively determine the price of renewable energy has also required adjustments to avoid speculative behavior and ensure the construction of plants (for example, bid bonds, guarantees on project completion, penalties on construction delays, and so on).

The use of price- and quota-based instruments is necessary in the absence of externality pricing. Today, many countries have adopted emissions trading frameworks and have also learned many lessons in the process of establishing carbon markets.

Ultimately, it is clear that a policy package needs to be not only effective in terms of the capacity deployed and electricity generated but also economically efficient—that is, delivered at the lowest possible cost while remaining sustainable and socially inclusive.

SOURCE: JACOBS 2012; ELIZONDO–AZUELA AND BARROSO 2011; IEA 2008.

Technology progress

On the technology development front, there has been continuous progress in efficiency, and cumulative experience has translated into increasingly cost-effective solutions. For instance, the investment cost of wind energy fell from $2,500/kilowatt (kW) in the mid-1980s to $630-1,270/kW in 2012, while the cost of PV systems fell from about $7,000/kW to $750–$1,100/kW over the same period (IRENA 2013b) (figure 4.9). Similar trends occurred in the sugarcane-based bioethanol industry (see learning curve in annex 2).

Today, many countries manufacture solar PV modules, although China, the United States, Japan, Canada, and Norway have the largest market shares (China supplies 30 percent of the global market volume). Wind turbines, on the other hand, are manufactured mainly by China, Denmark, the United States, Spain, Germany, and India.

About 30 GW of solar PV was installed globally every year between 2010 and 2012, bringing the total installed PV capacity from 40 GW to more than 100 GW (EPIA 2013). In addition, total wind power capacity reached over 282 GW globally in 2012, representing an increase of almost 20 percent from 2011 (GWEC 2013). The market expansion of renewable technologies in many regions of the world has also brought considerable cost reductions. For instance, the cost of solar PV modules dropped by 42 percent in 2011 while the cost of onshore wind turbines fell by 10 percent.

FIGURE 4.8 **LEARNING CURVES FOR WIND AND SOLAR PV MODULES**

▲ SOLAR THIN FILM PANEL – CDTE (IRENA 2012) ◆ SOLAR PANEL CRYSTALINE C–SI – CDTE (IRENA 2012) ● ONSHORE WIND POWER PLANTS (US) (IPCC 2011)

SOURCE: IRENA ANALYSIS WITH DATA FROM EPIA AND PHOTOVOLTAIC TECHNOLOGY PLATFORM (2011), IPCC (2011), BAZILIAN AND OTHERS (2012), AND SOLOGICO (2012).
NOTE: PV = PHOTOVOLTAIC.

Critical for the widespread integration of renewable energy sources into power systems will be the introduction of technologies, operational protocols, and practices to manage the issue of variability. This can involve a number of options, including more flexible generation from nonvariable sources (renewable and fossil), grid extension, demand-side management, and storage. Although energy storage solutions are in different stages of development, they are quickly progressing along the technology development path (IRENA 2012, Chen and others 2009) (box 4.2).

Technology innovation has played a critical role in the development and commercialization of renewable energy solutions. According to BNEF, UNEP, and Frankfurt School (2012), despite the fact that corporate research and development (R&D) in renewable energy has decreased over the past few years, venture capital and government R&D increased substantially between 2004 and 2011 (with CAGRs of 30 and 14 percent, respectively).

BOX 4.2 Electricity storage

At present, the only commercial storage option is pumped hydro power by which surplus electricity (for example, electricity produced overnight by base-load coal or nuclear power) is used to pump water from a lower to an upper reservoir. The stored energy is then used to produce hydropower during daily high-demand periods. Pumped hydro plants are large-scale storage systems with a typical efficiency between 70 percent and 80 percent, which means that a quarter of the energy is lost in the process.

Other storage technologies with different characteristics (that is, storage process and capacity, conversion back to electricity and response to power demand, energy losses and costs) are currently in demonstration or pre-commercial stages, including compressed air energy storage (CAES), flywheels, electrical batteries and vanadium redox flow cells, super capacitors, and superconducting magnetic storage. In addition, thermal energy storage is under demonstration in concentrating solar power (CSP) plants where excess daily solar heat is stored and used to generate electricity at sunset.

No single electricity storage technology scores high in all dimensions. The technology of choice often depends on the size of the system, the specific service, the electricity sources, and the marginal cost of peak electricity.

For example, pumped hydro currently accounts for 95 percent of the global storage capacity and still offers a considerable expansion potential but does not suit residential or small-size applications. CAES expansion is limited due to the lack of suitable natural storage sites. Electrical batteries have a large potential with a number of new materials and technologies under development to improve performance and reduce costs. Heat storage is practical in CSP plants. The choice between large-scale storage facilities and small-scale distributed storage depends on the geography and demography of the country, the existing grid and the type and scale of renewable technologies entering the market.

While the energy storage market is quickly evolving and expected to increase 20-fold between 2010 and 2020, many electricity storage technologies are under development and need policy support for further commercial deployment. Electricity storage considerations should be an integral part of any plans for electric grid expansion or transformation of the electricity system. Storage also offers key synergies with grid interconnection and methods to smooth the variability of electricity demand (demand-side management).

SOURCE: IRENA 2012.

Evolution of investment

BNEF reports that global investments in renewable -source-based power generation and fuels reached a record of $277 billion in 2011 (figure 4.10) (BNEF database 2012).[11] This was more than six times the figure for 2004 and almost twice the total investment in 2007, the last year before the acute phase of the recent global financial crisis.

In 2011 renewable-source-based power generation capacity (excluding large hydro) accounted for 44 percent of new generation capacity added worldwide, up from 34 percent in 2010. This increase in investment and capacity came at a time when the cost of renewable power equipment was falling rapidly. Furthermore, renewable energy technologies continued to attract investments despite overall uncertainty about economic growth and policy priorities in developed countries.

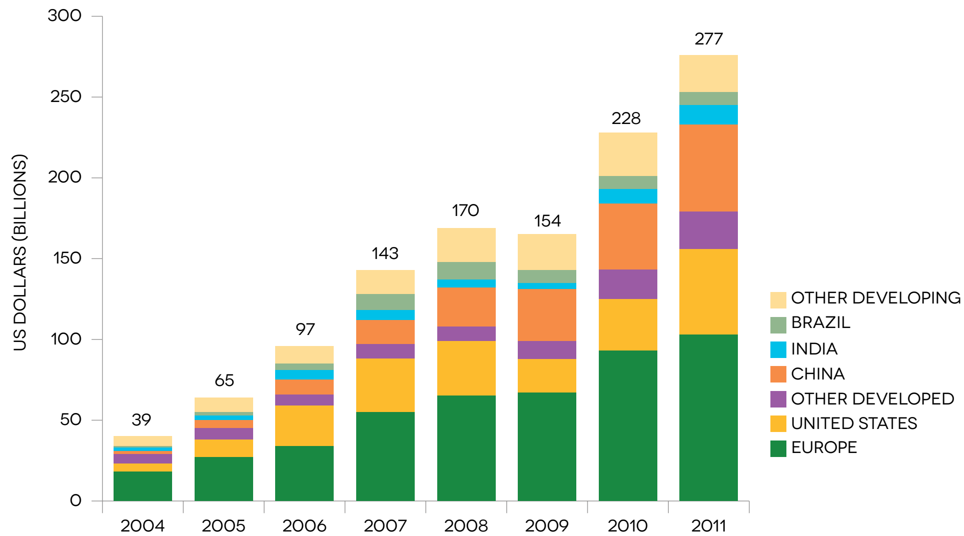


FIGURE 4.9 GLOBAL INVESTMENTS IN RENEWABLE ENERGY BY COUNTRY, 2004–2011 (US$ BILLION)

SOURCE: BNEF DATABASE 2013; BNEF, UNEP, AND FRANKFURT SCHOOL 2012.
NOTE: DATA INCLUDE INVESTMENTS IN HYDROPOWER PLANTS WITH CAPACITIES IN THE RANGE OF 1–50 MW. INVESTMENT DATA INCLUDE THE FOLLOWING CATEGORIES: ASSET FINANCE, PUBLIC MARKETS, VENTURE CAPITAL AND PRIVATE EQUITY, INVESTMENTS IN SMALL DISTRIBUTED CAPACITY, GOVERNMENT R&D, AND CORPORATE R&D

Developing countries, especially emergent economies, made up 35 percent of this total investment, compared to 65 percent for developed economies. Indeed, Brazil, China, and India together accounted for about $74 billion, or 27 percent of the total new investments in renewable energy globally in 2011 (BNEF, UNEP, and Frankfurt School 2012).

Renewable energy markets are also expanding into middle- and lower-income developing nations. In 2011 an estimated 8.4 percent of total new investments in renewable energy took place in developing countries outside large emergent economies, most notably in Thailand, Indonesia, Ukraine, Romania, Bulgaria, Turkey, and Costa Rica.

Overall, developed countries led the way in investments in solar initiatives, while developing economies had the upper hand in new investments in wind-based generation.

[11] Almost 90 percent of this investment went to either solar (57 percent) or wind-based projects (33 percent).

Deployment diversification

Development of newer renewable deployment—other than traditional biomass and hydropower—is becoming increasingly widespread, with growth shifting beyond traditional support markets in the developed world. The number of countries with cumulative renewable source–based electricity capacities above 100 megawatts (MW) increased significantly in the period 2005–2010. The number of countries with wind-based capacity above this threshold increased from 23 in 2005 to 38 in 2010. Solar has also seen a significant increase in terms of the number of countries that reached this threshold in these five years, growing from 3 to 15 countries in total. Biomass and waste also achieved a high level of capacity deployment, expanding by another 5 countries in 2005–2010.

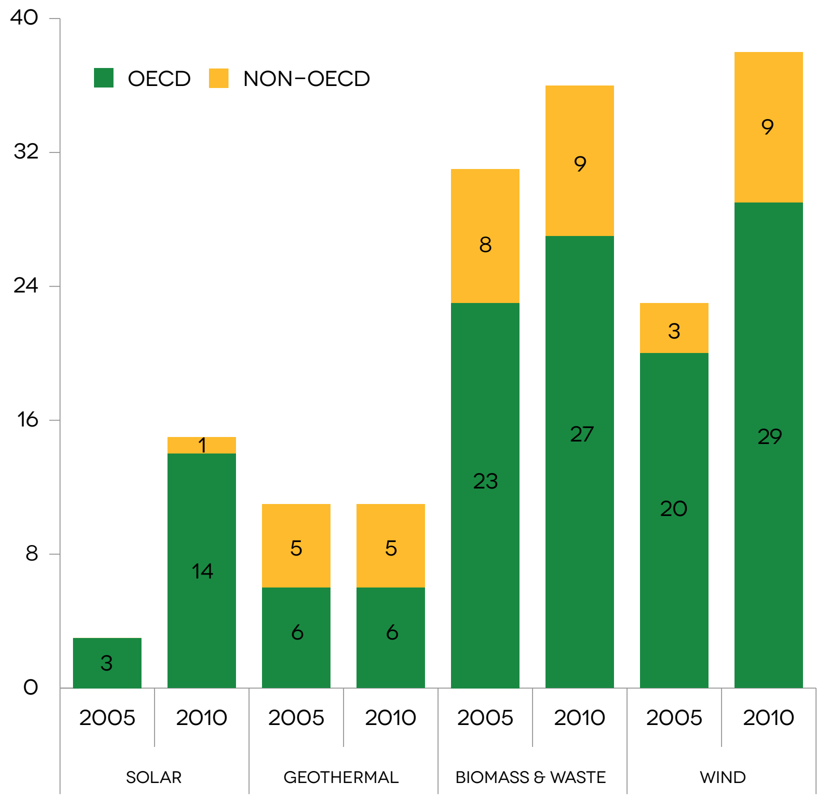


FIGURE 4.11 **NUMBER OF COUNTRIES WHOSE CUMULATIVE INSTALLED CAPACITY EXCEEDED 100 MW AS OF 2010**

SOURCE: EIA DATABASE (2012).
NOTE: OECD = ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT.

SECTION 3. COUNTRY PERFORMANCE

Key drivers for country support to renewable energy development

The introduction of renewable energy brings multiple benefits to society. Indeed, most countries deploying renewable energy are motivated by a combination of social objectives that vary depending on their economic conditions, resource endowments, and strategic priorities. This combination of objectives may include reducing greenhouse gas emissions and local environmental impacts, enhancing energy security, stimulating economic and industrial development, and increasing access to reliable, affordable, and clean modern energy services.

Many countries have strongly supported renewable energy as part of an *environmental and climate change policy* in addition to other social objectives. For instance, renewables play a key role in the climate change mitigation strategies of all EU member states, Norway, Australia, Mexico, India, and many others.

The overall contribution of renewable energy to *local environmental sustainability* has also driven many countries to introduce specific renewable energy policies, especially in nations where the consumption of traditional biomass or the use of fossil fuels results in acute air pollution levels, biodiversity loss, or deforestation. In Nepalese villages, for example, modern renewable energy systems have been deployed to mitigate the negative impacts on biodiversity and deforestation resulting from the unsustainable use of biomass. China, in particular, has explicitly aimed at increasing renewable energy to lower and avoid the regional and local environmental impacts of coal-based power generation. Many other countries have also explicitly supported renewables to reduce local environmental impacts.

At the same time, *energy security* is a key strategic priority of almost all nations. Renewable energy can improve security of supply in a variety of ways, including reducing dependence on imported fuels, contributing to technological and fuel diversification, hedging against fuel price volatility, and enhancing the national trade and fiscal balances. Since the early 1970s, for example, Brazil has promoted the production of ethanol from sugarcane to decrease dependency on imported fossil fuels for transport. Also, in many fuel-dependent countries where the avoided cost of power generation or heating is high, renewable energy represents a competitive alternative that comes without an incremental cost or additional burden on taxpayers or consumers.

Indeed, the justification of renewable energy deployment on economic grounds, including a solid understanding of the full range and valuation of benefits, is essential to policy making and regulatory design.

$277 BILLION
WAS SPENT ON
RENEWABLE ENERGY FINANCING IN THE YEAR 2010.

A few high- and middle-income economies have also strongly focused on renewable energy to support economic *growth and job creation*. Denmark, Germany, China, and India among others have provided specific incentives to stimulate technology innovation, promote the domestic manufacture of renewable energy equipment, and create a local market for companies installing and developing renewable energy projects. Germany, for instance, has spent more on PV R&D than any other country in Europe, with the aim of growing a competitive export industry of components, final products, and manufacturing equipment (IPCC 2011).

Renewable energy can also contribute to *increasing energy access* in peri-urban and rural areas. Many developing countries (including, for example, Argentina, Bolivia, Brazil, Bangladesh, China, India, Sri Lanka, Tonga, and Zambia) have introduced energy access programs and policies to increase access to energy services with renewable-energy -based solutions.

Growth of renewable energy markets

Fast-moving countries

Renewable energy sources beyond traditional biomass and hydropower, including modern solid biomass, biofuels, biogas, waste, geothermal, wind, solar, and marine energy, contributed 5.4 percent to TFEC in 2010. About 97 percent of this volume was produced and consumed by high-income and emerging economies, most notably the United States, Europe, Japan, Brazil, China, and India.

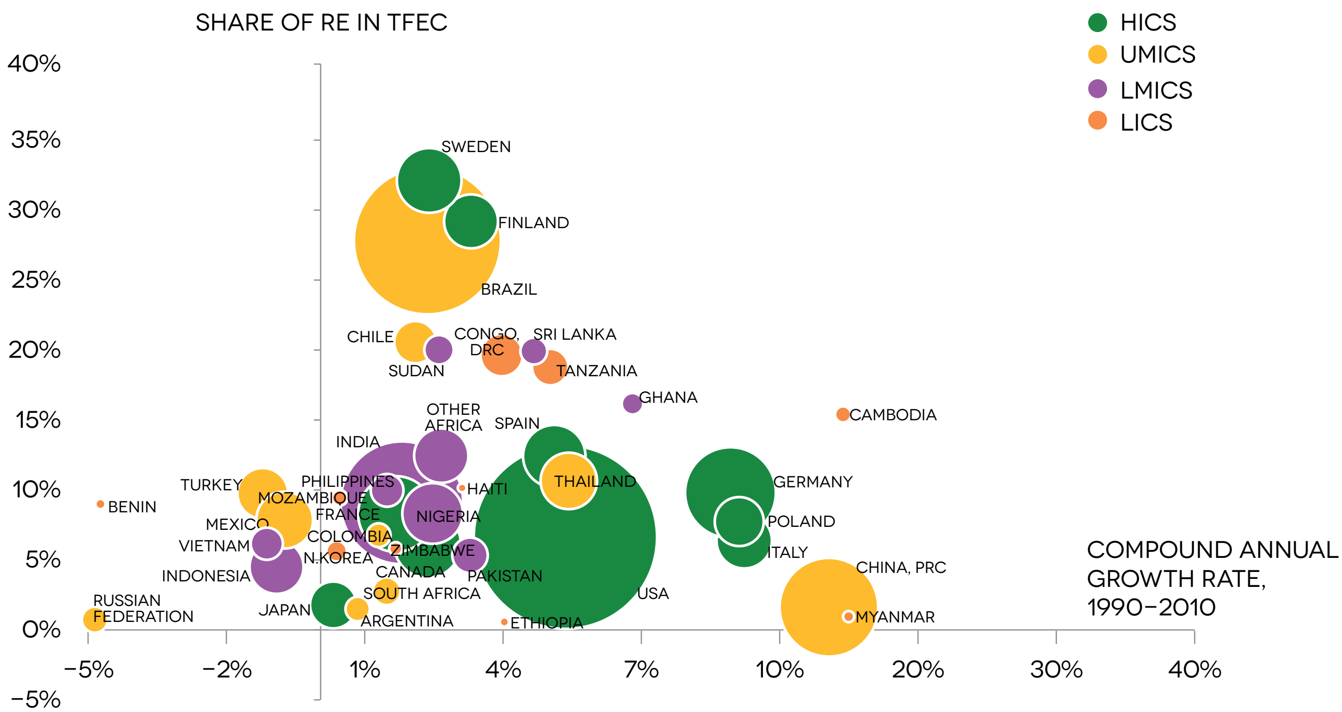


FIGURE 4.11 **RENEWABLE ENERGY'S SHARE (EXCLUDING TRADITIONAL USE OF BIOMASS AND HYDROPOWER) OF COUNTRY TFEC AND CAGR, 1990–2010**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.
NOTE: FIGURE INCLUDES THE USE OF MODERN BIOMASS. (DRC AND TANZANIA APPEAR DUE TO THEIR HIGH USE OF MODERN BIOMASS IN THE INDUSTRIAL SECTOR). BUBBLE SIZE DEPICTS VOLUME IN TERMS OF PJ OF FINAL ENERGY CONSUMPTION. THE NEGATIVE CAGRS EXHIBITED IN TURKEY, MEXICO, INDONESIA, COLOMBIA, RUSSIA, AND BENIN ARE PRIMARILY DUE TO REDUCTION IN THE USE OF NON-TRADITIONAL SOLID BIOMASS (MOST NOTABLY IN INDUSTRY). TFEC = TOTAL FINAL ENERGY CONSUMPTION; CAGR = COMPOUND ANNUAL GROWTH RATE; DRC = DEMOCRATIC REPUBLIC OF CONGO.

Indeed, the development of these renewable energy markets has been led by a small group of pioneering countries that consistently introduced innovation on the technology, policy, and financing fronts in 1990–2010.

China, Germany, Italy, and Spain have rapidly increased their renewable-source-based consumption, while Sweden, Finland, and Brazil have achieved high shares of renewable energy in their total domestic consumption (as illustrated in figure 4.11).[12]

In hydropower Mozambique, China, Vietnam, Iceland, and Albania increased their consumption rapidly between 1990 and 2010, while China, Brazil, the United States, Canada, Norway, India and Russia maintained very high volume of consumption (figure 4.12).

[12] Bubble charts for each of the technologies considered are included in annex 3.

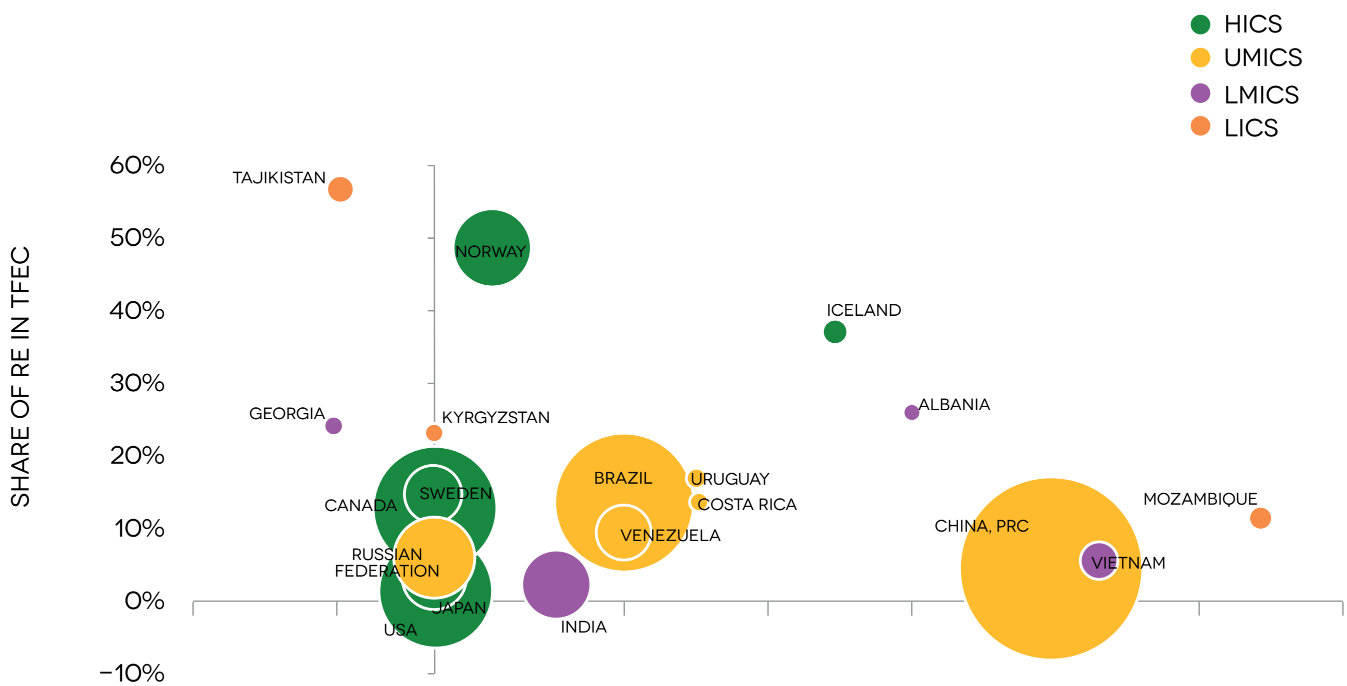


FIGURE 4.12 **SHARE OF HYDRO IN COUNTRY TFEC AND CAGR, 1990–2010**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.
NOTE: HICS = HIGH–INCOME COUNTRIES; LICS = LOW–INCOME COUNTRIES; LMICS = LOWER–MIDDLE–INCOME COUNTRIES; UMICS = UPPER–MIDDLE–INCOME COUNTRIES; TFEC = TOTAL FINAL ENERGY CONSUMPTION; CAGR = COMPOUND ANNUAL GROWTH RATE.

In 2010 the volume of renewable energy sources other than traditional biomass and hydropower consumed by Brazil, China, and India represented 76 percent of the volume consumed in the United States and European countries combined. When including hydro, these three emerging economies are among the top five renewable energy consumers in the world (as shown in figure 4.13).

China, in particular, has rapidly increased its hydro base in electricity and introduced bold industrial and renewable energy policies and strategies to promote the scale-up of wind-based electricity generation and solar PV.

The United States also stands out for the volume of renewable energy consumed, mainly due to its high consumption of biofuels (most in the form of corn-based bioethanol) and wind-based electricity generation. Brazil is ranked third in renewable energy consumption for its aggressive and pioneering support of sugarcane-based bioethanol production, its use of bagasse-based combined heat and power, and its high share of hydropower in electricity.

1,000 EJ
IS THE CUMULATIVE AMOUNT OF
RENEWABLE ENERGY SUPPLIED GLOBALLY BETWEEN 1990 AND 2010; EQUIVALENT TO THE CUMULATIVE FINAL ENERGY CONSUMPTION OF CHINA AND FRANCE OVER THE SAME PERIOD.

Table 4.6 lists the top five countries by region in terms of annual capacity additions in electricity from 2009 to 2010.

INCREMENTAL RENEWABLE ENERGY CONSUMPTION IN THE PERIOD 1990–2010 (PJ)

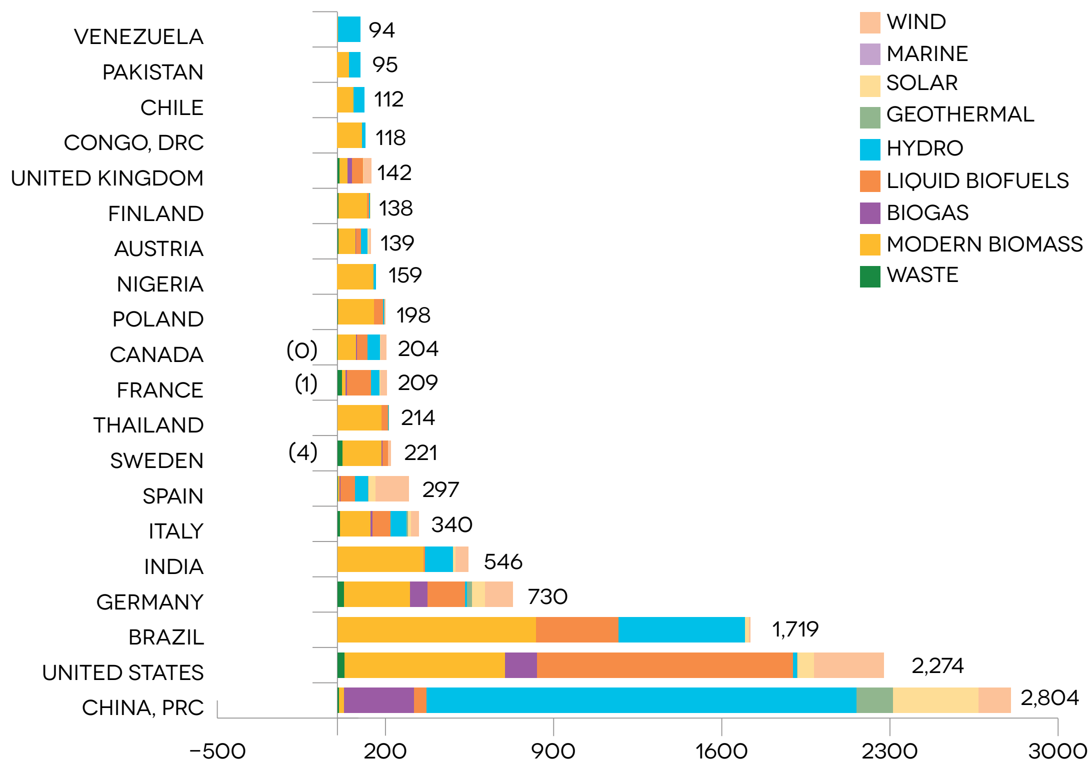


FIGURE 4.13 **TOP 20 COUNTRIES:** INCREMENTAL RENEWABLE ENERGY CONSUMPTION IN THE PERIOD 1990–2010 (PJ)

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.
NOTE: FIGURE EXCLUDES TRADITIONAL BIOMASS. DRC = DEMOCRATIC REPUBLIC OF CONGO.

56%
OF ELECTRICITY GENERATION IN
LATIN AMERICA COMES FROM RENEWABLE SOURCES – HIGHER THAN ANY OTHER REGION OF THE WORLD

	HYDRO	WIND	SOLAR AND MARINE	GEO-THERMAL	BIOMASS AND WASTE	TOTAL
North America	Canada	United States	United States	United States	United States	United States
	United States	Canada	Canada		Canada	Canada
Europe	Germany	Spain	Germany	Italy	Germany	Germany
	Switzerland	Germany	Italy	Germany	Austria	Italy
	Italy	France	Spain		Italy	Spain
	Sweden	UK	France		UK	France
	Croatia	Italy	Belgium		Netherlands	UK
Eastern Europe	Bulgaria	Poland	Slovakia		Czech Rep.	Poland
	Ukraine	Bulgaria	Bulgaria		Poland	Bulgaria
	Slovakia	Hungary	Hungary		Slovakia	Hungary
	Romania	Czech Rep.	Poland		Hungary	Slovakia
	Czech Rep.	Romania	Romania			Romania
Caucasus and Central Asia	Armenia	Azerbaijan				Armenia
		Kazakhstan				Azerbaijan
						Kazakhstan
Western Asia	Turkey	Turkey	Israel	Turkey	Turkey	Turkey
		Israel	Cyprus		Israel	Israel
		Cyprus				Cyprus
Eastern Asia	China	China	Japan	Japan	China	China
	Japan	Japan	China		S. Korea	Japan
	S. Korea	S. Korea	S. Korea			S. Korea
Southeastern Asia	Philippines	Vietnam		Philippines		Philippines
	Laos	Thailand		Indonesia		Laos
	Myanmar					Myanmar
						Vietnam
						Indonesia
Southern Asia	India	India	Bangladesh		India	India
	Iran	Iran				Iran
	Nepal					Bangladesh
						Nepal
						Maldives
Oceania	Australia	Australia	Australia	N. Zealand		Australia
		N. Zealand				N. Zealand

	HYDRO	WIND	SOLAR AND MARINE	GEO-THERMAL	BIOMASS AND WASTE	TOTAL
Latin America and Caribbean	Brazil	Brazil	Mexico		Brazil	Brazil
	Ecuador	Mexico			Chile	Ecuador
	Peru	Chile				Peru
	Guatemala	Dominica				Chile
	Panama	Nicaragua				Guatemala
Northern Africa	Algeria	Egypt				Egypt
		Morocco				Morocco
		Tunisia				Tunisia
						Algeria
Sub-Saharan Africa	Ethiopia	Kenya			Uganda	Ethiopia
	Sierra Leone	S. Africa				Sierra Leone
	Uganda	Eritrea				Uganda
	Kenya					Kenya
	Guinea					Guinea
World	China	China	Germany	N. Zealand	Brazil	China
	Brazil	United States	Italy	Italy	China	Germany
	Turkey	India	Japan	United States	Germany	United States
	India	Spain	Spain	Turkey	Austria	Italy
	Ethiopia	Germany	France	Philippines	India	India

TABLE 4.6 **TOP FIVE COUNTRIES IN ANNUAL CAPACITY ADDITIONS, 2009–2010, BY REGION**

SOURCE: U.S. ENERGY INFORMATION ADMINISTRATION DATABASE 2012.

In addition to these pioneering countries, many others have begun to introduce renewable energy for several reasons, most notably energy security and local environmental sustainability.

In Africa, for instance, countries such as Kenya, Uganda, Ethiopia, Mali, and Tanzania are consistently progressing toward the deployment of renewable energy. Other developing nations, such as Bangladesh, Honduras, Nepal, and Maldives, are also working toward assessing the magnitude of their renewable energy resource potential.

62%
OF TOTAL FINAL ENERGY CONSUMPTION
IN AFRICA COMES FROM RENEWABLE SOURCES – HIGHER THAN ANY OTHER REGION OF THE WORLD

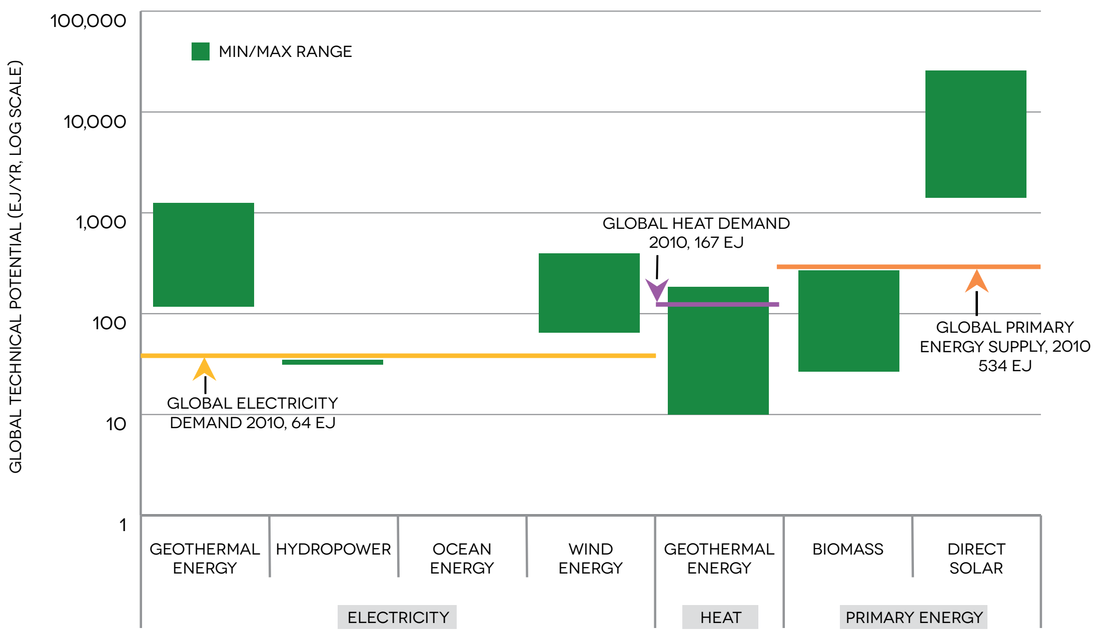


FIGURE 4.14 **ESTIMATED GLOBAL TECHNICAL RE POTENTIAL**

SOURCE: IPCC 2011.

High-impact opportunities

75%
OF THE WORLD'S UNEXPLOITED
POTENTIAL IN HYDROPOWER IS LOCATED IN AFRICA, ASIA AND SOUTH AMERICA.

Technical potential

Technical studies have consistently found that total global technical potential for renewable energy is substantially higher than global energy demand projected to 2050 (IPCC 2011) (figure 4.14). Technical potential for solar energy is the highest among renewable energy sources, but substantial potential also exists for biomass, geothermal, hydro, wind, and ocean energy.

Available data suggest that most of this technical potential is located in the developing world (figure 4.15 and table 4.7). For instance, at least 75 percent of the world's unexploited potential in hydropower is located in Africa, Asia, and South America, and about 65 percent of total geothermal potential is found in non-OECD countries (IJHD 2011; IPCC 2011). Also, many developing nations are located in the solar belt, the area with the highest solar irradiance across the globe.

Clearly, the challenge will be to capture and utilize a sizable share of this vast global technical potential in a cost-effective and environmentally and socially sound manner.

Meeting a higher share of global consumption with renewable energy sources will pose important technical challenges. For instance, scaling up the use of renewable energy will require the proactive planning of transmission systems, often on a broader regional scale, to allow for optimization of sources and balancing of variability. In fact, regional integration can allow increased resource use efficiency due to seasonal and dispatching complementarities (for example, among hydro, wind and solar resources). This can be particularly important in regions with a high potential for large hydropower (for example, South Asia), or regions where resource endowments exhibit high complementarities (for example, East Africa).

At the same time, the parallel deployment of energy efficiency measures that reduce peak demand on the grid while easing transmission losses and bottlenecks will help make renewable energy objectives more attainable. Indeed, energy systems will need to be planned and operated with both the use of renewable sources and deployment of energy efficiency measures in mind.

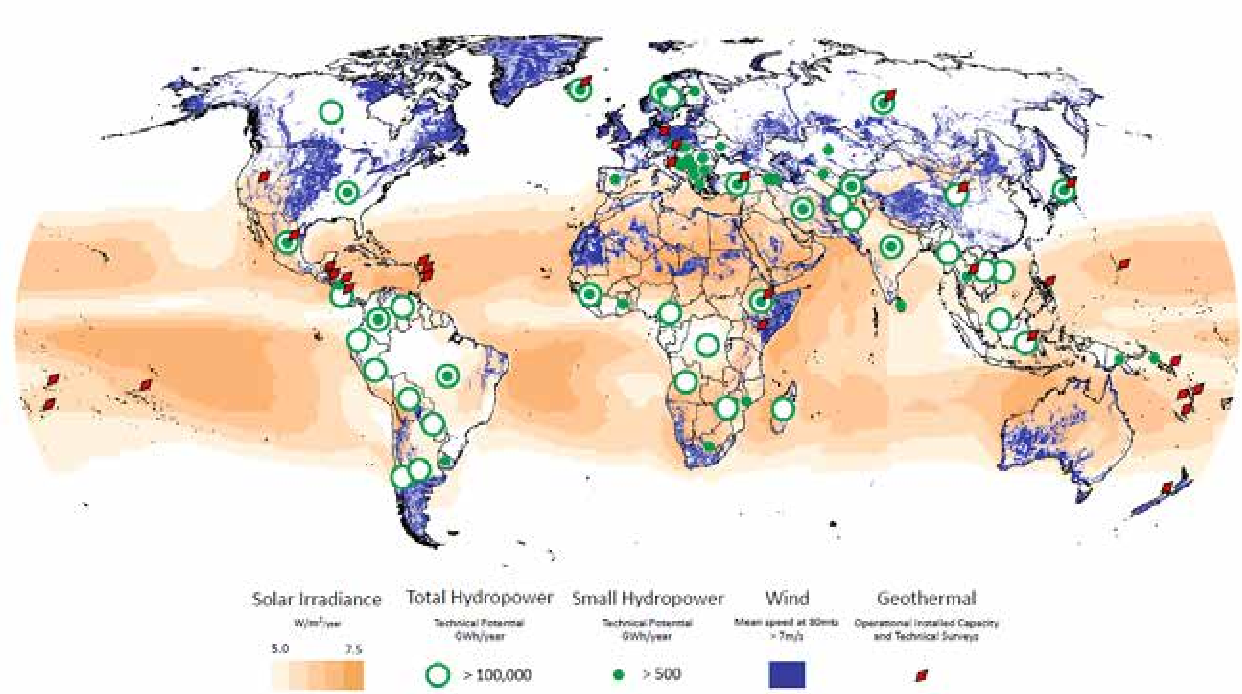


FIGURE 4.15 **HOT SPOTS: POTENTIAL FOR HYDRO, SOLAR, WIND, AND GEOTHERMAL**

SOURCE: MAP PREPARED BY AUTHORS WITH DATA FROM ÁSMUNDSSON 2008; IJHD 2011; IPCC 2011; MCCOY–WEST AND OTHERS 2011; UNEP AND NREL/U.S. DOE 2012.

The following table lists countries with high potential for renewable energy development by region and source.

REGION	SOLAR	WIND	GEOTHERMAL	LARGE HYDROPOWER[a]	SMALL HYDROPOWER[b]
EUR	Greece, southern Italy, southern Portugal and Spain	Iceland, Baltic Countries, Corsica, northern Spain, northern Europe, Scandinavia, southern France, southern Italy, Switzerland, the United Kingdom	Austria, France, Germany, Iceland, Italy, Portugal	Italy, Norway, Sweden	Bosnia and Herzegovina, Croatia, Estonia, Finland, Greece, Ireland, Latvia, Luxembourg, Macedonia (FYROM), Montenegro, Norway, Poland, Serbia, Spain
EE		Balkan countries, Russia, Ukraine	Russia		Hungary, Ukraine, Romania, Russia, Slovak Republic, Bulgaria, Czech Republic
CCA		Kazakhstan, Tajikistan, Turkmenistan, Uzbekistan		Georgia, Kyrgyzstan, Tajikistan,	Armenia, Azerbaijan, Georgia, Kazakhstan, Tajikistan, Uzbekistan
WAS	Central China, Iraq, Arabian Peninsula, India, Turkey	Black Sea countries (Turkey), Urals region (Russia),	Tonga, Turkey	Iraq, Turkey	Israel,Turkey
EAS		Southwestern China, northeastern China, Japan, Mongolia	China, Japan	Japan, China, Mongolia	Japan, Taiwan

REGION	SOLAR	WIND	GEOTHERMAL	LARGE HYDROPOWER[a]	SMALL HYDROPOWER[b]
SEA		Parts of Indonesia	Indonesia, Philippines, Thailand	Cambodia, Indonesia, Laos, Malaysia, Myanmar, Vietnam	Philippines, Thailand
SAS	Eastern Iran, southern Pakistan	India, Nepal, Pakistan		Afghanistan, Bhutan, India, Iran, Nepal, Pakistan,	India, Iran, Pakistan, Sri Lanka
NAF	Algeria, Egypt, Lybia, Morocco	Algeria, Egypt			Egypt
SSA	Saharan countries (particularly Mauritania, Mali, Niger, Chad, Sudan), eastern Africa (Somalia and Ethiopia), southern Africa (particularly Namibia, South Africa, and Botswana)	Central Chad, eastern Africa, Madagascar, Namibia, western Sahara, Somalia, South Africa, Sudan	Ethiopia, Kenya	Angola, Ethiopia, Cameroon, Congo, Gabon, Guinea, Madagascar, Mozambique, Zimbabwe	Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Ethiopia, Ghana, Guinea, Mauritius, Mozambique, Namibia, South Africa, Sudan, Uganda, Zambia
NAM	Southwestern North America (the U.S. Southwest, the northwest and Yucatan Peninsula of Mexico)	Alaska, central North America (the United States, Canada), Greenland, northeastern North America (the United States, Canada)	Mexico, United States	Canada, Mexico, United States	Mexico, United States
LAC	Andean region (Peru, Bolivia, Ecuador, northern Chile), Caribbean islands, El Salvador, Guatemala, Nicaragua, northeastern Brazil	Central America, northeastern Brazil, Patagonia (Argentina, Chile)	Costa Rica, Dominica, El Salvador, Guatemala, Nicaragua, St. Kitts and Nevis, St. Vincent and the Grenadines	Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Paraguay, Peru, Venezuela	Belize, Brazil, Colombia, Dominica, El Salvador, Grenada, Honduras, Nicaragua, Panama, Suriname, Uruguay
Oceania	Australia, Indonesia, Philippines	Australia and New Zealand (southwest, northeastern coastal zones, and Tasmania), parts of Papua New Guinea	Australia, Fiji, French Polynesia, New Zealand, New Caledonia, northern Mariana Islands, Papua New Guinea, Samoa, Solomon Islands, Vanuatu	Australia, New Zealand	New Caledonia, French Polynesia, Papua New Guinea

TABLE 4.7 **HOT SPOTS: COUNTRIES WITH HIGH POTENTIAL IN RENEWABLE ENERGY (AS SUGGESTED FROM AVAILABLE DATA)**

SOURCE: ÁSMUNDSSON 2008; IJHD 2011; IPCC 2011; MCCOY-WEST AND OTHERS 2011; UNEP AND NREL/U.S. DOE 2012.

NOTE: CCA: CAUCASUS AND CENTRAL ASIA; EAS: EASTERN ASIA; EEU: EASTERN EUROPE; EUR: EUROPE; LAC: LATIN AMERICA AND CARIBBEAN; NAF: NORTHERN AFRICA; NAM: NORTH AMERICA; OCEANIA: OCEANIA; SAS: SOUTHERN ASIA; SEA: SOUTHEASTERN ASIA; SSA: SUB-SAHARAN AFRICA; WAS: WESTERN ASIA.

a. Total hydropower for countries with technical potential greater than 100,000GWh/yr.

b. Definitions of small hydropower vary by country but are generally in the range of 5–30 MW.

Economic potential

Renewable energy is becoming increasingly competitive when compared to fossil-fuel-based alternatives (figure 4.16). For instance, the levelized costs of small- and large-scale hydropower and on-shore wind are already in the same cost range as fossil-fuel-fired electricity generation. When the resource potential or quality is high, biomass and geothermal-based power generation may also exhibit competitive costs, especially in non-OECD countries. In particular, a recently dominant feature of renewable energy market dynamics has been the falling price of photovoltaic modules, which are making this technology more competitive. Solar PV is on grid-parity in areas with very high solar irradiance, such as North Africa, Saudi Arabia and Australia.

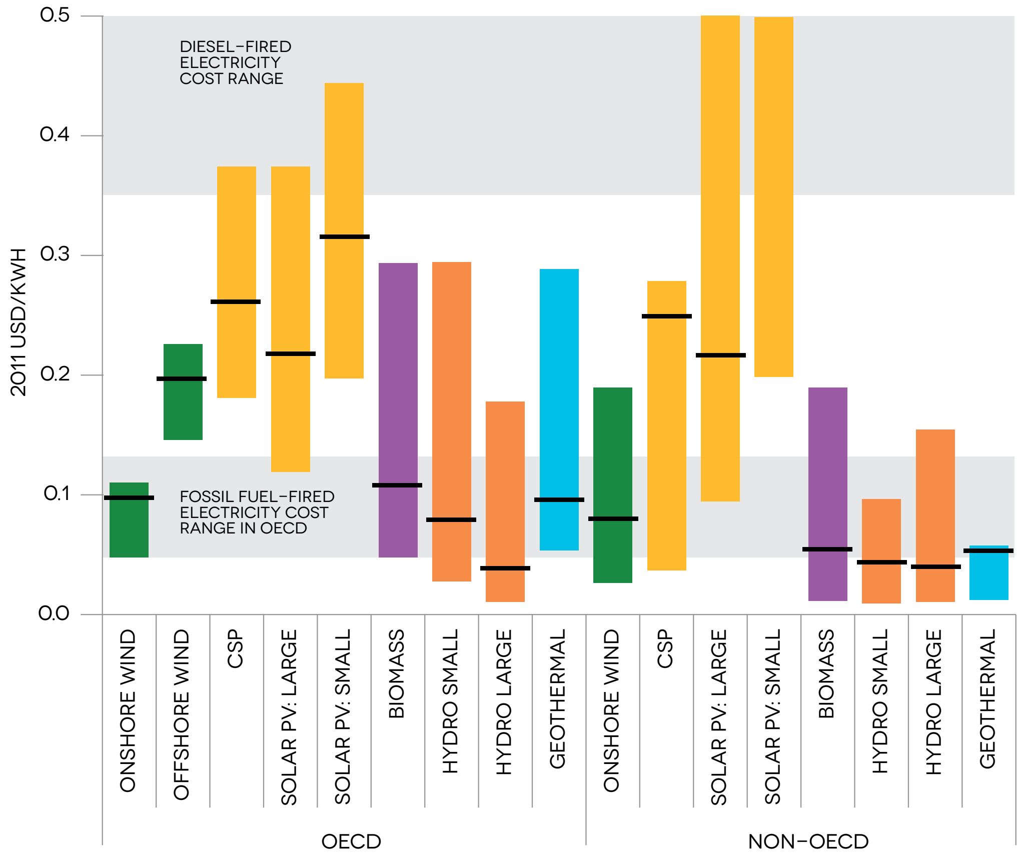


FIGURE 4.16 **LEVELIZED COSTS OF POWER GENERATION, 2012**

SOURCE:IRENA 2013B

NOTE: LEVELIZED COST REPRESENTS THE PER KILOWATT-HOUR COST OF BUILDING AND OPERATING A GENERATING PLANT OVER AN ASSUMED FINANCIAL LIFE AND DUTY CYCLE. WHILE LEVELIZED COSTS ARE A CONVENIENT SUMMARY MEASURE OF THE OVERALL COMPETITIVENESS OF DIFFERENT GENERATING TECHNOLOGIES, THE MEASURE DOES NOT COVER THE OVERALL SYSTEM COSTS. THE FULL COST OF INTRODUCING DIFFERENT GENERATION OPTIONS (ESPECIALLY VARIABLE) DEPEND ON THE SPECIFIC CONDITIONS OF THE SYSTEM; FOR EXAMPLE, THE EXTENT TO WHICH VARIABLE SOURCES MATCH THE DEMAND PROFILE AND COMPLEMENT THE MIX OF EXISTING SOURCES AND TECHNOLOGIES.

At the same time, renewables are competitive in countries vulnerable to high and volatile oil prices or those with high electricity prices; this is especially true in net-oil-importing countries particularly landlocked countries and SIDS. For instance, all countries in Central America and the Caribbean are net oil importers. In both subregions, oil provides more than 90 percent of primary energy needs and supplies more than half of power generation. The impact of oil price levels and changes on power generation costs is significant in these countries, and so electricity tariffs are very high. For example, the average residential tariff in Central America for consumption of 100 kWh reached 15 cents/kWh in 2010 (CEPAL 2011). In this subregion, only 9 percent of power generation is supplied by renewables other than hydropower, mainly geothermal, but also wind (CEPAL 2011).

In West Africa, where many countries are net oil importers, residential electricity tariffs are in the range of 15–30 cents/kWh (for consumption of 100 kWh), mainly due to high oil prices and the need to use emergency thermal generation (Briceño-Garmendia and Shkaratan 2011). In Uganda the levelized cost of diesel-HFO-based thermal generation is roughly 20–25 cents/kWh, much higher than the costs of biomass, small hydropower, or wind-based generation (estimated at 8 cents, 10 cents, and 12.4 cents per kWh, respectively). In countries with such problems, renewable energy has the potential to play a key role in hedging against high and volatile fuel oil prices.

Indeed, more than 55 developing economies exhibit high oil dependencies with imports supplying at least 50 percent of their domestic consumption needs. At the same time, almost all of the 53 small island developing states (SIDS) are completely dependent on oil and gas.[13] Even when considering the diversity of available fuels and energy sources, developing countries are more vulnerable (see Figure 4.17).

The competitiveness of renewable energy still depends on its relative cost vis-à-vis fossil fuels. Today, fossil fuels benefit from huge subsidies of around $523 billion annually around the world, while renewable energy support stands at just $88 billion (IEA 2012c). Phasing out fossil fuel subsidies while incorporating carbon-pricing mechanisms that fully reflect the externality cost of fossil-fuel-based energy would be critical steps toward accelerating the scale-up of renewable energy.

Nevertheless, levelized cost comparisons between variable sources of renewable energy (notably wind and solar) and others (such as large hydro, geothermal and fossil fuels) are not straightforward. The full cost of introducing different generation options (especially variable) depends on the specific conditions of the system—for example, the extent to which variable sources match the demand profile and complement the mix of existing sources and technologies.

Ultimately, attaining the SE4ALL target for renewable energy depends to a large extent on the efforts of countries with high energy demand and consumption. These countries (including most developed and emerging economies) would have to significantly increase their efforts to scale up renewables, introducing effective and efficient policy mechanisms across all segments of the energy sector and strengthening the overall business environment to attract and leverage different sources of finance.

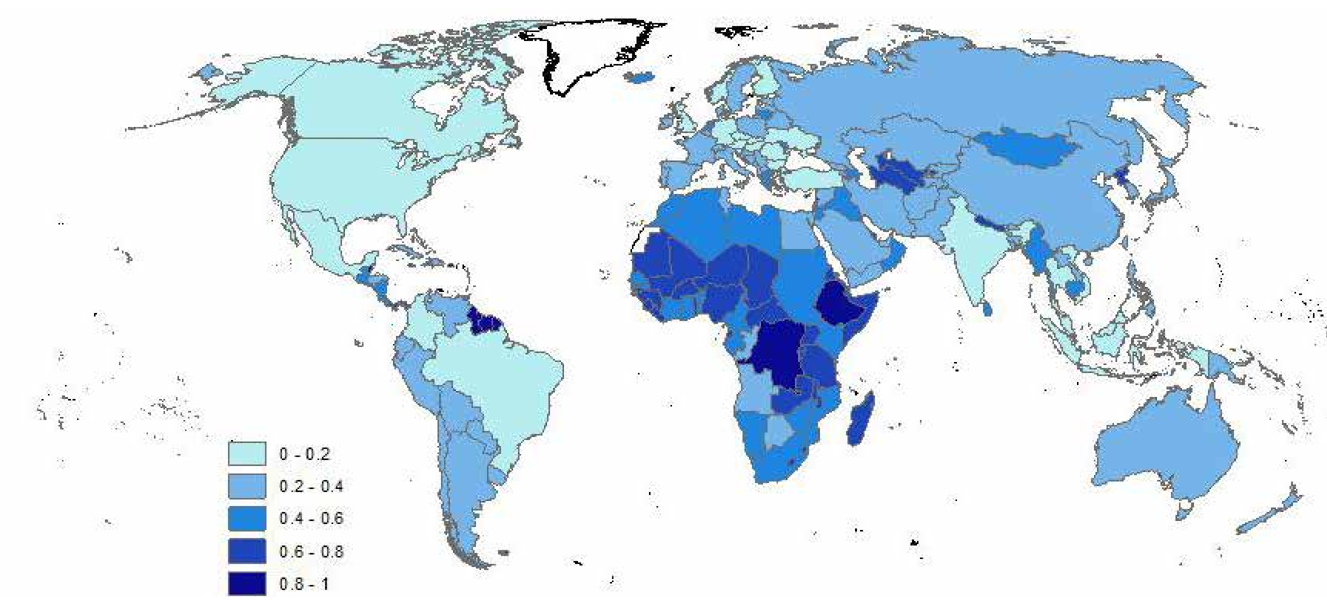


FIGURE 4.16 **DIVERSITY INDEX OF PRIMARY ENERGY MIX (BASED ON HERFINDAHL–HIRSCHMAN INDEX HHI)**

SOURCE: PREPARED BY AUTHORS FROM IEA DATA FOLLOWING BACON AND KOJIMA (2008), KOJIMA (2012)
NOTE: THE ENERGY SOURCES CONSIDERED IN THE PRIMARY ENERGY MIX ARE NATURAL GAS, OIL AND OIL PRODUCTS, COAL (COAL AND PEAT), HYDROPOWER, OTHER RENEWABLES (BIOFUELS, WASTE, GEOTHERMAL, SOLAR, WIND, OTHER), AND NUCLEAR. HIGHER INDEX VALUES INDICATE LOWER DIVERSITY IN PRIMARY ENERGY MIX, AND THEREFORE, INCREASED VULNERABILITY TO CHANGES.

13 A notable exception is Trinidad and Tobago, an island country that produces both oil and gas.

SECTION 4. THE SCALE OF THE RENEWABLE ENERGY CHALLENGE

This section looks at the scale of the challenge to double the proportion of renewable energy in the global energy mix. It does this by comparing current trends with the trajectory required to meet the target. It then looks at projections of the proportion of renewable energy under various scenarios, and attempts to draw some lessons about the conditions needed to achieve the target. Finally, it highlights some of the main challenges associated with this ambitious target, discusses opportunities, and concludes with general policy recommendations.

Current trends in the use of renewable energy

As shown in section 2 of this chapter, there have been rapid rises in the deployment of several renewable energy sectors in recent years. Generation from wind and solar has grown at double-digit annual percentage rates, and the transport fuel sector has also grown strongly. Overall, the level of energy generation from renewables has been growing steadily, at a 2 percent CAGR (in terms of TFEC), and has increased in absolute terms by 36 percent since 1990.

But as shown in figure 4.18, overall global energy consumption has also been rising at nearly the same rate (1.5 percent). As a result, despite the sustained growth in renewable energy production, the overall level of renewables as a proportion of global energy needs has essentially remained stable, at close to 18 percent.

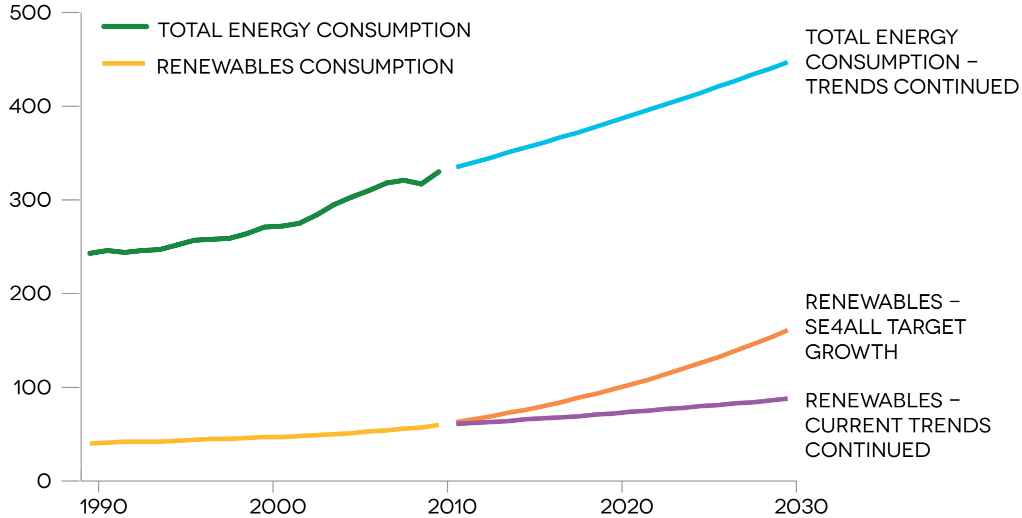


FIGURE 4.18 **GLOBAL TRENDS IN RENEWABLE ENERGY AND TOTAL FINAL ENERGY CONSUMPTION, 1990–2030**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.

Figure 4.18 also shows that if current trends continued to 2030, renewable energy consumption would rise by 56 percent to around 95 EJ. But if trends in TFEC were also to continue to 2030, this would increase by 48 percent to 490 EJ, and the share of renewables in the global energy mix would increase only to 19.4 percent.

If overall energy consumption were to stabilize, doubling the contribution of renewables would imply consumption of around 118 EJ by 2030, requiring an annual growth rate of 3.5 percent (a 50 percent increase over current levels). If current overall growth in energy demand continues, meeting the target would require the consumption of renewables to triple to around 177 EJ by 2030, an annual growth rate of 5.9 percent, which is 2.5 times the current growth rate. Given the likely reduction in the "traditional" use of biomass, the increase in sustainable renewable production would have to be even larger.

19.4 %
OF TOTAL FINAL ENERGY CONSUMPTION
FROM RENEWABLE SOURCES PROJECTED FOR THE YEAR 2030 UNDER BUSINESS AS USUAL; BARELY ONE PERCENTAGE POINT HIGHER THAN TODAY.

This highlights how challenging it will be to meet this goal, and underscores the importance of the link between the SE4ALL goals for renewable energy, energy efficiency, and energy access. Achieving the renewable energy goal is likely to depend both on rapid expansion of deployment rates for renewables as well as on considerable progress being made in reducing overall global energy consumption via energy efficiency improvements.

Future scenarios

There are a wide range of energy scenarios that consider how energy demands may evolve in the future and what the role of renewable energy in the global energy mix will be. These scenarios use different approaches: some are based on policy considerations; others are based on a least-cost modeling approach, given a portfolio of technology options; others are goal-oriented exercises that place constraints on future scenarios (for example, by setting global emission limits). Scenario analysis also uses different assumptions about many of the essential parameters, including those relating to population and economic development and how these are coupled with energy demand, the availability and costs of technologies, and so on.

Several national and international organizations, such as the IEA, the EIA, the International Institute for Applied Systems Analysis (IIASA), the European Union, and NGOs such as 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.

A detailed review of all the relevant modeling exercises is not attempted here, but a short summary of major projections for energy demand and supply in 2030, which highlights the wide range of projections of total final energy consumption and the renewable energy share (from 18 percent to 45 percent), is given in table 4.8.

ORGANIZATION	SCENARIO	TPED (EJ)	RENEWABLES (%)	TFEC (EJ)	RENEWABLES (%)
IEA Statistics 2010	2010 Energy Balances	533	13	324	18
IEA 2012c[a]	NPS 2030	687	17	425	21
	450 ppm 2030	605	23	384	27
	EWS 2030			380	22
IEA 2012[a]	2D	600			
EIA 2011[b]	Reference	684	13.9		
	High oil case	733	13.6		
	Low oil case	655	13.9		
IPCC 2011[c]	ReMind	590	32		
	MINICAM	608	24		
	MESAP/PlaNet	474	39		
IIASA 2012[d]	GEA 1	446	29.8	312	36.7
	GEA 2	458	29.7	321	36.3
	GEA 3	457	27.9	311	34.4
	GEA 4	443	33.3	303	40.7
	GEA 5	456	28.1	324	34.6
	GEA 6	454	34.7	314	40.9
ExxonMobil 2011[e]		618	14	478	24%
BP 2012[f]		683	14		
Shell 2013	Mountains	749	14		
	Oceans	777	17		
Greenpeace/EREC/GWEC 2012	Revolution			340	45%
WWF, Ecofys/OMA 2012				319	42%

TABLE 4.8 **ENERGY DEMAND PROJECTIONS AND RENEWABLE ENERGY SHARE IN MAJOR ENERGY SCENARIOS, 2030**

SOURCE: : IEA 2010, 2011, 2012A, 2012C; IPCC 2011; IIASA 2012; EXXONMOBIL 2012; BP 2012; SHELL 2013; GREENPEACE, EREC, AND GWEC 2012; WWF, ECOFYS, AND OMA 2011.

NOTE: TPED = TOTAL PRIMARY ENERGY DEMAND; TFEC = TOTAL FINAL ENERGY CONSUMPTION.

a. TPED is based on the physical energy content method, which assumes 33 percent efficiency for nuclear; 100 percent efficiency for renewable energy resources like hydro, wind, and solar PV; 50 percent for CSP; and 10 percent for geothermal.

b. TPED is based on the substitution method.

c. In all scenarios, the direct equivalent method is used to measure primary energy demand.

d. TPED is based on the direct equivalent method, assuming 100 percent efficiency for both non-biomass renewables and nuclear.

e. The data are based on interpolations between the data points for 2025 and 2040.

f. 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 percent (that is, the average for OECD thermal power generation).

The following subsections summarize the major conclusions of three major modeling exercises: the IPCC analysis described in its Special Report on Renewable Energy; the modeling work carried out in support of the IEA's World Energy Outlook (IEA 2011); and the IIASA's Global Energy Assessment scenario analysis.

United Nations Framework Convention on Climate Change's (UNFCCC's) analysis

The IPCC Special Report on Renewable Energy reviewed a wide range of modeling exercises, covering 164 scenarios from 16 different large-scale integrated models, and drew some general lessons that provide a relevant context for understanding the SE4ALL goal:

- The models differ widely (by a factor of three) in terms of the anticipated growth of overall global energy production and demand.

- Renewable energy deployment plays a substantially higher role in scenarios associated with ambitious GHG emission targets. For scenarios targeting atmospheric carbon dioxide concentrations (CO2) at levels below 440 ppm, the median deployment level for 2030 is 139 EJ with the highest level of 252 EJ. But these low-emission scenarios exhibit a wide range of renewable energy deployment levels, depending on assumptions about the mix of low-carbon options to be deployed. Where carbon capture and storage (CCS) or nuclear generation is constrained, renewable energy plays a larger role.

- The range of figures for the proportion of renewables in the global energy mix also varies widely. More than half the scenarios show a contribution of over 17 percent, with the highest renewable energy share reaching 43 percent.

- The scenarios show that growth in renewable energy will be worldwide and not constrained to particular regions, although renewable energy will become most significant in emerging and developing economies, where growth in energy demand is likely to be focused. The scenarios also show that the full spectrum of renewable energy technologies will be deployed, with no dominant technology, although modern bioenergy, wind, and solar energy will make the largest contributions.

The IEA's World Energy Outlook scenarios

Table 4.7 shows the primary energy demand today and in 2030 according to the three IEA scenarios developed in the *World Energy Outlook* (IEA 2011). The Current Policies Scenario (CPS) assumes that current policy commitments are maintained. In this scenario, the level of renewables continues to grow sharply. But given the continuing rise of overall energy demand, the proportion of renewables rises only slightly by 2030, to 18.4 percent. The New Policies Scenario (NPS) factors in the impacts of announced policy commitments to improving energy efficiency and deploying low-carbon energy technologies. In this scenario, the modeling indicates that the proportion of renewables would increase more rapidly, reaching 21.1 percent by 2030. This is still significantly below the SE4ALL goal, however, highlighting that current policy commitments are insufficient to promote the type of change that the initiative envisions.

The WEO 450 Scenario sets out an energy pathway that is consistent with a 50 percent chance of meeting the goal to limit the increase in average global temperature to 20C compared with preindustrial levels. It assumes that more vigorous policy action is taken in the years up to 2020 and that, thereafter, OECD and other major economies set economy-wide emissions targets consistent with a trajectory in which greenhouse gas levels are stabilized at a level of 450 ppm of CO2 equivalent. In this scenario, the overall level of renewables rises to 27 percent, which is still significantly below the 36.1 percent SE4ALL target. The emissions trajectory associated with the WEO 450 Scenario is consistent with the 2°C Scenario (2DS) developed in the context of IEA's Energy Technology Perspectives 2012. In the 2DS, renewables make up around 50 percent of electricity generation in 2030, and their share of total average world electricity generation increases to 57 percent by 2050.

The WEO 450 Scenario foresees a higher share of renewables and increased energy efficiency, and also includes ambitious deployment of CCS technology, assuming around 35 percent of CCS in coal-fired power generation by 2030. Other scenarios use higher levels of renewable power generation instead of CCS technologies to reduce global CO2 emissions.

The IIASA's Global Energy Assessment scenarios

Within the suite of IIASA's Global Energy Assessment (GEA) scenarios, a number of different energy pathways explore alternative combinations of energy efficiency improvements and supply-side transformations to achieve ambitious targets for sustainable development (table 4.9). These include the goals of:

- Providing almost universal access to affordable clean cooking and electricity for the poor
- Limiting air pollution and health damages from energy use
- Improving energy security throughout the world
- Limiting climate change

The main aim is to provide a better understanding of what is needed to achieve these goals in terms of the combination of measures, time frames, and costs. This involves consideration of the extent to which changes in the demand for energy services together with demand-side efficiency measures can reduce the energy consumed to provide mobility, housing, and industrial services. Alternatively, if there is less emphasis on reducing energy demand, then a more rapid expansion of a broader portfolio of low-carbon supply-side options is needed; the successful implementation of demand-side policies increases the flexibility of supply-side options (and vice versa).

The scenarios are grouped in terms of three levels of differentiation. First, the level of energy demand is considered via three GEA pathway groups, which represent different emphases in terms of demand-side and supply-side changes. Each group varies, in particular, with respect to assumptions about the comprehensiveness of demand-side policies to enhance efficiency, leading to pathways of comparatively low energy demand (GEA-Efficiency), intermediate demand (GEA-Mix), and high demand (GEA-Supply).

The second level of differentiation considers what dominant transportation fuels and technologies might emerge, distinguishing between systems in which conventional liquid fuel systems remain important and those where advanced systems based on electricity/hydrogen take on a major role. For each combination, the diversity of the portfolio of supply-side options is then considered: first, allowing for the unconstrained deployment of the full range of technology options (including renewables, nuclear, and CCS), then looking at a range of ten options where deployment of one or more these technology options is constrained.

The third level of differentiation considers feasible supply-side transitions (for example, use of CCS) as well as demand-side measures.

21%–45%
IS THE RANGE IN THE SHARE OF
RENEWABLE ENERGY IN TFEC BY 2030 ESTIMATED BY LEADING GLOBAL ENERGY MODELS

PATHWAY	CHARACTERISTICS	% RE IN TFEC, 2030
GEA 1	Assumes limited potential of land-based mitigation options, including low potential for biomass; no negative emissions technologies (Bio-CCS) and limited potential for afforestation/reforestation measures. Transportation sector follows an "advanced" trajectory (allowing for rapid expansion of, for example, electric vehicles).	36.7
GEA 2	Assumes the phase-out of nuclear power generation in the medium term, and no CCS. Transportation sector follows an "advanced" trajectory (allowing for rapid expansion of, for example, electric vehicles).	36.3
GEA 3	Assumes limited potential for bioenergy and intermittent renewables (solar and wind). Transportation sector follows a "conventional" trajectory (future vehicles continue to reply predominantly on liquid fuels).	34.4
GEA 4	Assumes limited potential of land-based mitigation options, including low potential for biomass; no negative emissions technologies (Bio-CCS) and limited potential for afforestation/reforestation measures. Transportation sector follows a "conventional" trajectory (future vehicles continue to reply predominantly on liquid fuels).	40.7
GEA 5	Assumes no CCS. Transportation sector follows a "conventional" trajectory (future vehicles continue to reply predominantly on liquid fuels).	34.6
GEA 6	Assumes the phase-out of nuclear power generation in the medium term, and no CCS. Transportation sector follows a "conventional" trajectory (future vehicles continue to reply predominantly on liquid fuels).	40.9

TABLE 4.9 **CHARACTERISTICS OF THE SIX GEA PATHWAYS THAT MEET THE SE4ALL TARGET FOR RENEWABLE ENERGY**

SOURCE: IIASA 2012.
NOTE: CCS CAN ALSO BE USED IN COMBINATION WITH BIOENERGY (BIOCCS) TO PRODUCE NET NEGATIVE CARBON DIOXIDE (CO_2) EMISSIONS. GEA = GLOBAL ENERGY ASSESSMENT; CCS = CARBON CAPTURE AND STORAGE; TFEC = TOTAL FINAL ENERGY CONSUMPTION ALL OF THE SIX PATHWAYS CORRESPOND TO THE EFFICIENCY SCENARIO OF THE GLOBAL ENERGY ASSESSMENT (GEA).

A general conclusion of the analysis is that the role of renewables and other low-carbon supply-side technologies is greater in the scenarios where restricting overall growth in energy demand is less successful, because of added pressure to decarbonize the supply side. The role of renewable technologies (particularly for power generation) will increase substantially, and renewable energy will play a significant role in achieving all the scenarios meeting the GEA sustainability objectives. But the specific SE4ALL renewable energy goal is not achieved in all the scenarios. In the scenarios where the renewable energy proportion equals or exceeds the doubling target, liquid transport fuels are still an important part of the mix (and the most advanced transport technologies are not deployed). This opens up greater opportunities for biofuels, and so increases the overall share of renewable energy.

Conclusions from scenarios

These three exercises indicate several conclusions:

- Current deployment growth rates are not high enough to achieve the SE4ALL target on renewables (see figure 4.19). The level will need to rise by 50 percent–250 percent, depending on trends in overall global energy demand. The scale of the challenge depends equally on the success in stimulating the deployment of renewables and constraining increases in energy demand. As a result, the achievement of this target is intimately linked to success in achieving the complementary SE4ALL energy efficiency goal.

- Exercises show a wide range of potential energy futures, depending on the aims and constraints applied within different models and scenarios. The IPCC 's review of modeling exercises (*Special*

Report on Renewable Energy Sources and Climate Change Mitigation) shows the share of renewables in the global energy mix to range between 17 and 43 percent (in terms of primary rather than final energy consumption).

- Consideration of the IEA's CPS and NPS indicate that neither current policy commitments nor those under consideration will be enough to stimulate sufficient deployment of renewables to meet the SE4ALL goals.

- The six IIASA GEA scenarios concerned with meeting sustainability targets for energy access, limiting air pollution and health damages from energy use, improving energy security, and limiting climate change all include high levels of renewable energy deployment, although the overall level does not reach the SE4ALL goals in every case.

Overall the scenarios show how important renewables are in any future sustainable energy mix, and at the same time highlight their links with energy efficiency and other low-carbon technologies. The SE4ALL target falls within the scope of many scenarios that aim to constrain climate change and meet other sustainability goals (although, as shown in figure 4.19, it falls at the upper end of the spectrum of results from the scenarios).[14] Strong policy action is needed in the short term to stimulate deployment of the technologies and to improve energy efficiency if the goal is to be achieved.

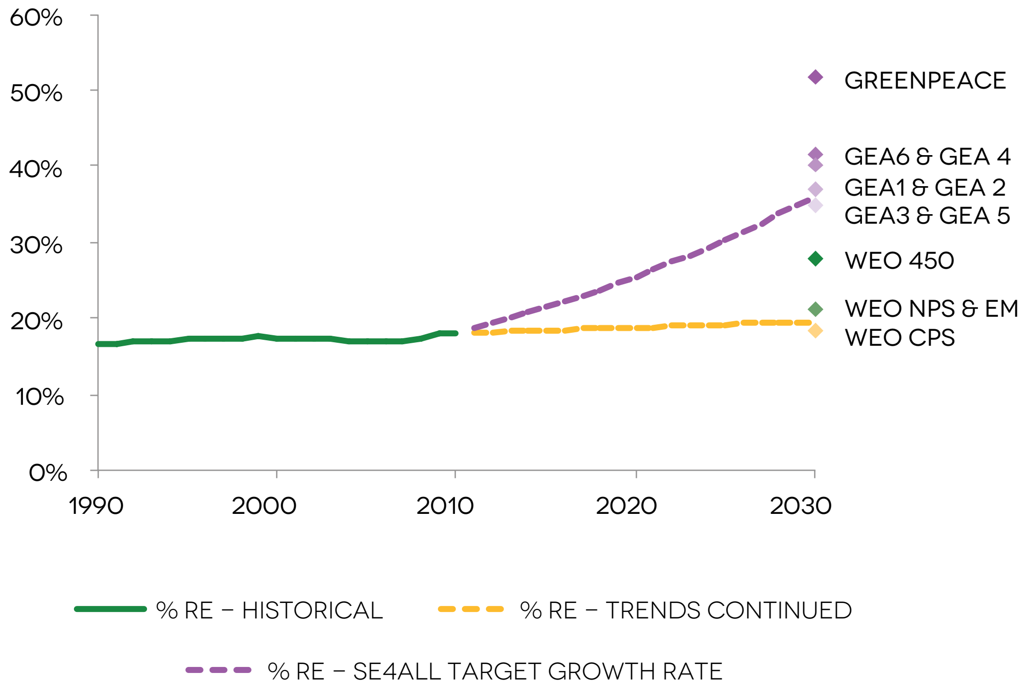


FIGURE 4.19 **SHARE OF RENEWABLE ENERGY IN GLOBAL TOTAL FINAL ENERGY CONSUMPTION: CURRENT TRENDS AND SCENARIOS**

SOURCE: IEA 2012C; EXXONMOBIL 2012; IIASA 2012; GREENPEACE, EREC, AND GWEC 2012.
NOTE: WEO = WORLD ENERGY OUTLOOK; CPS = CURRENT POLICIES SCENARIO; NPS = NEW POLICIES SCENARIO; GEA = GLOBAL ENERGY ASSESSMENT; EM = EXXONMOBIL; RE = RENEWABLE ENERGY.

[14] Based on available data sources (with their associated statistical limitations), the share of renewable energy in TFEC is estimated to be 18 percent as the starting point in 2010. This implies an SE4ALL objective of 36 percent for year 2030. Because the inclusion of sustainability considerations would lower this initial condition and target, they should be regarded as an upper bound.

Barriers and opportunities related to the SE4ALL

This section discusses the main barriers and opportunities for attaining the SE4ALL objective of doubling the share of renewable energy in the global energy mix.

The challenges of achieving SE4ALL targets vary across regions. They are influenced by a number of factors:

- Expected growth in renewable energy production
- Expected growth in overall TFEC
- Expected trends in the use of traditional biomass

Table 4.10 shows historical trends in the share of renewables for different regions around the world, and compares this with the projected data from the WEO 450 Scenario.

Within the OECD the share of renewable energy has been rising due to successful policy efforts and low growth in overall energy demand, as well as the low share of traditional biomass. These trends are expected to continue, and the OECD countries are expected to significantly increase renewables' share of TFEC.

For the non-OECD countries, we can see several observed and expected trends, depending on the patterns of overall energy growth and the opportunities for using renewables and switching away from inefficient biomass use. For regions with a continuing high share of renewables in the power sector (from hydro) and lower use of traditional biomass, we can expect a trend in which the overall share of renewables continues to increase (for example, in the non-OECD Americas). In regions where the use of traditional biomass is widespread (that is, in Africa and Asia), a transition to more efficient biomass fuels does not increase the proportion of renewables even when biomass is used more efficiently, since "raw" fuels determine the statistics. But more efficient uses of biomass potentially free up resources for other applications.

In the WEO 450 Scenario, the Middle East also sees a substantial increase in the share of renewable energy (5.4 percent).

	1990	2000	2010	2030 WEO 450	2030 GEA 1–6	2030 ALL GEA
OECD34	6.9	7.7	10.0	28		
Africa	62.2	63.1	61.7	65		
Non-OECD Americas	38.0	32.7	34.5	47		
Asia excluding China	51.1	43.6	36.7	37		
China (region)	33.2	28.9	19.3	23		
Non-OECD Europe and Eurasia	3.3	4.8	5.4	10		
Middle East	1.0	0.5	0.6	6		
World	16.6	17.4	18.0	28	34–41	23–41

TABLE 4.10 **SHARE OF RENEWABLES IN TOTAL FINAL ENERGY CONSUMPTION BY REGION (AFTER ALLOCATION)**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D; IEA 2011; AND IIASA (2012).
NOTE: WEO = WORLD ENERGY OUTLOOK; GEA = GLOBAL ENERGY ASSESSMENT; OECD = ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT.

Economic and market opportunities and barriers

The costs of many renewable energy technologies have been a major barrier to their adoption, a problem compounded in many cases by market issues, such as subsidies for competitive energy supply, and by a lack of costing methods to include social and environmental costs such as those related to carbon emissions. Strong growth in renewable deployment has led to significant reductions in the costs of some of the principal technologies. Renewables can now provide a cost-competitive solution in many circumstances.

For mini-grid and off-grid markets, renewable energy technologies are competitive or cheaper than other energy sources in many cases (depending on available sources and fuels). For grid-integrated projects, renewable energy technologies are increasingly competitive in a substantial number of countries. This cycle of increased deployment and reduced costs is likely to continue and will be an important driver for the accelerated renewable energy deployment needed to achieve the target. But in many markets economic barriers still need to be addressed by policy measures that make up for the lack of a level playing field, support market introduction, foster the development of local supply chains and infrastructure, and stimulate the deployment that will lead to further cost reduction and competitiveness.

In addition, there are large market opportunities, especially in growing countries in Asia, Africa, and Latin America. In its CPS, the IEA estimates that 75 percent of total new capacity additions in electricity will be added in non-OECD countries by 2030 (IEA 2012c). This scenario also foresees the addition of 60 percent of total new renewable energy capacity and 88 percent of total new hydroelectric capacity in non-OECD countries (these relative shares are very similar under the IEA's NPS).

$250–400 BILLION
IS THE ANNUAL
FINANCING REQUIREMENT FOR RENEWABLE ENERGY THROUGH 2030 TO MEET SE4ALL OBJECTIVES.

With regard to biofuels, the IEA estimates in both the CPS and NPS that about 40 percent of the expected incremental consumption projected to 2030 will originate in non-OECD countries.

Noneconomic opportunities and barriers

Section 3 has already discussed a number of important drivers for renewable energy, including energy security, climate change, and local environmental conditions. The prospective analysis using global energy models shows that scenarios aimed at reducing CO_2 emissions have higher shares of renewables, although this share depends also on how other low-carbon solutions like CCS are deployed.

On the other hand, several scenarios highlight noneconomic barriers related to:

- Policy uncertainty and risk from ineffective policy design, discontinuity, or insufficient transparency of policies and legislation
- Institutional and administrative issues, including a lack of strong, dedicated institutions; lack of clear responsibilities; and complicated, slow, or nontransparent permitting procedures
- Financial barriers associated with the absence of adequate funding opportunities and financing products for renewable energy technologies
- Infrastructure and integration issues that mainly center on the flexibility of the energy system (for example, the power grid) to integrate/absorb renewable energy technologies
- Lack of knowledge about the availability and performance of renewable energy technologies as well as lack of skilled workers
- Environmental barriers linked to experience with planning regulations and public acceptance of renewable energy technologies

The relative importance of these barriers differs for each technology and market, and the priority changes as a technology matures along the commercialization and deployment path. Also, as one barrier is overcome, others may become apparent.

Policy requirements

Effective policies designed to tackle these barriers are a key requirement to facilitate renewable energy deployment. This is the case even when renewables can provide a cost-competitive energy source, given the nonfinancial regulatory issues that can inhibit deployment.

Policy makers need to be able to deploy policy portfolios that have maximum impact in stimulating deployment and are as cost-effective as possible. Key issues include:

- Establishing a predictable renewable energy policy framework, integrated into an overall energy strategy with clear targets
- Implementing a portfolio of incentives based on technology and market maturity where these are necessary
- Adopting a dynamic policy approach based on monitoring of policy impacts in the context of national and global market trends.

Broadening the geographic base and the need for capacity building

To meet the SE4ALL goal for renewable energy, countries that have already started to deploy renewables need to continue along this path and maintain or accelerate progress. But achieving this challenging goal will depend on a much broader range of countries taking steps to stimulate deployment of renewables as a major component of their overall energy mix. It is likely they can do this in the light of accumulated experience with policy portfolios and technological deployment gained elsewhere. They can also benefit from the significant and continuing cost reductions that are making renewables cost-competitive with other energy sources in a much broader range of circumstances.

But in order to effectively diversify deployment there is a need to build capacity in these new countries in the areas of:

- Awareness of the potential contribution of renewable sources to national energy needs among decision and policy makers
- Awareness of internationally accepted best policy practices
- Development of appropriate regulatory frameworks and institutions
- Information and data gathering (for example, on resource potentials and infrastructure needs)
- Technology skills, supply chain and installation and maintenance capabilities.
- Provision of finance from local and international sources.Public information

Conclusions

In the two decades between 1990 and 2010, the family of renewable energy technologies has matured and established a strong foothold in global energy supply. The range of technologies that can be considered commercially proven has grown, and costs have been reduced significantly. With new pressures on energy supply and security, along with the need to reduce global emissions, the case for deployment is now stronger than ever. Growing energy demand, higher fossil-fuel prices, and the continually diminishing costs of key technologies like wind and solar open up new opportunities for renewables as affordable and sustainable options in each sector (electricity, heat, and transport).

Given the significant scale of the challenge posed by the SE4ALL renewables target, a concerted effort will be needed from governments—both those that have already started along the path of renewable energy deployment and those still exploring the options—to make renewables a key component of their future sustainable energy mix. It will also require a major coordinated effort from a wide range of relevant international organizations to track progress, to identify and promote best practices in policy making and project implementation, and to assist in necessary capacity building to facilitate the diffusion of these technologies into global energy markets.

References

Ásmundsson, R. K. 2008. *South Pacific Islands Geothermal Energy for Electricity Production*. ÍSOR-2008/032, compiled for the Icelandic International Development Agency. http://www.edinenergy.org/pdfs/pacific_islands_geothermal.pdf.

Bacon, R., and M. Kojima. 2008. *Coping with Oil Price Volatility*. Washington, DC: Energy Sector Management Assistance Program (ESMAP), the International Bank for Reconstruction and Development / World Bank Group. http://esmap.org/sites/esmap.org/files/8142008101202_coping_oil_price.pdf

Bazilian, Morgan, I. Onyeji, M. Liebrich, I. MacGill, J. Chase, J. Shah, D. Gielen, D. Arent, D. Landfear, and S. Zhengrong. 2012. "Re-considering the Economics of Photovoltaic Power." Bloomberg New Energy Finance, https://www.bnef.com/.

BNEF (Bloomberg New Energy Finance), UNEP (United Nations Environment Programme), and Frankfurt School. 2012. *Global Trends in Renewable Energy Investment 2012*. Frankfurt School of Finance and Management, Franfurt, Germany.

BNEF Renewable Energy Investment Data Base, 2013. https://www.bnef.com/Renewables/

BP (British Petroleum) 2012. *BP Energy Outlook 2030*. London.

Briceño-Garmendia, Cecilia, and Maria Shkaratan. 2011. "Power Tariffs: Caught between Cost Recovery and Affordability." Policy Research Working Paper 5904, World Bank, Washington, DC.

Chen, H., T. N. Cong, W. Yang, C. Tan, Y. Li, and Y. Ding. 2009. "Progress in Electrical Energy Storage System: A Critical Review." *Progress in Natural Science* 19: 291-312.

CEPAL (Comision Economica para America Latina y el Caribe). 2011. Centroamerica: *Estadisticas del Subsector Electrico*, 2010. Mexico: UN CEPAL.

DOE (U.S. Department of Energy). 2001. "Renewable Energy: An Overview." http://www.nrel.gov/docs/fy01osti/27955.pdf.

EIA (U.S. Energy Information Administration). 2011. I*nternational Energy Outlook 2011*. Washington, DC.

Elizondo-Azuela, Gabriela, and Luiz Barroso. 2011. "Design and Performance of Policy Instruments to Promote the Development of Renewable Energy: Emerging Experience in Selected Developing Countries." Energy and Mining Sector Board Discussion Paper No. 22, World Bank, Washington, DC.

EPIA (European Photovoltaic Industry Association). 2013. "World's Solar Photovoltaic Capacity Passes 100-Gigawatt Landmark after Strong Year." http://www.epia.org/index.php?eID=tx_nawsecuredlandu=0andfile=/uploads/tx_epiapressreleases/130211_PR_EPIA_Market_Report_2012_FINAL_01.pdfandt=1363974656andhash=51671f0c9b602ecae6cc5acc83b17506dcc0d4ef.

European Photovoltaic Industry Association (EPIA) and Photovolatic Technology Platform, 2011, Solar Europe Industry Initiative Implementation Plan 2010-2012, EPIA, Brussels.

ExxonMobil. 2012. *ExxonMobil—The Outlook for Energy: A View to 2040*. Irving, Texas: ExxonMobil.

Goldemberg, J. 2004. "The Case for Renewable Energy." Thematic Background Paper, International Conference for Renewable Energy, Bonn. http://www.ren21.net/Portals/97/documents/Bonn%202004%20-%20TBP/The%20case%20of%20Renewable%20Energies.pdf.

Greenpeace International, EREC (European Renewable Energy Council), and GWEC (Global Wind Energy Council). 2012. *Energy [R]evolution: A Sustainable World Energy Outlook*. Greenpeace International, EREC, and GWEC. Amsterdam.

GWEC. 2013. "Global Wind Statistics 2012."
http://www.gwec.net/wp-content/uploads/2013/02/GWEC-PRstats-2012_english.pdf.

IEA (International Energy Agency). 2000. "Implementing Agreement for Hydropower Technologies and Programmes, Annex III: Hydropower and the Environment: Present Context and Guidelines for Future Action." IEA, Paris. http://www.ieahydro.org/reports/HyA3S5V2.pdf.

———. 2002. "Renewable Energy Working Party 2002." IEA, Paris.
http://www.energy.anetce.com/2002_iea_renewables54.pdf.

———. 2007. "Renewable Energy Consumption and Electricity Preliminary 2006 Statistics." IEA, Paris.
http://www.eia.gov/cneaf/solar.renewables/page/prelim_trends/rea_prereport.html.

———. 2008. "Deploying Renewables Principles of Effective Policies." OECD/IEA, Paris.

———. 2010. "Implementing Agreement for Hydropower Technologies and Programmes, Update of Recommendations for Hydropower and the Environment: Briefing Document." IEA, Paris. http://www.ieahydro.org/uploads/files/finalannexxii_task2_briefingdocument_oct2010.pdf.

———. 2011. *World Energy Outlook 2011*. Paris: IEA, OECD Publishing.

———. 2012a. *Energy Technology Perspectives 2012: Pathways to a Clean Energy System*. Paris: IEA, OECD Publishing.

———. 2012b. *Medium Term Renewable Energy Market Report*. Paris: IEA.

———. 2012c. World Energy Outlook 2012. Paris: IEA, OECD Publishing. http://www.worldenergyoutlook.org/publications/weo-2012/.

———. 2012d. *IEA World Energy Statistics and Balances*. Paris: IEA, OECD Publishing.
http://www.oecd-ilibrary.org.libproxy-wb.imf.org/statistics.

IEA, OECD, EUROSTAT. 2005. Energy Statistics Manual, International Energy Agency, Organisation for Economic Co-Operation and Development and Eurostat, Paris, France.

IIASA (International Institute for Applied Systems Analysis). 2012. Global Energy Assessment—Toward a Sustainable Future. Cambridge, U.K. and Laxenburg, Austria: Cambridge University Press and IIASA.
http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/Home-GEA.en.html.

IJHD (International Journal of Hydropower and Dams). 2011. *World Atlas and Industry Guide*. Wallington, Surrey: IJHD.

International Hydropower Association. 2010. *Hydropower Sustainability Assessment Protocol*. London: International Hydropower Association. http://www.hydrosustainability.org/getattachment/7e212656-9d26-4ebc-96b8-1f27eaebc2ed/The-Hydropower-Sustainability-Assessment-Protocol.aspx.

IPCC (Intergovernmental Panel on Climate Change). 2011. *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*. Prepared by Working Group III of the Intergovernmental Panel on Climate Change. Cambridge, England, and New York, NY: Cambridge University Press.

IRENA (International Renewable Energy Agency). 2012. E*lectricity Storage Technology Brief*. Bonn, Germany: IRENA.
http://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP%20Tech%20Brief%20E18%20Electricity-Storage.pdf.

———. 2013a. *Doubling the Share of Renewable Energy: A Roadmap to 2030*. Bonn, Germany: IRENA.
http://irena.org/DocumentDownloads/Publications/IRENA%20REMAP%202030%20working%20paper.pdf.

———. 2013b. *Renewable Power Generation Costs in 2012: An Overview*. Bonn, Germany: IRENA. http://irena.org/DocumentDownloads/Publications/Overview_Renewable%20Power%20Generation%20Costs%20in%202012.pdf.

Jacobs, David. 2012. *Renewable Energy Policy Convergence in the EU: The Evolution of Feed-in Tariffs in Germany, Spain and France*. Surrey, England: Ashgate.

Kojima, M. 2012. Notes on Diversity Indices. Personal communication.

McCoy-West, A. J., S. Milicich, T. Robinson, G. Bignall, and C. C. Harvey. 2011. "Geothermal Resources in the Pacific Islands: The Potential of Power Generation to Benefit Indigenous Communities." Proceedings, 36th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, January 31. http://www.geothermal-energy.org/pdf/IGAstandard/SGW/2011/mccoy.pdf.

REN21. 2007. *Renewables 2007 Global Status Report (GSR)*. Paris: Ren21. http://www.ren21.net/gsr.

———. 2012. *Renewables 2012 Global Status Report (GSR)*. Paris: Ren21. http://www.ren21.net/gsr.

Shell (2013): New Lens Scenarios: A Shift in Perspective for a World in Transition

Sologico, 2012. Sologico market price data, Sologico/pvXchange GmbH, Cologne. See www.sologico.comUN Energy Statistics Database, 2012. http://data.un.org/Explorer.aspx?d=EDATA

UN Energy Statistics Database. http://data.un.org/Explorer.aspx?d=EDATA

UNEP (United Nations Environment Program) and NREL/U.S. DOE (National Renewable Energy Laboratory, U.S. Department of Energy). 2012. "Solar and Wind Energy Resource Assessment (SWERA)." Data from the National Renewable Energy Library and the United Nations Environment Program (UNEP). http://maps.nrel.gov/SWERA.

Van den Wall Bake, J. D., M. Junginger, A. Faaij, T. Poot, and A. Walter. 2009. "Explaining the Experience Curve: Cost Reductions of Brazilian Ethanol from Sugarcane." *Biomass and Bioenergy* 33 (4): 644-58.

WWF (World Wide Fund for Nature), Ecofys, OMA (Office for Metropolitan Architecture). 2011. *The Energy Report, 100% Renewable Energy by 2050*. Gland, Switzerland.

Yepez-Garcia, R., and J. Dana. 2012. *Mitigating Vulnerability to High and Volatile Oil Prices: Power Sector Experience in Latin America and the Caribbean*. World Bank: Washington, DC.

ANNEX 1: Concepts, data, and methodology

SOURCE	PRIMARY DATA SOURCE	SOURCE	SECONDARY DATA AND ANALYSIS	REPORTS	COUN-TRIES	TIME SERIES	DATA GAPS
BP			X	Annual Statistical Review of World Energy	67	1965–2011	No gaps
EIA	X		X	International Energy Outlook			
Enerdata Information Services			X	Global Energy and CO2 Database	184	1970–2010	No gaps
FAO	X			Wood fuel data and analysis			
IEA	X	Country surveys		IEA Energy Statistics	138	1960–2010	No gaps
IIASA			X	Annual Global Energy Assessment Report			
IRENA			X	Renewable Energy Country Profiles			
OECD			X	Annual OECD Fact Book			
Platts				Biofuels capacity			
REN 21		Network of over 400 data contribu-tors	X	Annual Global Sta-tus Report			
UN Data	X	Country surveys		UN Data	Over 220	1950–2009	Data gaps in some time series
UN Stats			X	UN Stats Monthly Bulletin of Stats Online			
WEC			X	Annual World Energy Trilemma Report			
WHO	X	Country surveys		WHO Household energy Database			
World Bank			X	World Development Indicators			

TABLE A1.1 **COMPARISON OF ENERGY DATA SOURCES**

SOURCE: AUTHORS'S COMPILATION.

This section provides descriptions of different primary energy accounting methods and an illustration of how primary and final energy are calculated following different methods.

Primary energy accounting

The IEA energy production statistics are based on a physical energy content primary energy accounting method. There are in fact three main ways of presenting the primary energy data, which can affect the overall size of the global energy mix and of the renewable share within it. These are:

- The physical energy content method (used by IEA and Eurostat)
- The partial substitution method (used by EIA)
- The direct equivalent method (used in some IPCC reports)

A description of these methods is found in the table A1.2.

DESCRIPTION	EXAMPLES	USERS
Physical energy content		
Adopts the principle that the primary energy form should be the first energy form used downstream in the production process for which multiple energy uses are practical. This leads to the choice of the following primary energy forms: (a) heat for nuclear, geothermal, and solar energy, and (b) electricity for hydro, tide/wave/ocean and solar PV energy. The method counts the power plant input for fossil fuels (and biomass), but counts power plant output for nuclear, wind, solar, hydro and geothermal. Thus, it uses conversion efficiencies to calculate the primary energy equivalent of renewable energy output.	The primary energy equivalent of hydropower and solar PV assumes 100% conversion efficiency to "primary electricity" (that is, 1 kWh of electricity converts into a gross energy input of 3.6 MJ) The primary energy equivalent of nuclear assumes 33% thermal conversion efficiency (average for nuclear plants in Europe) to "primary electricity" (that is, 1 kWh equals 10.9 MJ of primary energy). For geothermal, the primary energy equivalent is calculated using 10 % conversion efficiency for electricity (in this case, 1 kWh equals 36 MJ) and 50% for geothermal heat.	OECD IEA Eurostat Enerdata
Substitution method		
Reports primary energy from noncombustible sources as if they had been substituted for combustible energy. In other words, it counts the equivalent primary energy of fossil fuels needed to generate a given volume of renewable-source-based electricity. The method uses different conversion factors for different types of renewable energy output. The share of renewables under this method is thus considerably higher than in the "physical energy content" method.	BP applies 38% conversion efficiency to electricity generated from nuclear and hydro. WEC applies 38.6% to electricity from nuclear and all other noncombustible renewable sources.	Used in slightly different variants by: BP US EIA WEC IIASA (GEA)

DESCRIPTION	EXAMPLES	USERS
Direct equivalent method		
Counts one unit of secondary energy provided from noncombustible sources as one unit of primary energy. In this method, secondary energy means at the point of end use; that is, as electricity or heat. It counts all forms of electricity equally regardless of origin and does not use conversion efficiencies.	The primary energy equivalent of noncombustible or renewable-source-based electricity assumes 100% conversion efficiency to "primary electricity" (that is, 1 kWh of electricity converts into 3.6 MJ of primary energy)	UN Statistics IPCC Reports IIASA (IPCC)

TABLE A1.2 **METHODS TO ACCOUNT FOR THE PRIMARY ENERGY OF NONCOMBUSTIBLE SOURCES**

SOURCE: IPCC 2011); REN21 2007.
NOTE: DIFFERENT VARIANTS OF THE SUBSTITUTION METHOD USE DIFFERENT CONVERSION FACTORS.

Table A1.3 shows the figures for total primary energy supply calculated by the three methods for 2010 along with the calculated contribution from renewables to the global energy mix.

	PHYSICAL CONTENT METHOD		DIRECT EQUIVALENT METHOD		SUBSTITUTION METHOD	
	EJ	%	EJ	%	EJ	%
Fossils	433	81%	433	85%	433	79%
Nuclear	30	6%	10	2%	26	5%
Renewables:	69	13%	68	13%	91	17%
Hydro	12	2.32%	12	2.42%	33	5.92%
Wind	1	0.23%	1	0.24%	3	0.59%
Bioenergy	52	9.78%	52	10.21%	52	9.49%
Solar	1	0.14%	1	0.14%	1	0.17%
Geothermal	3	0.51%	1	0.11%	1	0.17%
Ocean	0	0.00%	0	0.00%	0	0.00%
Other	1	0.25%	1	0.26%	1	0.24%
Total	534	100%	511	100%	550	100%

TABLE A1.3 **TOTAL WORLD PRIMARY ENERGY SUPPLY IN 2010 (EJ)**

SOURCE: IEA 2012D.

To illustrate the effect of the different methodologies when renewables play a more significant role in the energy mix, table A1.4 shows the equivalent analysis based on the IEA's WEO 450 Scenario, in which stringent climate goals are met through the application of the full range of low-carbon energy technologies including renewables. In this scenario the proportion of renewables can range between 23 percent and 29 percent, depending on the methodology used, and the ratio between the 2010 and 2030 figures range from 1.70 for the substitution method to 1.78 for the other two methodologies.

The advantage of the primary methodology is that figures are based directly on the physical measurement of energy content for fossil fuels. The disadvantages are that for low-carbon electricity sources the primary energy content has to be calculated and the resulting figures depend on the accounting convention used and are not always directly related to useful energy production.

	PHYSICAL CONTENT METHOD		DIRECT EQUIVALENT METHOD		SUBSTITUTION METHOD	
	EJ	%	EJ	%	EJ	%
Fossils	408	67%	408	73%	408	62%
Nuclear	61	10%	20	4%	53	8%
Renewables:	141	23%	129	23%	192	29%
Hydro	20	3%	20	4%	54	8%
Bioenergy & wastes	86	14%	86	15%	86	13%
Other renewables	34	6%	22	4%	52	8%
Total	610	100%	557	100%	653	100%

TABLE A1.4 **TOTAL WORLD PRIMARY ENERGY SUPPLY IN 2030 IN WEO 450 SCENARIO (EJ)**

SOURCE: IEA 2012D.

Final energy accounting

The data for this methodology come from the total final energy consumption (TFEC) figures within the IEA statistics (these exclude nonenergy uses of fossil fuels such as those for plastics and chemicals). The TFEC figures for power and commercial heat are lower than the figures for their supply because of the energy used within power and heat plants and transmission and distribution losses.

Within the TFEC figures, heat and electricity (secondary energy sources) represent energy commodities ready to be used for energy consumption. Other primary energy sources can be directly used for energy consumption (for example, fossil fuels and bioenergy used for heating in the residential sector), and these are still reported in terms of their fuel content. These sources need to go through further transformation processes (for example, combustion) in order to provide energy services. Such transformation implies losses due to efficiency of conversion. The TFEC level therefore does not represent only useful energy, or energy service, but for direct uses of combustible sources it only represents inputs into a transformation process that will ultimately deliver useful energy. The final energy service is not reported in energy statistics because it is not practical to measure.[15]

In order to establish the contribution of each technology the figures for electricity and commercial heat have to be allocated to the relevant technology. This can be done based on the proportions of production, attributing the losses proportionally (although this penalizes the renewables' share since both internal energy losses and transmission and distribution losses tend to be smaller, at least for distributed renewable sources).

[15] A household will know how much biomass/gas/electricity it used for its heating system but will not measure how much heat the heating system produced. It would be possible to make country/use-specific assumptions on conversions in the final energy sector and estimate useful energy service—but this is a topic for an analytical study, not a statistical assessment.

Table A1.5 shows the breakdown of final consumption figures for 2010, before and after the allocation of electricity and heat, using final energy consumption figures based on the IEA's WEO 450 Scenario.

	TOTAL FINAL CONSUMPTION		TOTAL FINAL ENERGY CONSUMPTION		TOTAL FINAL ENERGY CONSUMPTION AFTER ALLOCATION	
	EJ	%	EJ	%	EJ	%
Fossils	243	66%	209	63%	263	79%
Nuclear	0	0%	0	0%	8	3%
Renewables:	47	13%	47	14%	61	18%
Hydro	0	0.00%	0	0.00%	10	3%
Wind	0	0.00%	0	0.00%	1	0.35%
Bioenergy	46	12.61%	46	13.91%	48	14%
Solar	1	0.17%	1	0.19%	1	0.27%
Geothermal	0	0.08%	0	0.09%	0	0.15%
Ocean	0	0.00%	0	0.00%	0	0.00%
Other renewables	0	0.00%	0	0.00%		0.02%
Electricity	64	18%	64	19%	x	x
Heat	12	3%	12	3%	x	x
Total	366	100%	332	100%	332	100%

TABLE A1.5 **TOTAL FINAL ENERGY CONSUMPTION IN 2010**

SOURCE: IEA 2012D.

The advantage of using the TFEC as the basis for monitoring is that it allows a straight comparison in GWh for electricity-producing renewables/nuclear and for commercial heat and gets closer to measuring the useful energy. But bioenergy and direct use of fossil fuels for heat are still reported in terms of energy inputs, and the useful heat from these sources depends on the conversion efficiency. Non-energy uses are excluded. The disadvantage is that the energy in the electricity and commercial heat sectors has to be allocated to the relevant technology based on the production proportions, and the losses are disproportionally allocated to the renewable technologies.

	TOTAL FINAL ENERGY CONSUMPTION AFTER ALLOCATION	
	EJ	%
Fossils	256	67%
Nuclear	17	5%
Renewables:	109	28%
Hydro	18	5%
Bioenergy & wastes	72	19%
Other renewables	20	5%
Total	382	100%

TABLE A1.6 **TOTAL FINAL ENERGY CONSUMPTION IN 2030 IN WEO 450 SCENARIO**

SOURCE: IEA 2012D.

ANNEX 2. Global trends in renewable energy

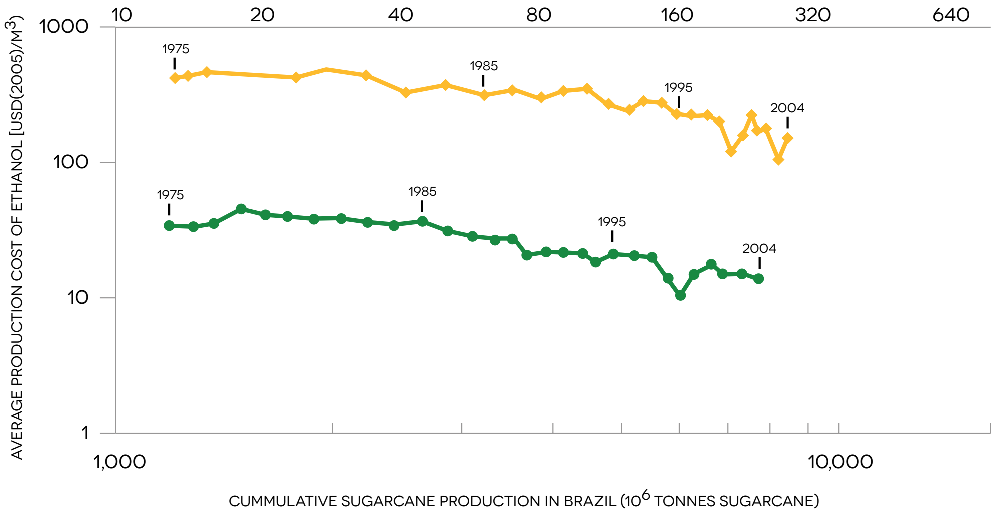


FIGURE A2.1 **LEARNING CURVE FOR SUGARCANE-BASED BIOETHANOL**

SUGARCANE PRODUCTION ETHANOL: SUGARCANE-BASED PRODUCTION

SOURCE: VAN DEN WALL BAKE. AND OTHERS 2009.

ANNEX 3. Country performance

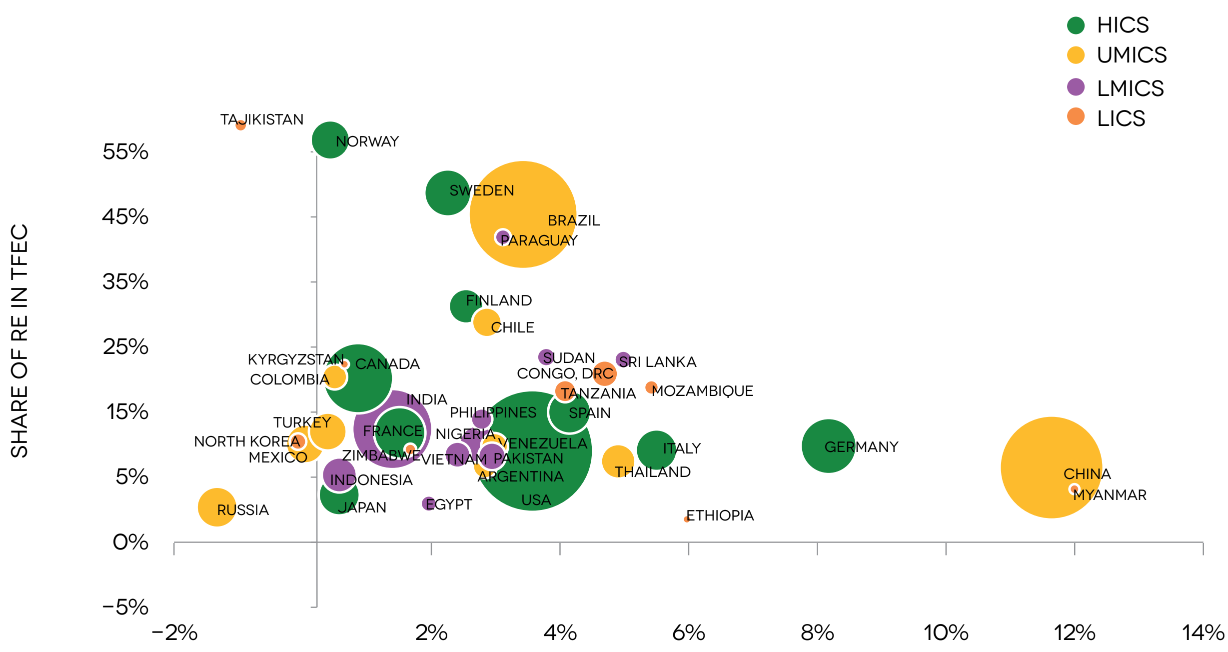


FIGURE A3.1 **SHARE OF RENEWABLE ENERGY (EXCLUDING TRADITIONAL USE OF BIOMASS) IN COUNTRY TFEC AND CAGR, 1990–2010**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.

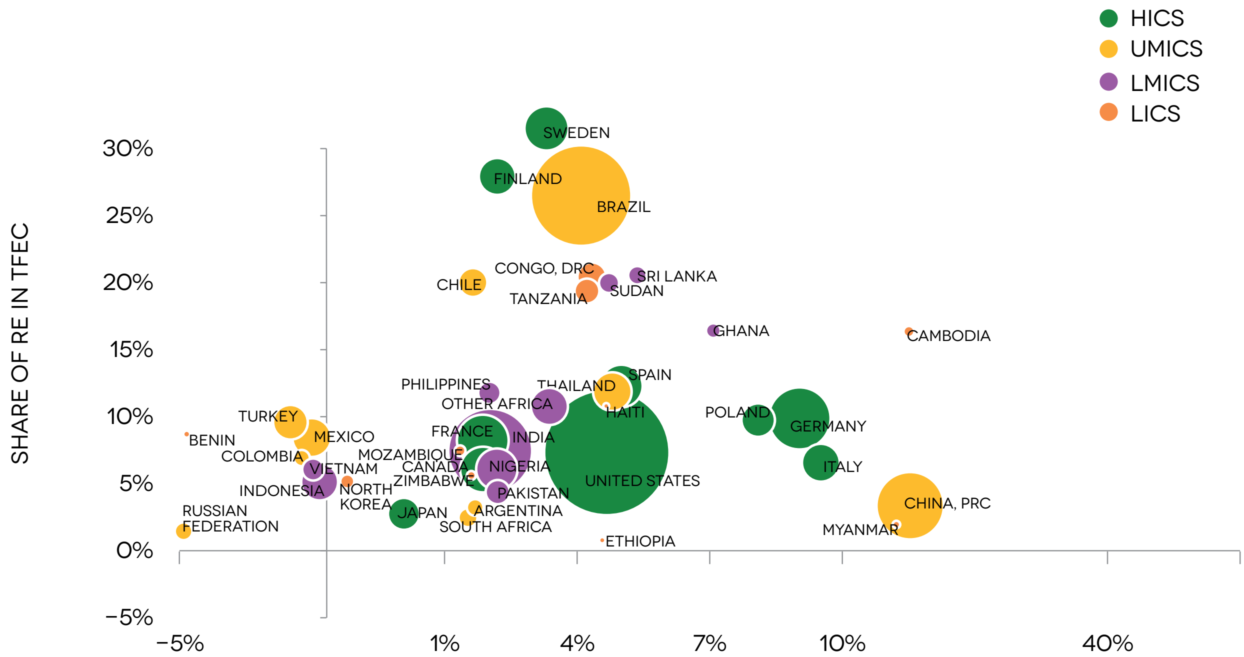


FIGURE A3.2 **SHARE OF RENEWABLE ENERGY (EXCLUDING TRADITIONAL USE OF BIOMASS AND HYDROPOWER) IN COUNTRY TFEC AND CAGR, 1990–2010**

SOURCE: IEA 2012D.

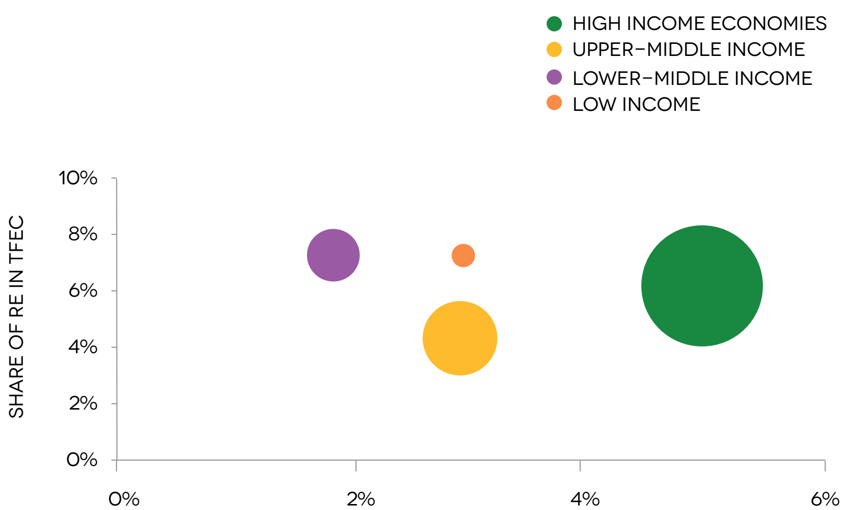
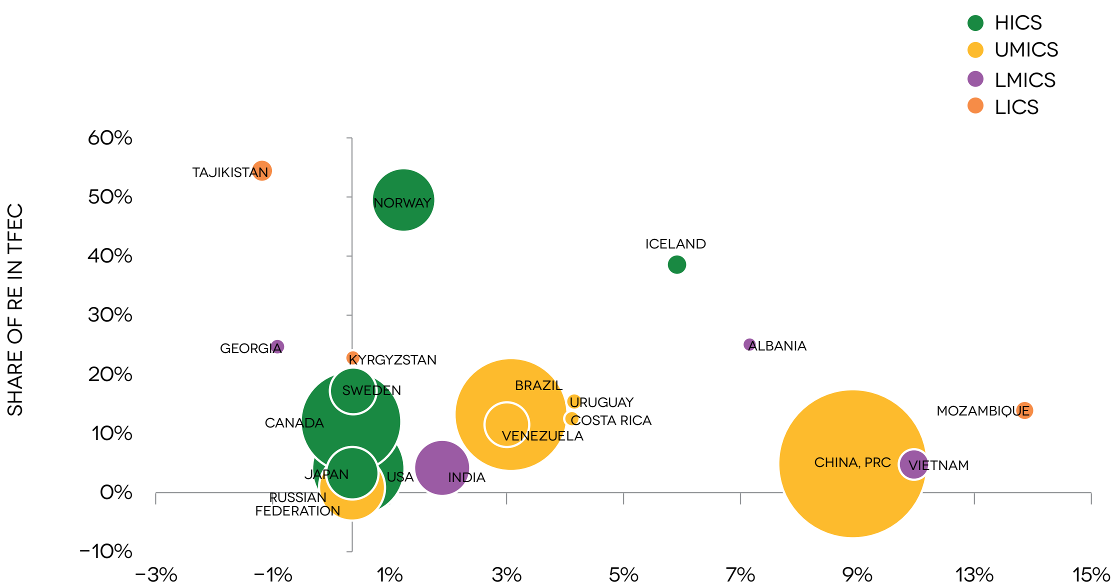


FIGURE A3.3 **SHARE OF NCRE IN TFEC VS. CAGR**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.

A. SHARE IN TFEC



B. SHARE IN TOTAL ELECTRICITY CONSUMPTION

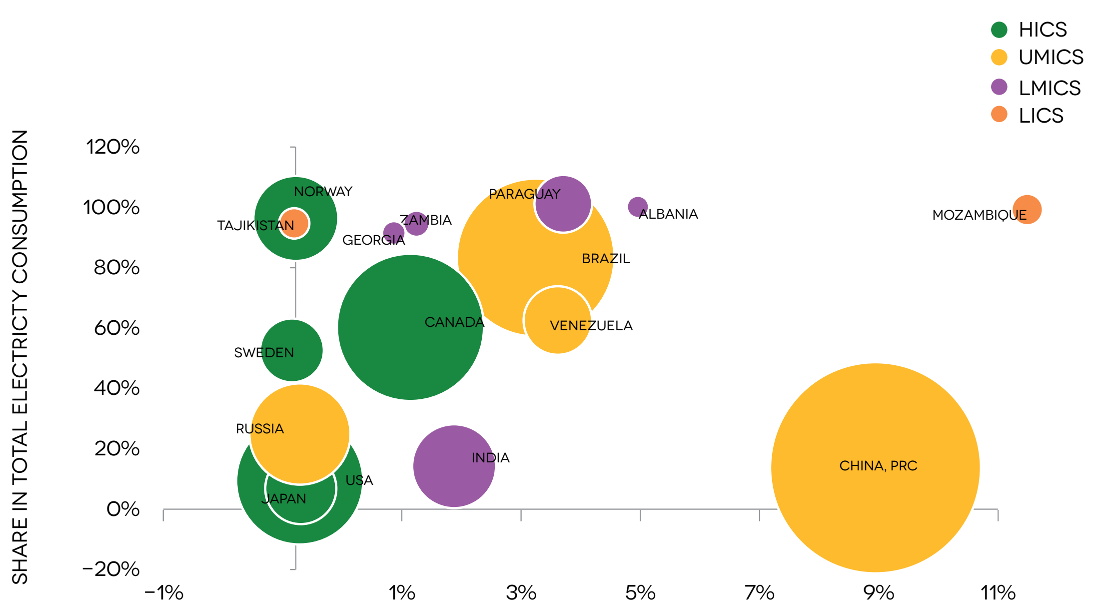


FIGURE A3.4 **SHARE OF HYDRO IN COUNTRY TFEC AND ELECTRICITY CONSUMPTION VS. CAGR, 1990–2010**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.

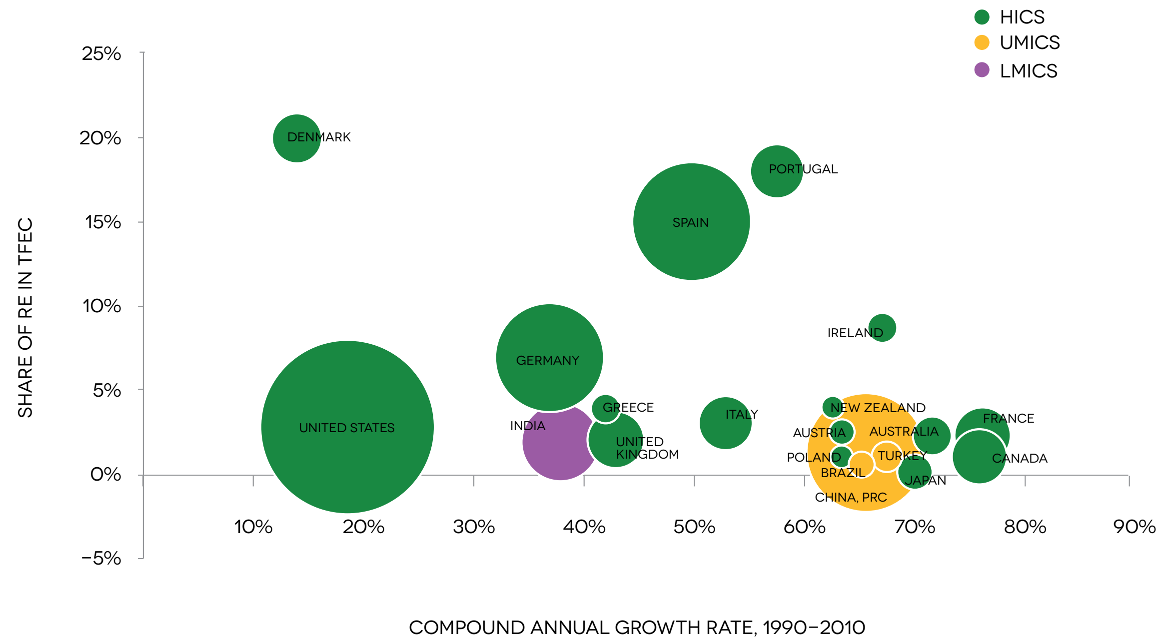


FIGURE A3.5 **SHARE OF WIND IN ELECTRICITY CONSUMPTION VS. CAGR, 1990—2010**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.

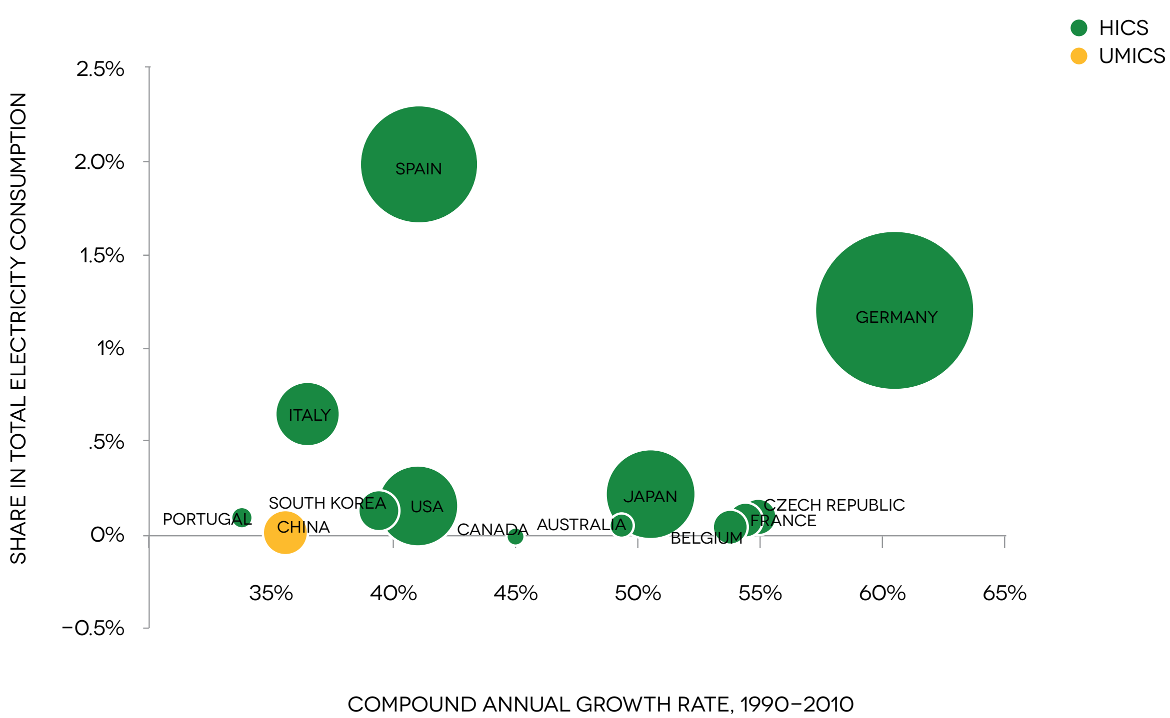


FIGURE A3.6 **SHARE OF SOLAR PV IN ELECTRICITY CONSUMPTION VS. CAGR, 1990—2010**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.

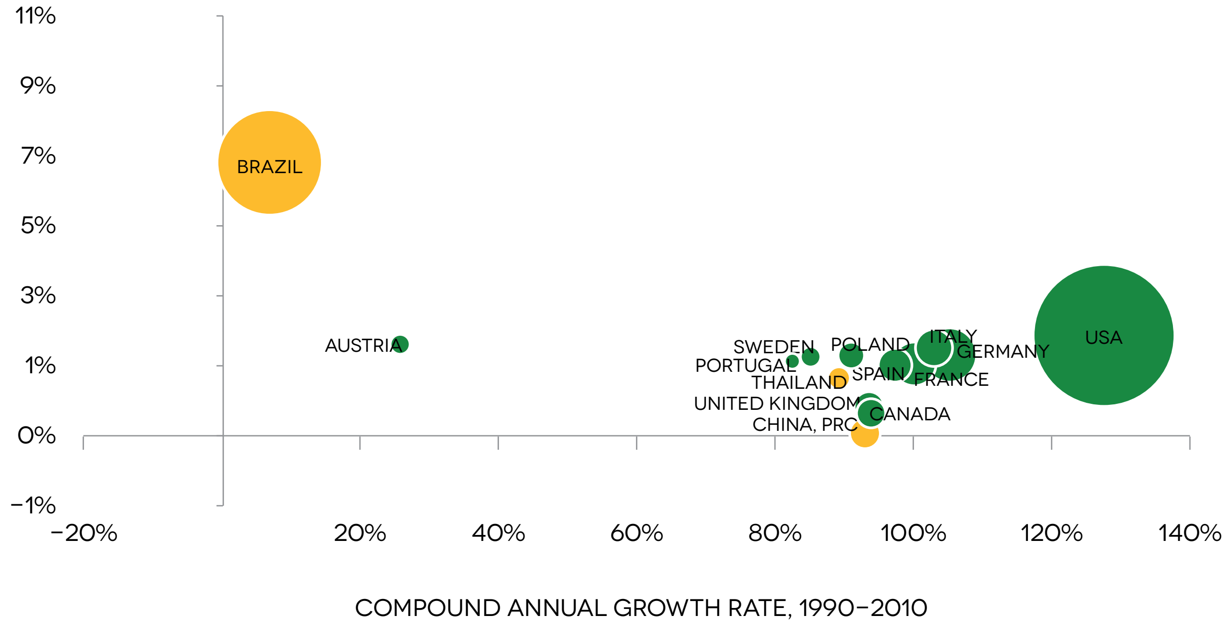


FIGURE A3.7 **SHARE OF BIOFUELS IN ELECTRICITY CONSUMPTION VS. CAGR, 1990–2010**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.

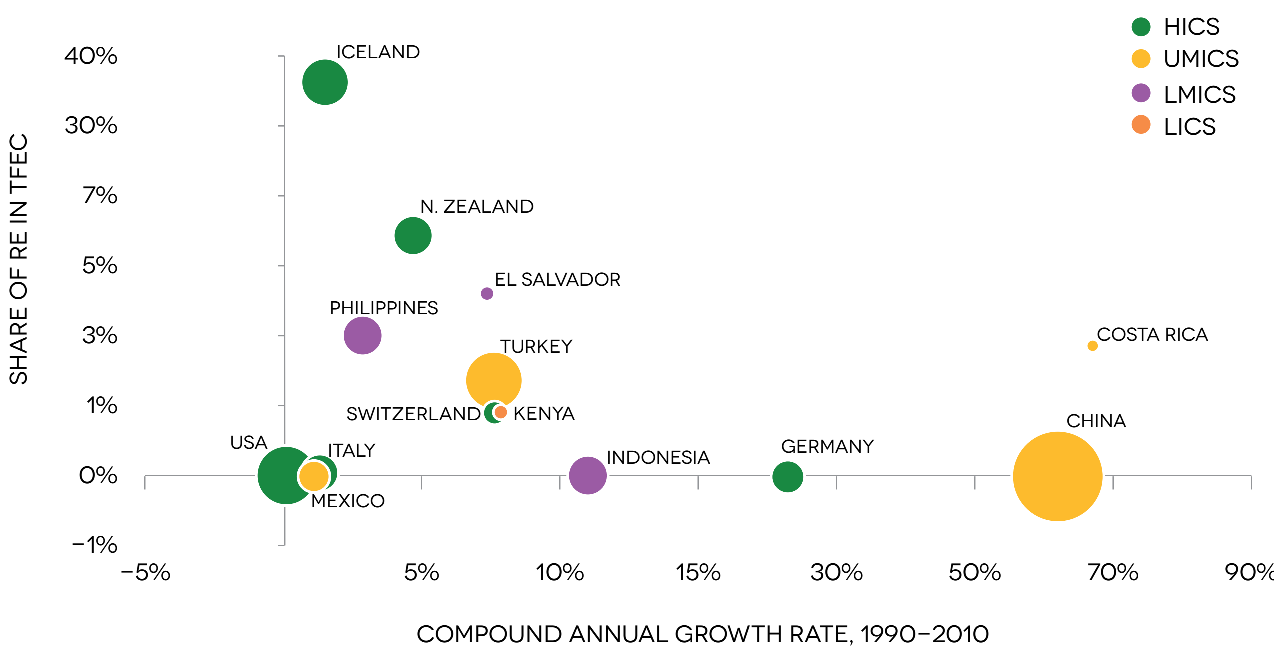


FIGURE A3.8 **SHARE OF GEOTHERMAL ENERGY IN COUNTRY TFEC VS. CAGR, 1990–2010**

SOURCE: AUTHORS' ANALYSIS BASED ON IEA 2012D.
NOTE: BUBBLE SIZE REPRESENTS VOLUME OF FINAL RENEWABLE ENERGY CONSUMPTION IN 2010. TFEC = TOTAL FINAL ENERGY CONSUMPTION; CAGR = COMPOUNT ANNUAL GROWTH RATE.