SUSTAINABLE ENERGY FOR ALL

PROGRESS TOWARD SUSTAINABLE ENERGY 2015

GLOBAL TRACKING FRAMEWORK REPORT

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TABLE OF CONTENTS

FOREWORD

In September 2015 the international community will adopt a new generation of targets, the Sustainable Development Goals (SDGs), defining how we believe a better world should look and how we can achieve it. For the first time, energy looks set to be fully recognized as a fundamental pillar of development in its own right—a precondition for progress in a wealth of other areas from health and education to jobs and gender equality. Energy production and consumption also need to be sustainable, if we are to avert catastrophic changes to our climate that will affect us all.

The UN's Sustainable Energy for All (SE4All) initiative, a multistakeholder partnership uniting the public sector, private sector and civil society, is seen by many as the logical rallying point for action on a sustainable energy SDG. With its three interlinked targets—ensuring universal access to modern energy services, doubling the global rate of improvement in energy efficiency, and doubling the share of renewable energy in the world's energy mix, all by 2030—it provides a road map for a future in which ending energy poverty does not have to come at the expense of the planet.

But as inspiring as these ambitious targets are, the action needed to reach them can easily lose both momentum and direction if there is no clear way to gauge progress. We need to see what is or isn't working, what to celebrate, and where we need to push harder. We need milestones along the way. Targets alone are meaningless without a credible and broadly accepted way of measuring whether they are actually being met.

SE4All's first *Global Tracking Framework (GTF)* in 2013, produced by energy experts from 15 agencies under the leadership of the World Bank and the International Energy Agency (IEA), provided that monitoring system. Even-handed and methodologically rigorous, it drew on data up to 2010 to provide a comprehensive snapshot of the status of more than 180 countries in terms of energy access, action on energy efficiency and renewable energy, energy consumption, and policy measures taken by successful countries. It identified places where the greatest gains can and should be made in each of these areas, the challenges and the success stories.

Two years later, with that baseline in place, we can already start to measure whether action on sustainable energy is bearing fruit. This second edition of the *GTF,* coordinated once again by the World Bank and IEA along with the Energy Sector Management Assistance Program (ESMAP), and now with even broader support from more than 20 agencies, draws on new data from the period 2010–2012. It provides an update of how the world has been moving toward the three objectives over that period, assesses whether progress has been fast enough to ensure that the 2030 goals will be met, and sheds light on the underlying drivers of progress.

GTF 2015 also explores a number of complementary themes. It includes a new chapter that provides essential context on the complex links between energy and four other key development areas: food, water, health, and gender. It provides further analysis of the financial cost of meeting the SE4All objectives, as well as the geographical and technological distribution of the investments that need to be made. It explores the extent to which countries around the world have access to the technology needed to make progress toward the three targets. And it identifies the improvements in data collection methodologies and capacity building that will be needed to provide a more nuanced and accurate picture of progress over time.

Part of this will involve reflecting the kind of complexity on the ground that cannot be captured by simple binary questions such as: Does this household have electricity access or not? For example, it may have power, but only for a short time in the day, or suffer unpredictable outages. To address the shortcomings of reporting energy access in a binary fashion, a new multitier framework designed by the World Bank has been piloted in a few locations, and plans are under way to launch a global access survey that will allow such data to be available in a standardized way for many countries.

Similar efforts are needed for better tracking of energy efficiency, requiring detailed reporting on activities and energy consumption by sector and individual end use. Countries will need to put resources and effort into collecting and reporting this more nuanced data, and international organizations will need to aggregate information from disparate sources to produce a consistent overall view.

In some areas, *GTF 2015* shows clear advances toward the SE4All targets. That is a reason to celebrate, without becoming complacent. In other areas the picture is less positive—a reason to redouble our efforts. Most important, *GTF 2015* provides tangible findings that will help to galvanize and guide further action, within a coherent framework that is ready to underpin a future sustainable energy SDG.

—Kandeh Yumkella
Secretary General's Special Representative for Sustainable Energy for All

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Key findings

The first SE4All *Global Tracking Framework (GTF 2013)* established a consensus-based methodology and identified concrete indicators for tracking global progress toward the three SE4All objectives. One is to ensure universal access to modern energy services. The second is to double the global rate of improvement in energy efficiency. And the third is to double the share of renewable energy in the global energy mix. *GTF 2013* also presented a data platform drawing on national data records for more than 180 countries, which together account for more than 95 percent of the global population. And it documented the historical evolution of selected indicators over 1990–2010, establishing a baseline for charting progress.

GTF 2015 presents an update on how fast the world has been moving toward the goal of sustainable energy for all.

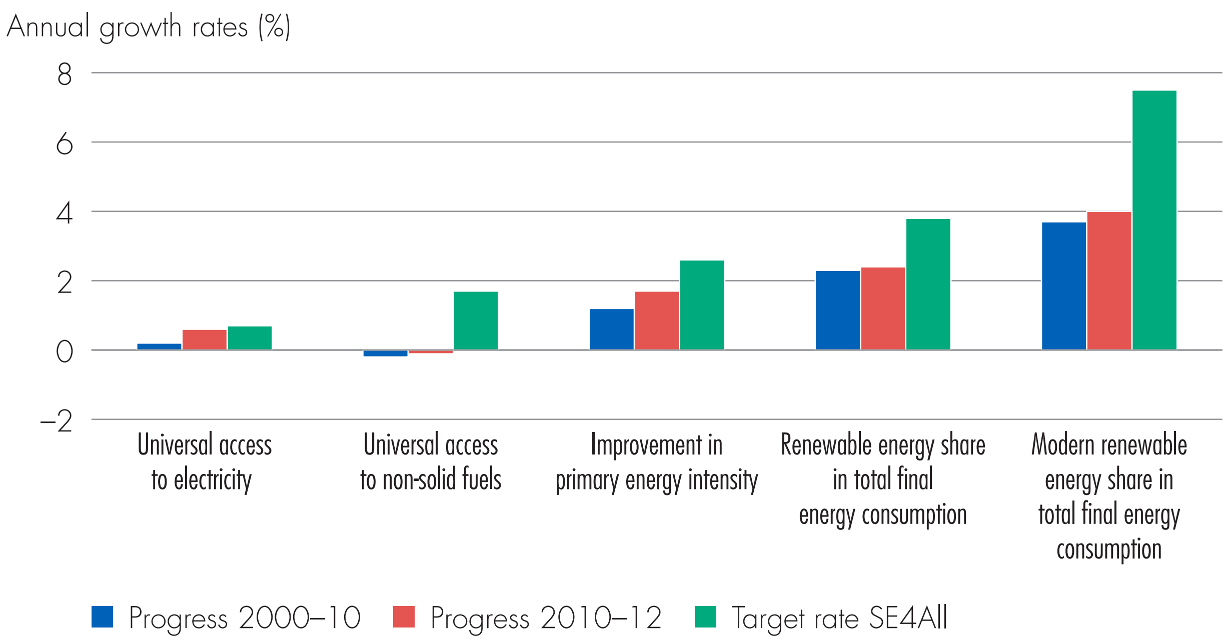
This second edition of the SE4All *Global Tracking Framework (GTF 2015)* provides an update on how fast the world has been moving toward the three objectives. Based on the latest data, it reports progress on selected indicators over the two-year tracking period 2010–12 and determines whether movement has been fast enough to meet the 2030 goals.

Overall progress over the tracking period falls substantially short of what is required to attain the SE4All objectives by 2030.

Across all dimensions of sustainable energy for all—whether access, efficiency, or renewables—the rate of progress during the 2010–12 tracking period falls substantially short of the rate that would be needed to ensure that the three objectives are met by 2030 (figure 1). Nevertheless, the 2010–12 tracking period does present some encouraging acceleration in progress relative to what was observed in prior decades.

Efforts must be redoubled to get back on track; particularly in countries with large access deficits and high energy consumption whose rate of progress carries substantial weight in the global aggregate.

Figure 1. **How far is the rate of progress from that required to attain SE4All?**



Source: World Bank Global Electrification database 2015; IEA, UN, and WDI data (2014); analysis by the International Renewable Energy Agency based on IRENA (2014).

Note: Figure shows average annual growth rates for access to electricity and non-solid fuels, and compound annual growth rates for renewable energy and energy efficiency.

Energy has a key enabling role in food security and nutrition.
Vanessa Lopes Janik/© World Bank

There have been notable advances in electrification—driven primarily by India—but progress in Africa remains far too slow.

The annual growth in access to electricity during the tracking period reached 0.6 percent, approaching the target growth rate of 0.7 percent required to reach universal access by 2030, and certainly much higher than the growth of 0.2 percent registered over 2000–2010 (see figure 1).

As a result, the global electrification rate rose from 83 percent in 2010 to 85 percent in 2012. This means that an additional 222 million people—mainly in urban areas—gained first time access to electricity; more people than the population of Brazil, and well ahead of the 138 million population increase that took place over the same period. Overall, the global electricity deficit declined from 1.2 billion to 1.1 billion. Global progress was driven by significant advances in India, where 55 million people gained access over 2010–12.

In order to advance towards universal access to electricity, countries need to expand electrification more rapidly than demographic growth. Out of the 20 countries with the largest electrification deficit, only 8 succeeded in doing so (figure 2a). For Sub-Saharan Africa as a whole—the region with by far the highest access deficit—electrification only just managed to stay abreast of population growth; although even this represents progress compared to earlier decades.

By contrast, access to clean cooking continues to fall behind population growth leading to negligible progress overall.

The annual growth in access to non-solid fuels during the tracking period was negative 0.1 percent, comparable to what was registered during the 2000–2010 period, and woefully short of the 1.7 percent target growth rate required to reach universal access by 2030 (see figure 1).

As a result, primary access to non-solid fuels barely rose from 58 percent in 2010 to 59 percent in 2012. This means that only 125 million additional people—mainly in urban areas—gained first time access to non-solid fuels; no more than the population of Mexico and falling behind the 138 million population increase that took place over the same period. Overall, the global access deficit barely moved from 2.9 billion; concentrated in rural areas of Africa and Asia. Out of the 20 countries with the largest access deficit, only 8 succeeded in expanding access to non-solid fuels more rapidly than population growth (figure 2b).

Traditional methods for measuring energy access significantly underestimate the scale of the challenge.

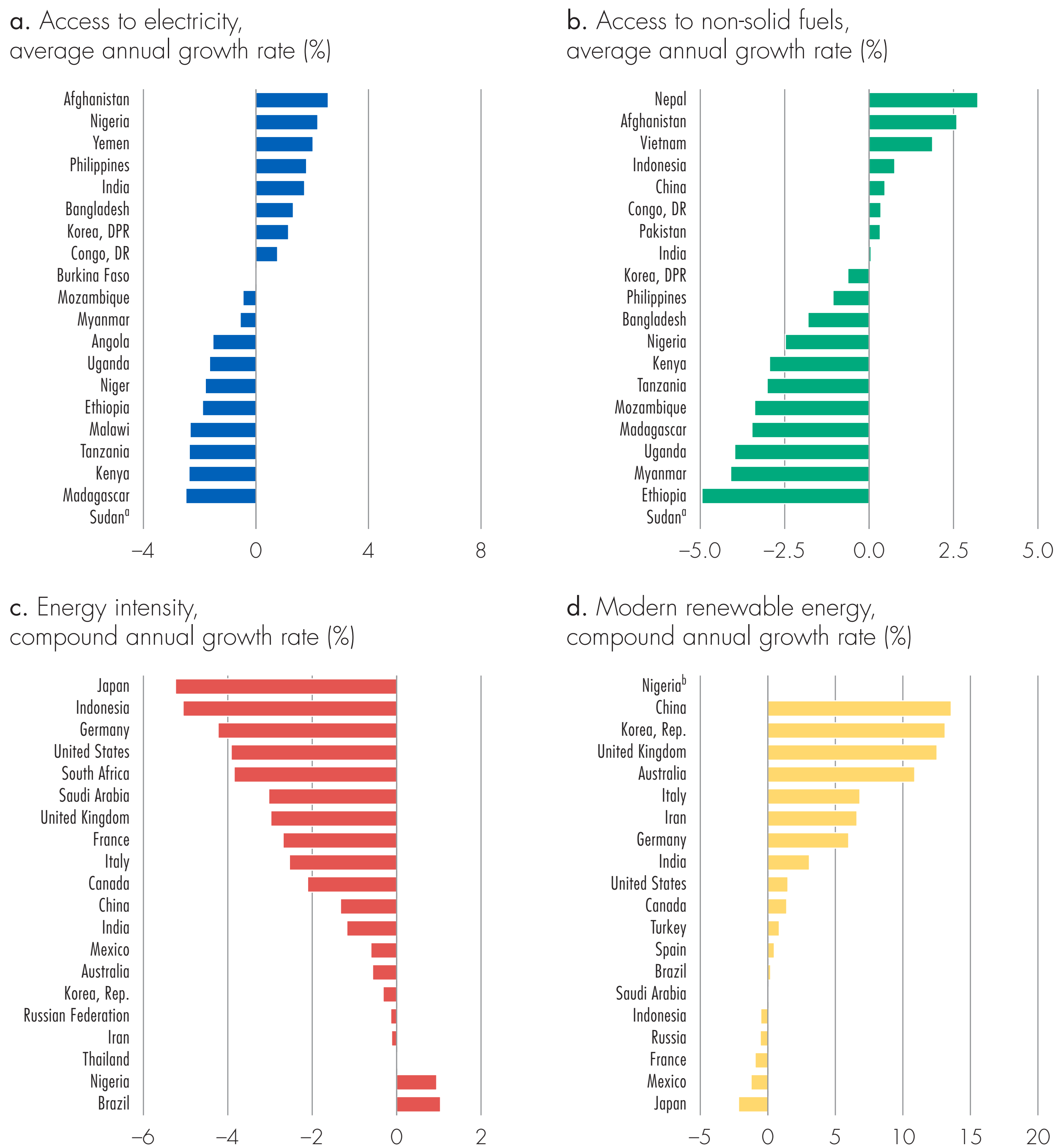
Traditional measures of energy access reported above, which focus on grid connections, are not able to capture broader deficiencies in the affordability, reliability and quality of service. This report presents an emerging multi-tier approach to access measurement that is able to capture these broader dimensions.

New evidence from the city of Kinshasa in the Democratic Republic of the Congo shows that—whereas traditional access indicators report 90 percent access to electricity due to widespread grid connections in the city—the multi-tier approach rates access at only 30 over 100 due to extensive limitations in hours of service, unscheduled blackouts and voltage fluctuations. The reality is that the streets of Kinshasa are dark on most nights and that few households can actually use the electrical appliances they own.

Progress in reducing global primary energy intensity over the tracking period was substantial, though still only two-thirds of the pace needed to reach the SE4All objective.

Primary energy intensity—the global proxy for energy efficiency, and influenced as well by changes in the

Figure 2. **High-impact countries, progress toward targets, 2010–12**



Source: IEA and UN data.

Note: Growth rate calculation involves two parameters—population with access and total population of the country.

a. Data from Sudan show a very high growth rate in access. This is not shown in the figure as it is due to a lower population in 2012 compared with 2010, resulting from the split with South Sudan.

b. Nigeria appears to have rapidly increased the use of modern solid biofuels; however, available data on solid biofuels, for modern or traditional uses, is still not accurate across most countries.

structure of the world economy—improved by more than 1.7 percent a year over the tracking period, considerably more than in the base period 1990–2010. The incremental change in energy intensity from 2010 to 2012 alone avoided primary energy use of 20 exajoules (EJ) in 2012, or more energy than Japan used that year. Still, the rate of improvement is nearly a full percentage point slower than the SE4All objective of an average annual 2.6 percent improvement between 2010 and 2030 (see figure 1).

Eight of the top 20 energy consumers—collectively responsible for nearly three-quarters of global energy use in 2012—had intensity improvements exceeding the 2.6 percent a year objective (figure 2c). These were mainly high-income countries recovering from recession, including Japan, Germany, the United States, France, Italy, and Canada, demonstrating that mature economies can achieve significant economic growth decoupled from rising energy consumption. But several large emerging countries also had high rates of improvement, notably Indonesia, South Africa, and (in a reversal from previous performance) Saudi Arabia. Russia, the most energy-intensive of the group due in part to its large fossil fuel production, showed only a marginal decline in energy intensity. Among the top energy consumers, only Brazil and Nigeria experienced rising intensity in the tracking period.

Of end-use sectors, industry was the largest contributor to reduced energy intensity between 2000 and 2012, both as efficiency increased and as the share of output from energy-intensive products declined. Transport followed closely in contribution to lower intensity, since fuel economy standards have had a major impact even as motor vehicle use has surged. Energy supply sectors have seen some improvement in efficiency, as with the declining midstream losses in the natural gas industry. Electricity transmission and distribution losses are falling, and many countries are using more-efficient gas-fired plants. But continued expansion of coal-fired capacity has led the average thermal efficiency of fossil power generation to stagnate.

The growth of renewable energy final consumption continued to accelerate in recent years, but to achieve the SE4All objective, the rate of progress will need to increase over 50 percent.

The share of renewable energy in total final energy consumption (TFEC) grew from 17.8 percent in 2010 to 18.1 percent in 2010–12. This represents a net increment in annual RE consumption of 2.9 exajoules (EJ), equivalent to energy consumption of Pakistan or Thailand in 2012. The increment resulted from both an acceleration in the growth of renewable energy and a deceleration in the growth of TFEC. Global renewable energy consumption grew at a compound annual growth rate (CAGR) of 2.4 percent over the tracking period, while global final energy consumption grew at only 1.5 percent. But the annual growth to attain the SE4All objective in renewable energy—including traditional uses of solid biofuels—is estimated at 3.8 percent (see figure 1).

The consumption of modern renewables (which exclude solid biofuels used for traditional purposes) grew even more rapidly, at a compound annual growth rate of 4 percent. Still, an annual growth rate of 7.5% would be required to attain the SE4All objective with modern renewables.

Five out of the top 20 largest energy consumers succeeded in increasing their annual growth in the consumption of modern renewables above 7.5% during the tracking period 2010–12 (figure 2d). These countries included Nigeria, China, Korea, United Kingdom and Australia. In large middle income countries, such as China and Nigeria, increases in the share of modern renewables (such as hydro, wind and solar) were offset by reductions in the share of traditional uses of solid biofuels. Thanks largely to China, East Asia increased consumption of modern renewables more than other regions.

Modern energy provision is a critical enabler of universal health coverage.

Nick van Praag/© World Bank

The uptake of renewable energy was stronger in electricity generation than in heat production or transport during the tracking period. The share of renewable energy consumption in the electricity sector rose by 1.3 percent over the tracking period, compared with much smaller increases in heating at 0.3 percent and transport at 0.1 percent. In both tracking years, renewable energy power generation capacity additions accounted for half of all capacity additions.

Declining technology costs have certainly helped foster growth of renewable consumption. In particular, solar PV (photovoltaic) saw rapidly declining costs, with PV module prices halving between 2010 and 2012. Increased use of solar energy accounts for a fifth of the increase of modern renewable energy consumption over the tracking period, behind wind (a fourth) and hydro (a third).

Today's investment flows of $400 billion a year would need to triple to achieve the necessary pace of progress.

A partial explanation for slow progress on sustainable energy objectives is the shortfall in investment. Global investment in areas covered by the three objectives was estimated at around $400 billion in 2010, while requirements are in the range of $1.0–1.2 trillion annually, requiring a tripling of current flows (table 1).

Energy and water resources are inextricably tied together.

Grant County Public Utility District/© NREL 12487

The bulk of these resources are needed for energy efficiency and renewable energy—about $500 billion per year for each—although the shortfall in energy efficiency investment is substantially larger than the shortfall of investment

Table 1. **Annual global investment—actual and required ($ billion)**

Annual investment	**Universal access to modern energy services**	**Universal access to modern energy services**	**Doubling the global rate of improvement in energy efficiency**	**Doubling the share of renewable energy in the global mix[a]**	
Source	Electrification	Cooking	Energy efficiency	Renewable energy	Total
Actual for 2012[b]	9	0.1	130	258	397
Required to 2030[c]	45	4.4	560	442–650	1,051–1259
Gap	36	4.3	430	184–392	654–862

a. This is the range for significantly increasing the share of renewable energy in total final energy consumption.

b. The total assumes 2010 investment in access figures for 2012.

c. Estimates are derived from various sources: Energy access, electrification: *SE4All Finance Committee Report,* World Bank (2014); Energy access, cooking: Energy for All Scenario, *WEO* (IEA, 2012); Energy efficiency: 450 scenario, *WEO* (IEA, 2014); Renewable energy lower bound: *WEO* 450 (IEA, 2014), corresponds to a 29.4 percent renewable energy share in total final energy consumption by 2030; Renewable energy upper bound: REmap 2030 (IRENA, 2014), corresponds to a 36 percent renewable energy share in total final energy consumption by 2030.

Source: Prepared by authors.

in renewable energy. Additional investments for energy efficiency are particularly needed in the transport sector where a high volume of new vehicles is expected to be sold. For renewables, increased adoption of renewable energy targets signals strong interest in scaling up renewable energy, yet new policies in place will need to be combined with emerging financing mechanisms to lower the spectrum and size of financial risks.

In 2013–14, the SE4All Advisory Board convened a Finance Committee that brought together private commercial and development banks to further identify financing gaps and to propose concrete approaches for attracting more capital. The Committee identified four broad investment themes that could help mobilize $120 billion in incremental annual investment by 2020: green-bond market development, structures that use development finance institutions' de-risking instruments to mobilize private capital, insurance products that focus on removing specific risks, and aggregation structures that focus on bundling and pooling approaches for small-scale opportunities.[1]

Also imperative is transferring state-of-the-art knowledge and technologies to countries with less capacity to adopt sustainable energy.

Countries will need to access cutting-edge knowledge and technologies relevant to sustainable energy if they are to contribute to the global achievement of the three SE4All objectives. Trade data for a basket of clean technology products demonstrates that about three-quarters of low- and lower-middle-income countries are participating in trade in clean energy products, particularly solar PV and energy efficient lamps. Trade volumes have grown steeply over the last decade, even if they remain small in absolute terms. Thanks to China's growing role in the solar PV industry, developing countries became net exporters of clean technology products in 2007.

Access to affordable energy services can reduce both time and effort spent in productive labor. John Isaac/© World Bank

Nevertheless, access to clean technologies remains constrained by import taxes and other non-tariff barriers. For instance, 50–70% of low and lower middle income countries apply import taxes to small hydropower turbines, as against 20% of high income countries. Developing countries are also constrained by the technical and commercial capacity of institutions and companies, as well as by a shortage of relevant skills among workers.

Understanding the interactions between energy and such priority areas of development as water, food, health, and gender is fundamental to meeting the objectives of the SE4All.

Analysis of the nexus between energy systems and other key areas of development—water, food, health, and gender—suggests that numerous opportunities can arise from wider cross-sector perspectives and more holistic decision-making in energy.

For example, energy efficiency typically has positive and synergistic feedbacks to other resource systems. Efficient use of energy reduces the need for power generation and thus the need for cooling water. Water efficiency is also energy efficiency: using water more efficiently can cut electricity consumption, as lower water demand reduces the need for pumping and treating water. Exploring the co-benefits of water saving tied to energy efficiency, as well as the potential to save energy through water efficiency, can thus help secure additional benefits.

Renewable energy can be either water-efficient or water-intensive. PV panels and wind turbines require little water and are generally much more water-efficient than conventional sources of electricity. Hydropower depends fundamentally on water, and lower rainfall (perhaps due to greater variability and to climate change) could reduce electricity production from that source.

Access to energy and to other energy-intensive products, services, and facilities can increase farmer incomes and boost agricultural productivity. Agricultural machinery and inputs such as fertilizers and pesticides can raise yields for farmers. Better access to roads and freight services as well as refrigeration and processing facilities can improve market access while reducing the spoilage of food, thus increasing the productivity of land by reducing field-to-consumer losses and improving farmers' incomes.

Health, too, gains from sustainable energy services in community health clinics, through cost-effective and life-saving interventions. Clinics need reliable access to energy for running medical equipment, for storing supplies such as blood, vaccines, and antiretroviral drugs, for staying open after dark, and for helping retain qualified staff. And street lighting may increase women's and girls' mobility before sunrise and after dark and by improving security reduce the risk of gender-based violence.[2,3]

All these areas have numerous interwoven concerns, including access to services, long-term maintenance and sustainability, environmental impacts, and price volatility. These issues manifest themselves in different ways in each, but the impacts are often closely related. Identifying these linkages early can help in targeting synergies and preempting subsequent potential tensions.

Meeting the SE4All objectives will require the implementation of a transformational strategies and policies.

Attaining the SE4All objectives will require significantly reducing fossil-fuel based activities, supporting technology innovation, introducing new finance and business models, and implementing transformational strategies and policies. This will be critical in high-impact countries—those with large access deficits and high energy consumption—but also in countries that wish to move in the direction of sustainable energy.

Notes

1. SE4All Finance Committee Report 2014.
2. Cecelski and others 2005.
3. Doleac and Sanders 2012.

OVERVIEW

Overview

Sustainable Energy for All (SE4All) is a global initiative co-chaired by the secretary-general of the United Nations and the president of the World Bank. It draws the world's attention to three key development objectives for the energy sector by 2030—ensuring universal access to electricity and modern cooking solutions, doubling the rate of improvement of energy efficiency, and doubling the share of renewable energy (RE) in the global energy mix. These objectives have been endorsed by the UN General Assembly, which in 2011 declared 2012 the Year of Sustainable Energy for All and in 2012 made 2014–24 the Decade of Sustainable Energy for All.

The international community soon recognized the importance of a tracking system to gauge global progress toward the three objectives and to hold policymakers accountable. Since the energy sector did not feature among the Millennium Development Goals, such a comprehensive tracking system was not fully in place and needed to be assembled from a range of sources.

To meet this need, the first edition of the SE4All *Global Tracking Framework*—co-led by the World Bank/ESMAP and the International Energy Agency (IEA)—was published in 2013, accomplishing several tasks. First, it established a consensus-based methodology and identified concrete indicators for tracking global progress toward the SE4All objectives (table O.1). Second, it presented a supporting data platform drawing on national data records for more than 180 countries, which together account for more than 95 percent of the global population. Third, it documented the evolution of the indicators over 1990–2010, to provide a baseline for assessing progress during the SE4All 2010–30 period.

This second edition of the *GTF* updates how the world has been moving toward the three objectives over 2010–12. Based on the latest data from many national sources, it reports progress over this period and sheds light on the underlying drivers. It also assesses whether progress has been fast enough to meet the objectives for 2030.

The report explores complementary themes. It provides further analysis of the investment volumes and geographic and technological distributions needed to meet the SE4All objectives. It explores the extent to which countries around the world have access to the technology and knowledge to progress toward those objectives. And it identifies the improvements in data collection methodologies and capacity building that will be needed to provide a more nuanced and accurate picture of progress over time.

The report also introduces and explores "nexus" concepts focusing on the links between energy and four priority areas of development: water, food, human health, and gender. Links between most of these areas and energy are well established but often presented in isolation from each other. The analysis considers the existing data and indicators as well as the related gaps that might be filled for tracking aspects of SE4All's work related to these nexus issues.

Energy access

Ensuring universal access to modern energy

Electrification

The global electrification rate increased from 83 percent in 2010 to 85 percent in 2012, up from 76 percent in 1990 (figure O.1). The rate in urban areas stayed largely stable during this tracking period, rising by 1 percentage point from 95 to 96 percent, but that in rural areas rose from 70 to 72 percent. Among the regions, improvements have been notable in South Asia (75 to 79 percent), Sub-Saharan Africa (32 to 35 percent), and Oceania (25 to 29 percent).

The absolute population living without electricity fell from 1.2 billion to 1.1 billion during the tracking period. The population to be electrified by 2030 is today's access deficit of 1 billion plus the projected population growth between 2012 and 2030 of 1.5 billion. The access deficit in 2012 is overwhelmingly rural, the forecast population increment almost entirely urban. By region, the deficit remains overwhelmingly concentrated in Sub-Saharan Africa and South Asia. The 20 highest access-deficit countries account for 83 percent of the global deficit. India, with an

Table O.1. **Overview of central GTF indicators developed in 2013, rationale, and data source**

Objective	Central indicator	Observation	Data source
Ensure universal access to modern energy, including electricity and cooking	Percentage of population with an electricity connection	• The presence of an electricity connection is a prerequisite for receiving electricity supply, but does not guarantee it	National household surveys following internationally standardized questionnaires (such as Demographic and Health Surveys, Income and Expenditure Surveys, Living Standard Measurement Surveys, Multi-Indicator Cluster Surveys, and some censuses)
	Percentage of population with primary reliance on non-solid fuels	• Solid fuel use for cooking (wood, charcoal, dung, crop residues, etc.) in the developing world is often associated with inefficiency and undesirable health impacts, although the extent of these depend on the characteristics of the cookstove used and the behavioral practices of the user • Non-solid fuels tend to be associated with efficient and healthy cooking practices, with some exceptions such as kerosene • Many households rely on multiple fuels for cooking, hence the focus on the primary fuel the household relies on	
Double the rate of improvement of energy efficiency	Compound annual growth rate of total primary energy supply to gross domestic product (GDP) at purchasing power parity (PPP).	• Energy intensity is a proxy for energy efficiency • Primary energy demand also captures energy lost in various energy transformation processes • PPP measures of GDP avoid undervaluing the output of developing economies	National energy balances collected in standardized form by the International Energy Agency (IEA) for larger countries and by the UN for smaller countries
Double the share of renewable energy in the global energy mix	Percentage of total final consumption of energy from renewable sources	• Renewable sources are all those replenished as they are consumed (including wind, solar, hydro, geothermal, biomass, biofuels, and ocean) • Final energy consumption does not include thermal energy lost in transformation processes and thus provides a fairer comparison with renewable energy sources where no transformation losses take place.	

Source: Prepared by authors.

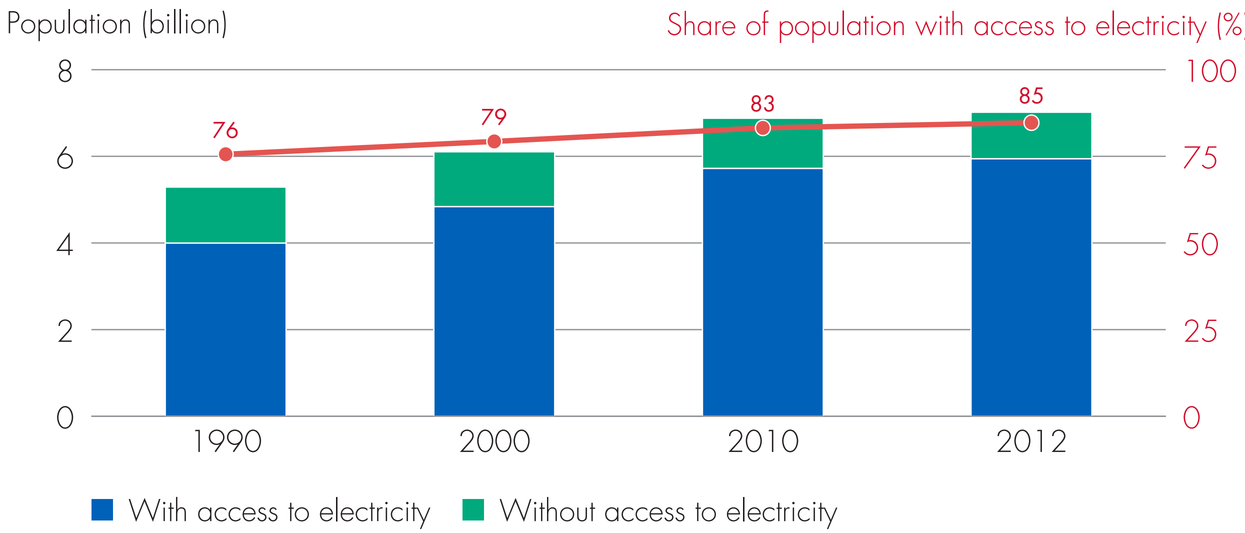
unelectrified population of 263 million, is followed by Nigeria (75 million) and Ethiopia (67 million).

The 222 million people who benefited from first-time access between 2010 and 2012 exceed the population of Brazil. The annual access increment of 111 million people marks a sharp acceleration from around 84 million people a year over 1990–2000 and 88 million in the subsequent decade. Yet universal access is still some distance away and requires an even higher annual pace of growth of 135 million from 2012 through 2030.

Urban areas accounted for 79 percent of the access increase between 2010 and 2012, about 34 percent of it in South Asia and 22 percent in Sub-Saharan Africa. Nationally, India was the highest absolute gainer at close to 55 million (figure O.2).

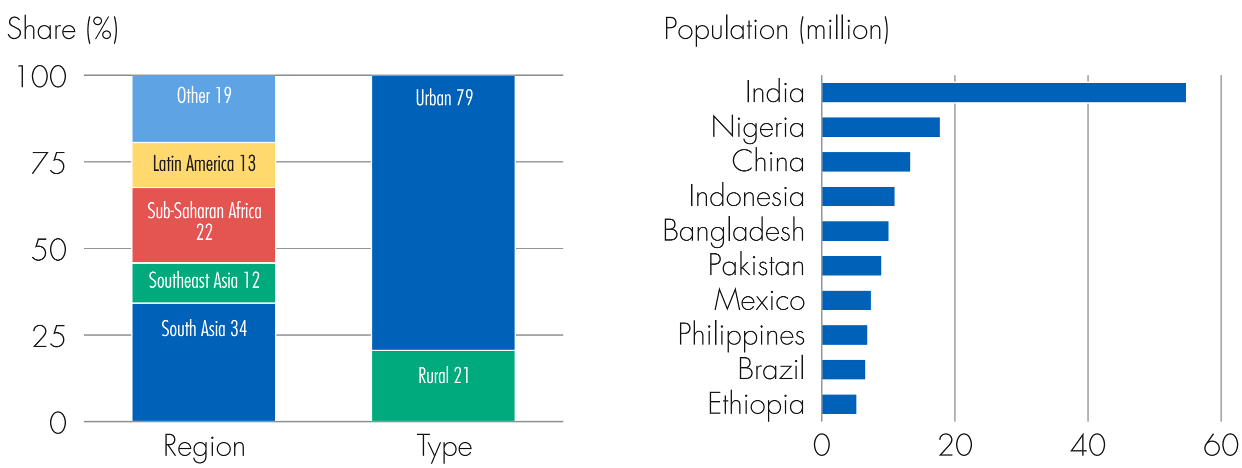
Although global electrification was faster than population growth over the tracking period—222 million against 138 million—regional experiences varied. Of the two largest access-deficit regions, South Asia's access outpaced its population increase by 54 million, while Sub-Saharan

Figure O.1. **Trends in access to electricity, 1990–2012**



Source: World Bank Global Electrification database 2015.

Figure O.2. **Global access to electricity increment, 2010–12**



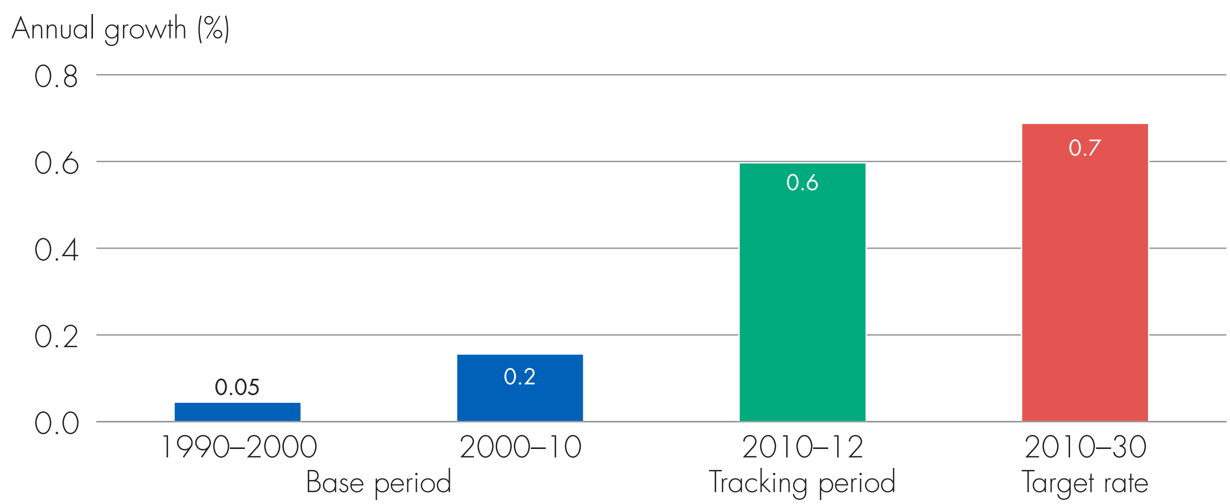
Source: World Bank Global Electrification database 2015.

Africa's population growth equaled it. In all other regions of the world, access improvements stayed ahead of population increase.

Growth of the net increase in access over population increase was 0.6 percent a year during the tracking period, significantly higher than the average growth rates of the past two decades (figure O.3), and close to the required (or target) growth rate of 0.7 percent.

The recent experience of the regions is noteworthy compared not only with each other but also against their own historical performance. Every region improved in the tracking period from the historical period of 1990–2010. Even Sub-Saharan Africa, where as noted the access increase equaled the population increase in the tracking period, performed better than its historical reference period when access fell behind population. But the most promising performance was in South Asia, where the growth rate

Figure O.3. **Annual growth rate of access to electricity**



Source: World Bank Global Electrification database 2015.

showed an impressive jump between the two periods (figure O.4).

Achieving the objective of universal electrification will depend critically on the top 20 access-deficit countries (the "high-impact" countries). Nine of them managed an access increase higher than or equal to the population increase in 2010–12, and eight of them achieved a growth rate higher than global annual growth rate of 0.6 percent. The rest saw no net increase in access or lagged behind the population increment (figure O.5).

Modern cooking

The global rate of access to non-solid fuels as the primary cooking fuel hardly budged from 58 percent to 59 percent between 2010 and 2012, compared with 48 percent in 1990 (figure O.6). The urban and rural access rates remained similar at 87 percent and 27 percent respectively during the tracking period. Among the regions, instances of improvement are limited to Caucasian and Central Asia, West Asia, Oceania, and East Asia, where the access rate rose by 2 percentage points.

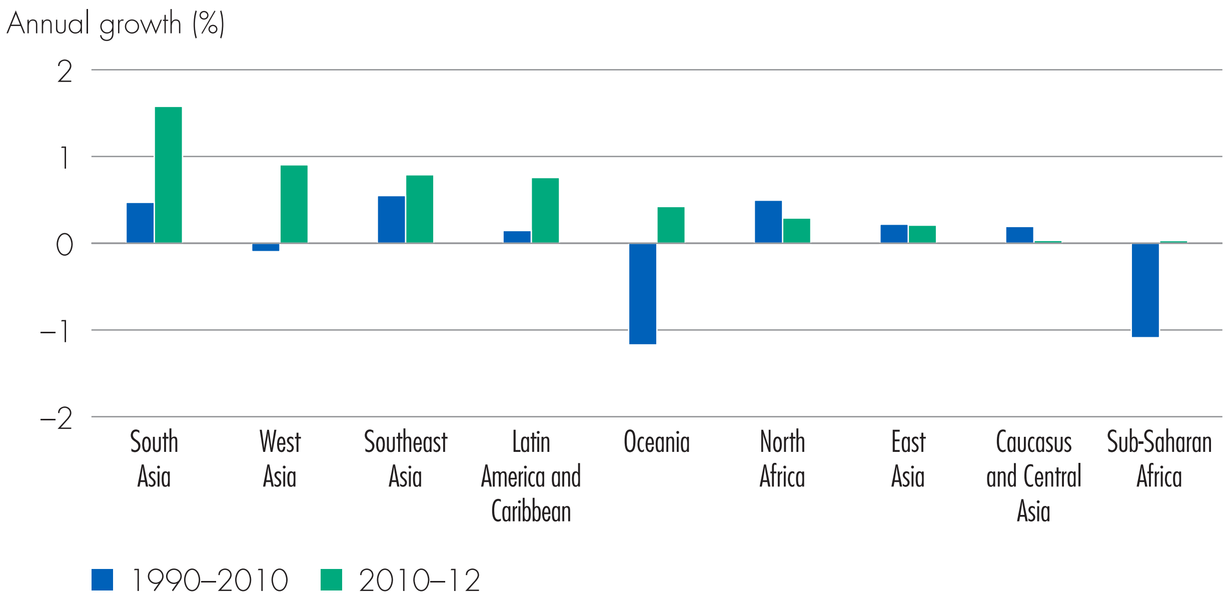
The absolute population living without access to non-solid fuels actually rose from 2.8 billion to 2.9 billion during the tracking period. The population to be served during the period to 2030 corresponds to the current access deficit plus the new population likely to be added (around 1.5 billion). While the access deficit in 2012 is a mix of rural and urban, the new population increment between 2012 and 2030 is almost entirely urban.

The access deficit remains overwhelmingly concentrated in South Asia, Sub-Saharan Africa, and East Asia and in rural areas everywhere. Even so, the urban challenge still accounts for 17 percent of the current access deficit. The 20 highest access deficit countries contribute 83 percent of the global deficit of a billion people. India and China, with the largest access deficits of 791 million and 610 million, are followed by Bangladesh and Nigeria, with 138 million and 127 million.

Thus, only 123 million people benefited from first-time non-solid fuel access during the tracking period, no more than the population of Mexico, a deceleration to around 63 million annually from historical progress of around 81 million over 1990–2000 and 62 million the following decade. This is much slower than the required annual pace of 222 million to reach the 2030 objective, which is unlikely to be attained without sharply accelerated performance.

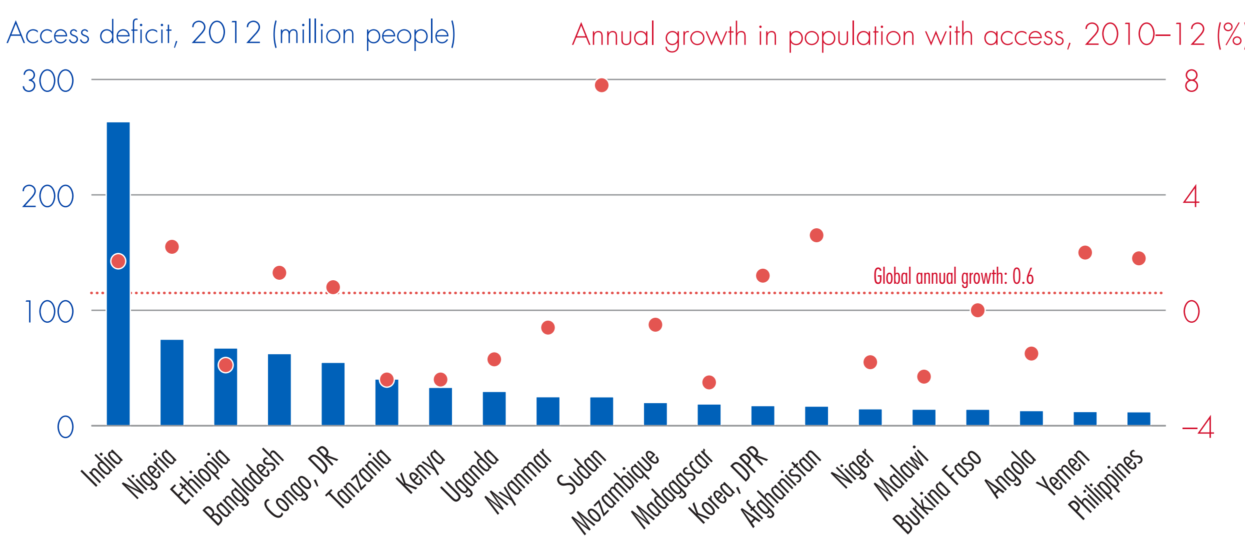
Urban areas saw almost all the access increase between 2010 and 2012 (figure O.7), with little net progress in rural areas. South Asia gained 18 percent of this new population having non-solid fuel access, with 19 percent in East Asia. Among countries, China was the highest absolute gainer, with close to 22 million over the tracking period, followed by India at 14 million. In Sub-Saharan Africa, South Africa is the other large gainer, with an access increase

Figure O.4. **Growth rate of access to electricity by region, 1990–2000 and 2010–12**



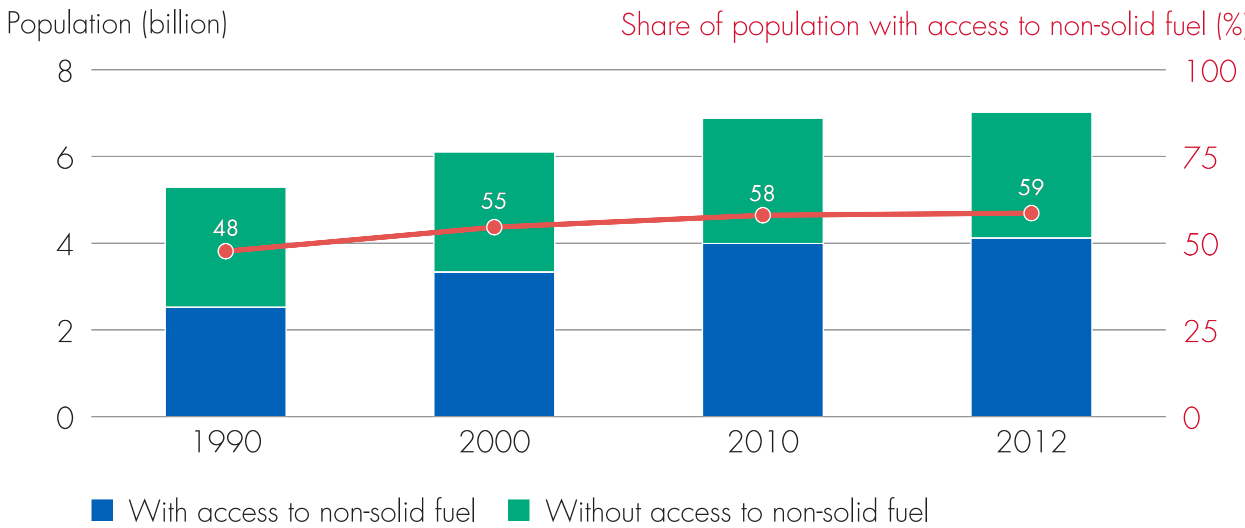
Source: World Bank Global Electrification database 2015.

Figure O.5. **Access to electricity: Access deficit and growth in the 20 high-impact countries, 2010–12**



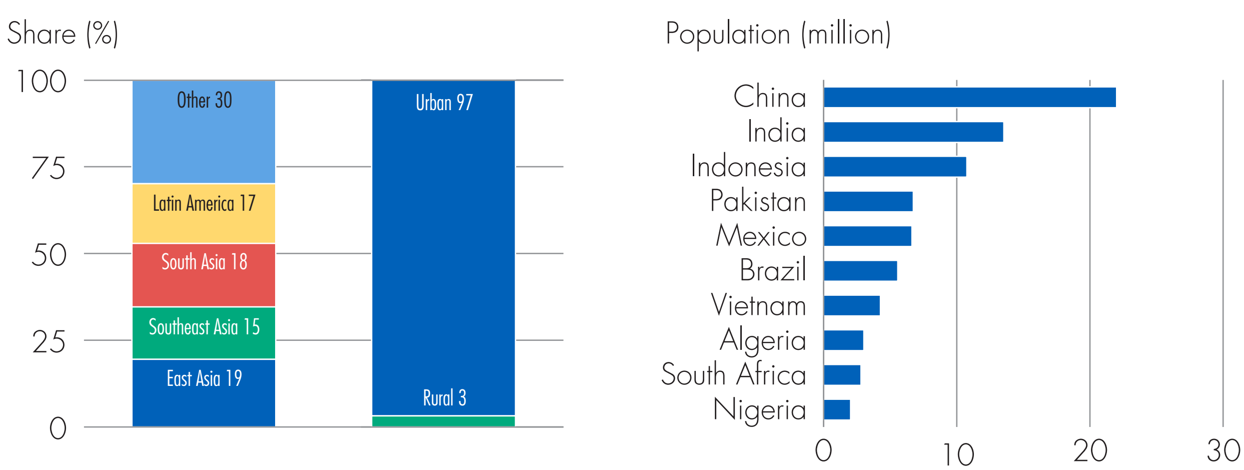
Source: World Bank Global Electrification database 2015.

Figure O.6. **Evolution of access to non-solid fuels**



Source: WHO Household Energy database 2015.

Figure O.7. **Global access to non-solid fuels increment, 2010–12**



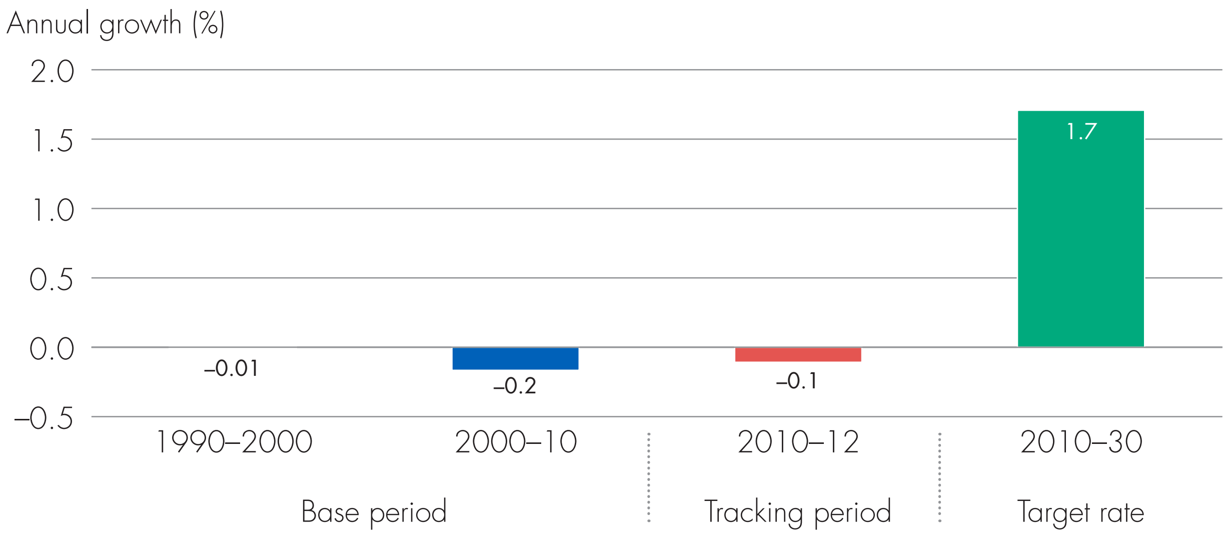
Source: WHO Household Energy database 2015.

of 2.4 million, while Nigeria and Angola also made some progress in reducing the access deficit.

The world's growth in access did not keep pace with population growth in the tracking period. In fact, compared with the access increment of 123 million, the population rose by 138 million. In East Asia and South Asia, access expansion stayed ahead of the population increase by 12 million and 1 million, while in Sub-Saharan Africa it lagged the population increase by 38 million. In all other regions, access improvements stayed ahead of the population increase.

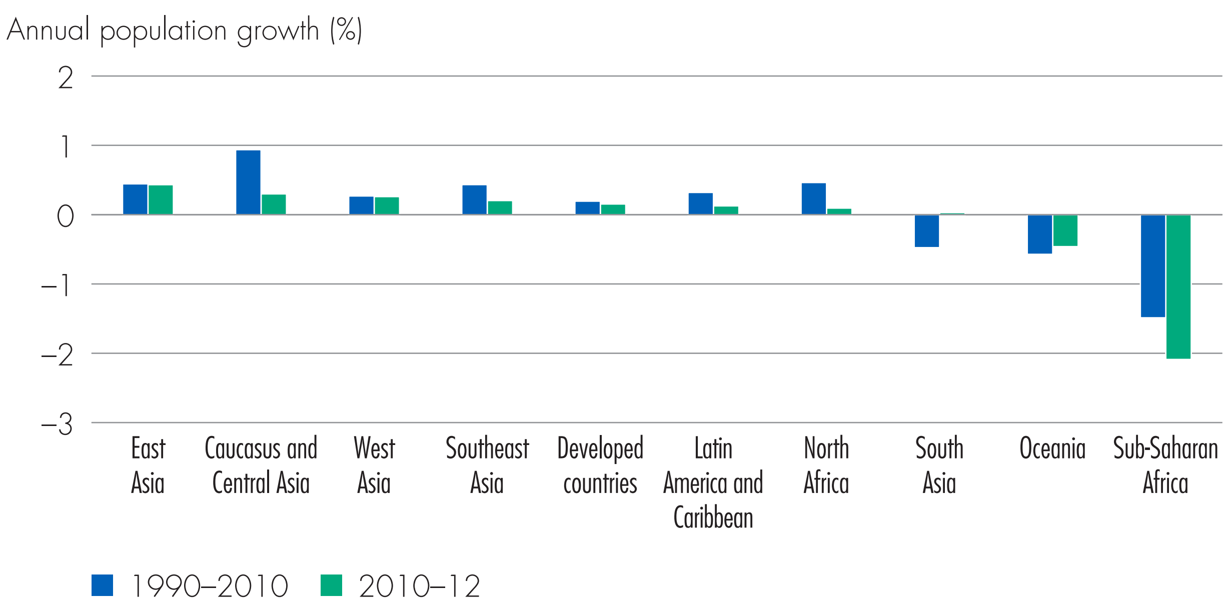
The growth of the net increase in access over population growth was –0.11 percent each year during the tracking period (figure O.8), continuing the negative growth of –0.2 percent annually between 2000 and 2010. (In 1990–2000, the access improvement at –0.01 percent annually just about kept pace with the population increase.) A comparison with

Figure O.8 **Annual growth rate of access to non-solid fuels**



Source: WHO Household Energy database 2015.

Figure O.9. **Growth in population with access to non-solid fuels by region, 1990–2010 and 2010–12**

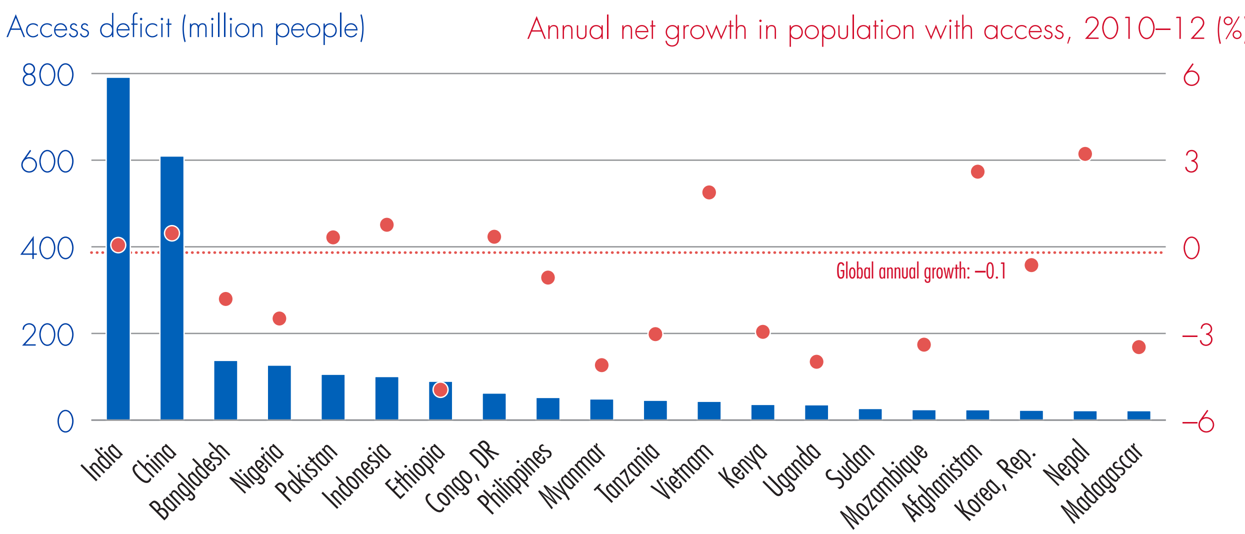


Source: WHO Household Energy database 2015.

historical growth rate suggests that South Asia turned the corner in the tracking period after negative growth during 1990–2010. Sub-Saharan Africa lagged the farthest behind in both the historical and the tracking periods (figure 0.9).

The net increase falls dismally short of the pace required to meet the global objective of universal access to modern cooking solutions—1.7 percent (222 million) annually from 2012 to 2030. And the current indicator cannot capture

Figure O.10. **Access to non-solid fuels: Access deficit and growth in the 20 high-impact countries, 2010–12**



Source: WHO Household Energy database 2015.

progress in the adoption of improved biomass cookstoves, which will be a big part of the solution.

The achievement of the SE4All objective of universal access will depend on the top 20 access-deficit countries. Only eight of them had an access increase higher than the population increase in 2010–12 and stayed above the global annual growth rate (figure O.10). The rest lagged behind the population increment.

Energy efficiency

Doubling the rate of improvement in energy efficiency

Global primary energy consumption grew at over 1.9 percent a year from 1990 to 2000, kept down by continual improvements in energy intensity. Had that not changed, energy consumption in 2012 would have been 25 percent higher (figure O.11). The incremental change in energy intensity from 2010 to 2012 alone (when primary energy use rose by 1.8 percent annually) avoided primary energy use of 20 exajoules (EJ) in 2012, or more energy than Japan used that year.

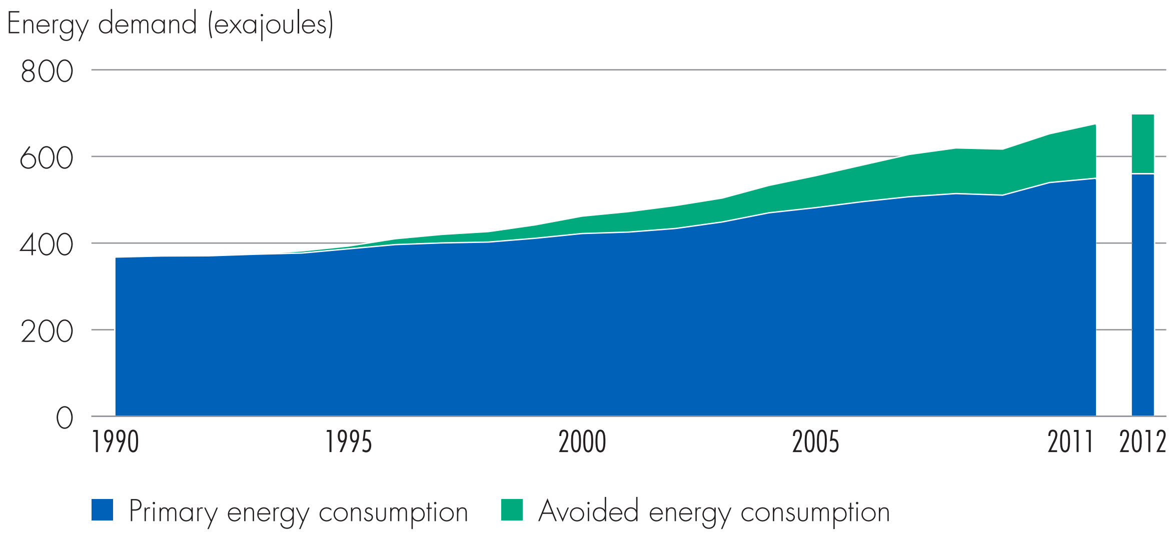
Progress in the tracking period

Primary energy intensity fell by more than 1.7 percent a year over the tracking period (figure O.12), far more than the average drop of about 1.3 percent a year from 1990 to 2010 and the 1.2 percent drop in 2000–2010. Still, even this recent improvement falls far short of the annual 2.6 percent needed between 2010 and 2030 to meet the SE4All objective of doubling the historical rate of decline in energy intensity.

The recent acceleration was driven primarily by high-income countries, whose compound annual growth rate of primary energy intensity fell even faster from 1.5 percent a year in the base period to 2.6 percent in the tracking period (figure O.13), taking them to the global target rate. Middle- and low-income countries, by contrast, experienced no such acceleration, although the pace remained relatively rapid. The striking exception is the upper-middle-income countries (UMICs), where the fall in primary energy intensity remained stubbornly low at around 0.5 percent a year. Owing in large part to rapid industrialization in these countries, energy intensity remains well above the global average.

In all the periods analyzed, upper-middle-income countries (UMICs)—with China the prime example—were by far the largest sources of avoided final energy consumption (figure O.14).[1] High-income countries (HICs) also contributed a great deal—one-third in the tracking period—demonstrating that large decoupling effects are not restricted to industrializing nations. Lower-middle-income countries (LMICs) saw a growing, but still small share of avoided final energy

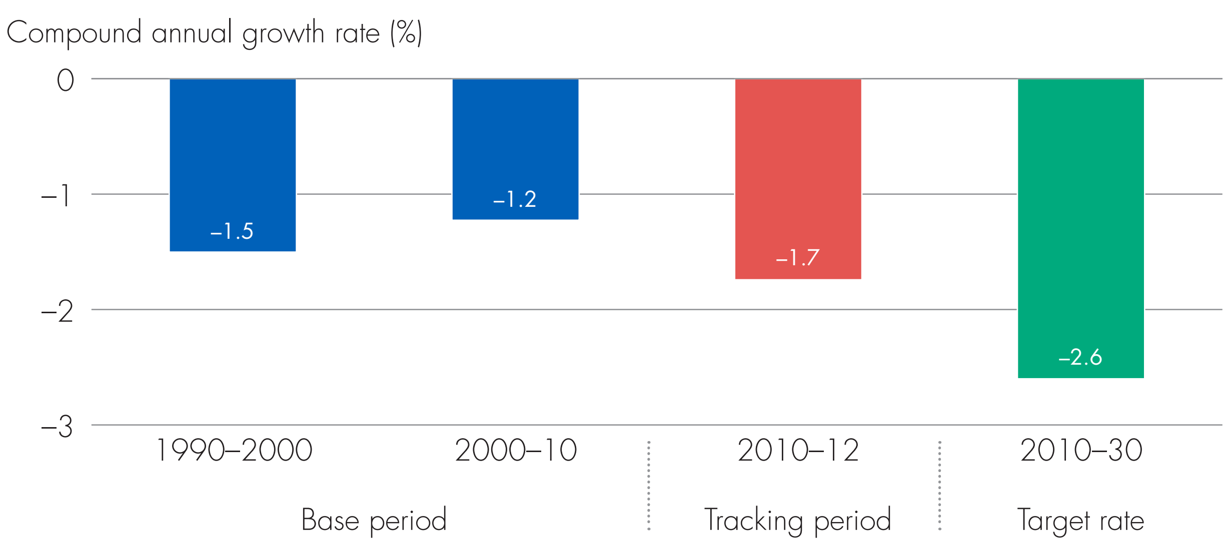
Figure O.11. **Actual and avoided global primary energy consumption due to declining energy intensity**



Source: Energy intensity decomposition analysis based on IEA, WDI, and UN data.

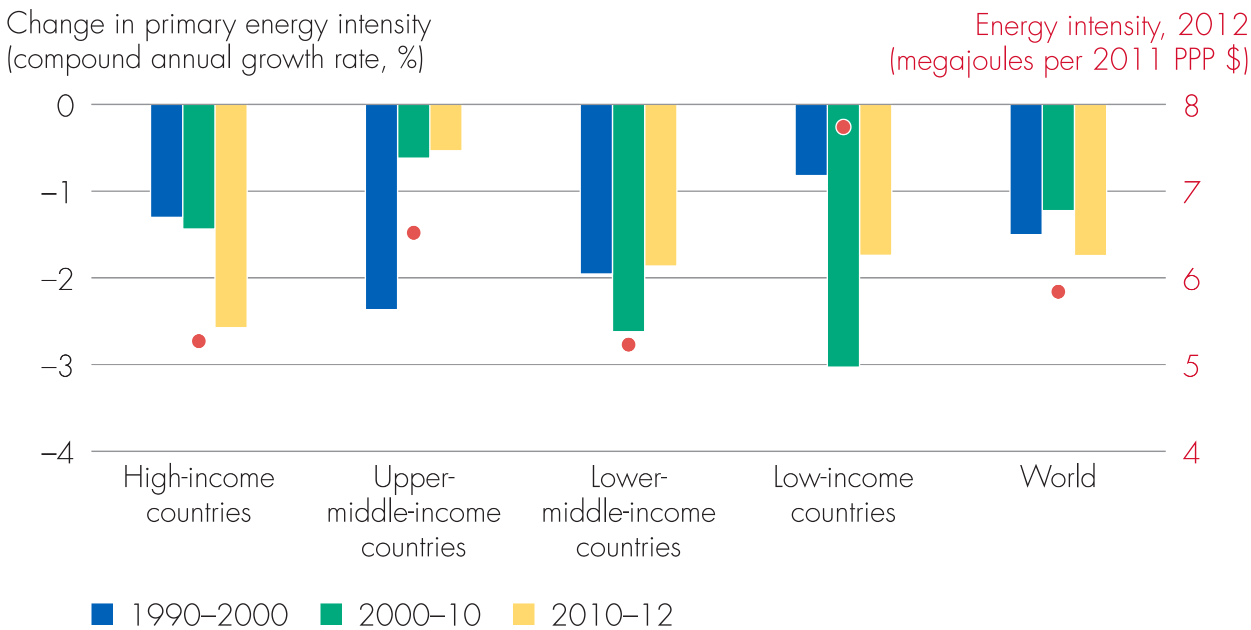
Note: Primary energy consumption is represented by total primary energy supply (TPES). Avoided energy consumption is estimated from the energy intensity component of decomposition analysis, with a base year of 1990; see chapter 3, annex 1.

Figure O.12. **Rate of change in global energy intensity (CGAR, PPP) compared with target**



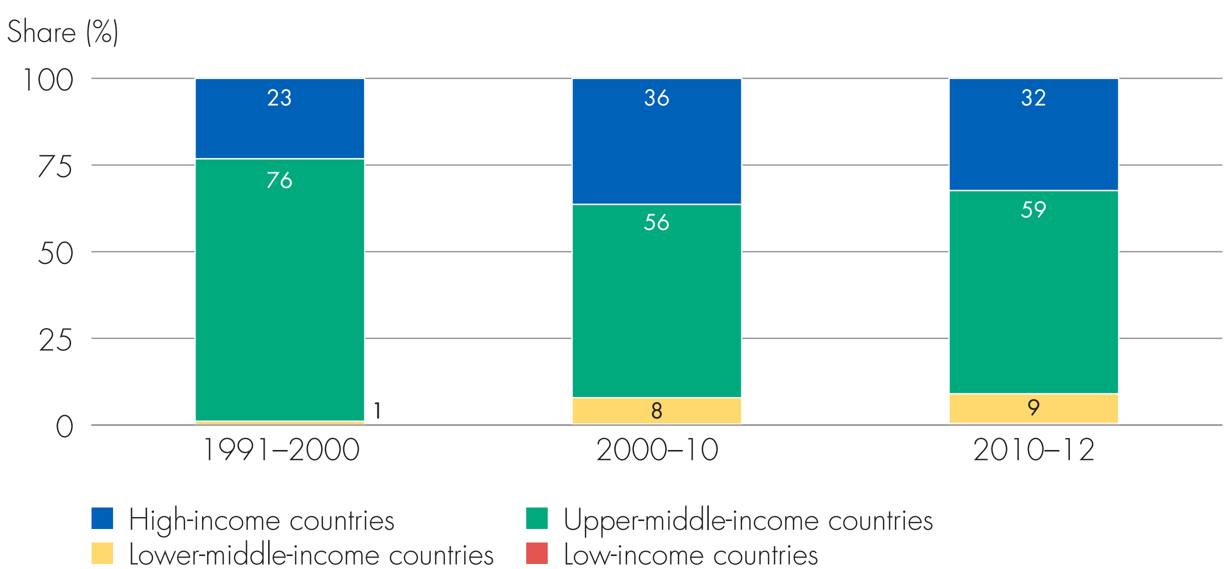
Source: IEA and WDI data.

Figure O.13. **Primary energy intensity by income group: rate of change and energy intensity**



Source: IEA and WDI data.

Figure O.14. **Share of avoided global final energy consumption by income group and time period**



Source: Energy intensity decomposition analysis based on IEA, WDI, and UN data.

Note: Avoided energy consumption is calculated relative to a base year of 1990.

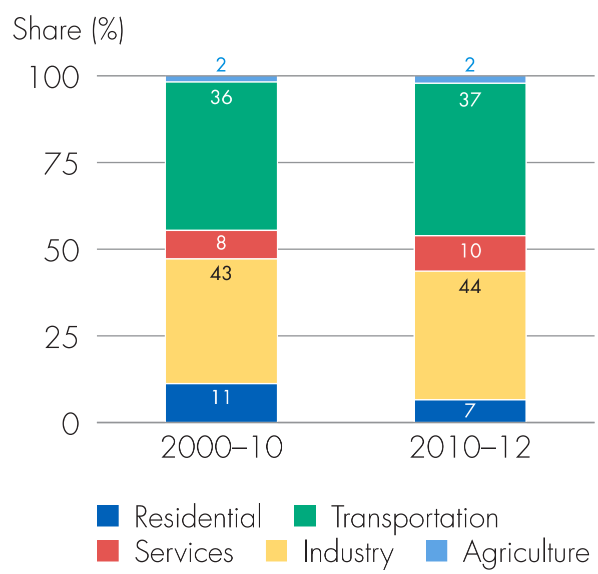
consumption in the tracking period, but low-income countries (LICs) did not exert an appreciable influence.

Among end-use sectors, industry was the largest contributor to reduced energy intensity between 2000 and 2012, followed closely by transport (figure O.15). Industry's energy efficiency has improved broadly, and many countries have set or strengthened their fuel economy standards. The relatively small contributions from the services and residential sectors points to a large store of potential future energy savings in buildings.

Provision of higher-quality energy in the form of electricity and gas contributes to national development, but it has a cost in rising conversion, transmission, and distribution losses. These rising inherent losses are partly offset by the introduction of more efficient technologies and better management to reduce loss rates from energy extraction and delivery. Attention to reducing leaks and better pipeline pressurization, for example, has led to a long-term decline in midstream gas sector losses. The picture is less rosy for electricity generation, because an ever-larger share of primary fossil energy is converted to electricity, and fossil fuels will continue to dominate the generation mix.

Technological progress means that the frontiers of efficiency for all fuels are constantly rising, but the average may not always follow (figure O.16). There has even been

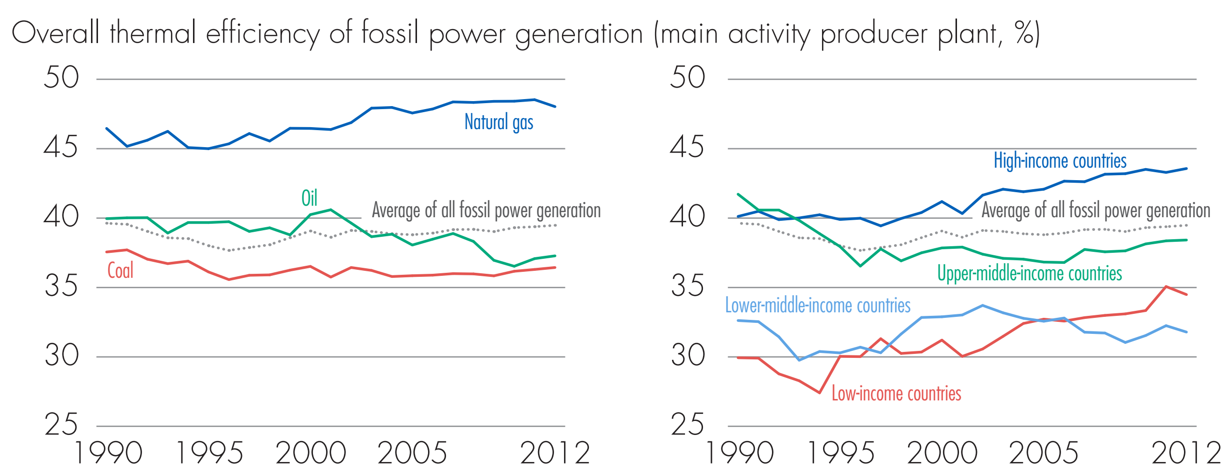
Figure O.15. **Share of avoided global final energy consumption by sector, 2000–12**



Source: Energy intensity decomposition analysis based on IEA, WDI, and UN data.

Note: Transport sector effects are based on global results of the IEA Mobility Model. These results cannot be disaggregated by country, region, or income group and are available only for 2000 and later.

Figure O.16. **Thermal efficiency of fossil power generation by fuel and income group**



Source: IEA data.

Note: Data are for main activity electricity plants, excluding, for instance, on-site power generation at industrial facilities.

a slight decline in the average efficiency of coal-fired power generation, due to rising self-use by power plants and the rapid construction of new coal-fired plants that do not use the best available technology. As coal dominates overall additions to generation capacity, average thermal efficiency of power supply has stagnated since 1990.

For transmission and distribution (T&D) losses, on the other hand, the trends are more promising. In 2012, global T&D losses of 1,880 terawatt-hours (TWh) were incurred, equivalent to 8.8 percent of worldwide generation that year. Loss rates have gradually fallen over the past decade, though trends vary widely among countries. Globally, the decline of 0.7 percentage points from 2002 to 2012 saved about 160 TWh a year, equivalent to Poland's electricity generation in 2013.

The regions that led the renewed decline in energy intensity in the tracking period included regions with high-income countries, like the European Union (EU) and North America, but also developing regions, notably Southeast Asia, and to a lesser extent Central Asia, Eastern Europe, and Sub-Saharan Africa (figure O.17). West Asia saw a decline in energy intensity, marking a turnaround, whereas North Africa exhibited a significant upward acceleration, attributable to the disruptions the region experienced at that time.

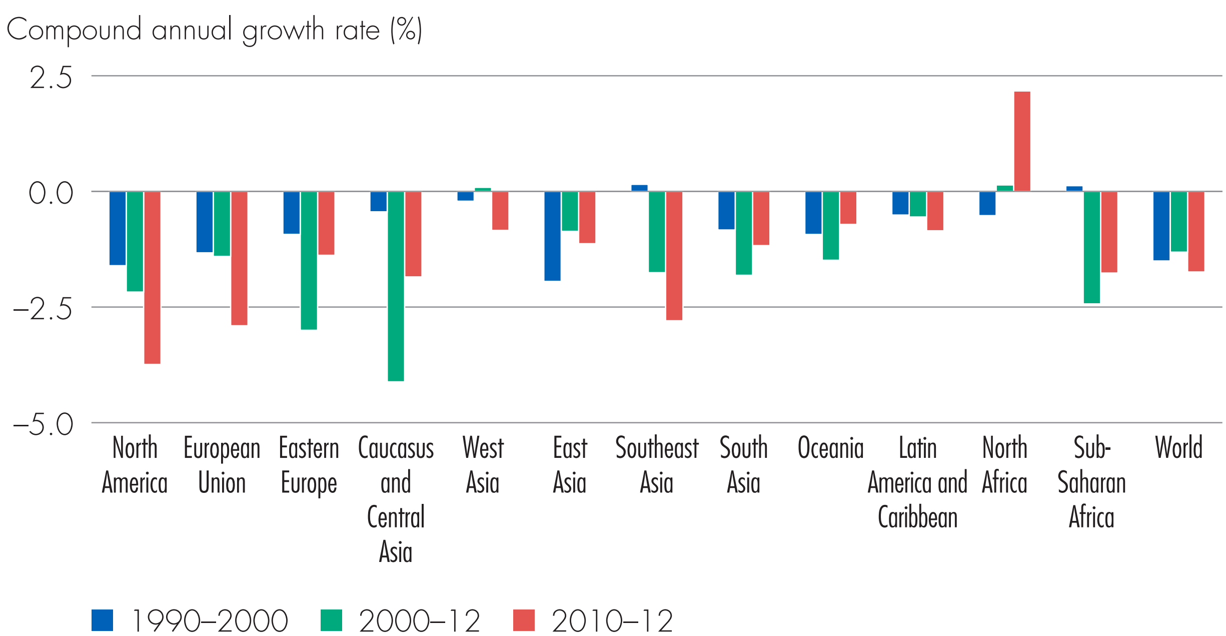
High-impact countries

The top 20 primary energy-consuming countries have a huge effect on achieving the global SE4All objective, as they were collectively responsible for nearly three-quarters of global energy use in 2012 (figure O.18). The top five alone accounted for more than half of all energy consumption.

China led the declines in intensity from 1990 to 2010, followed by the United Kingdom, India, and Nigeria, but a very different group emerged as leaders in the tracking period (figure O.19), when eight of the top 20 saw intensity declines exceeding 2.6 percent a year—showing that it is possible for mature economies to decouple economic growth from rising energy consumption.

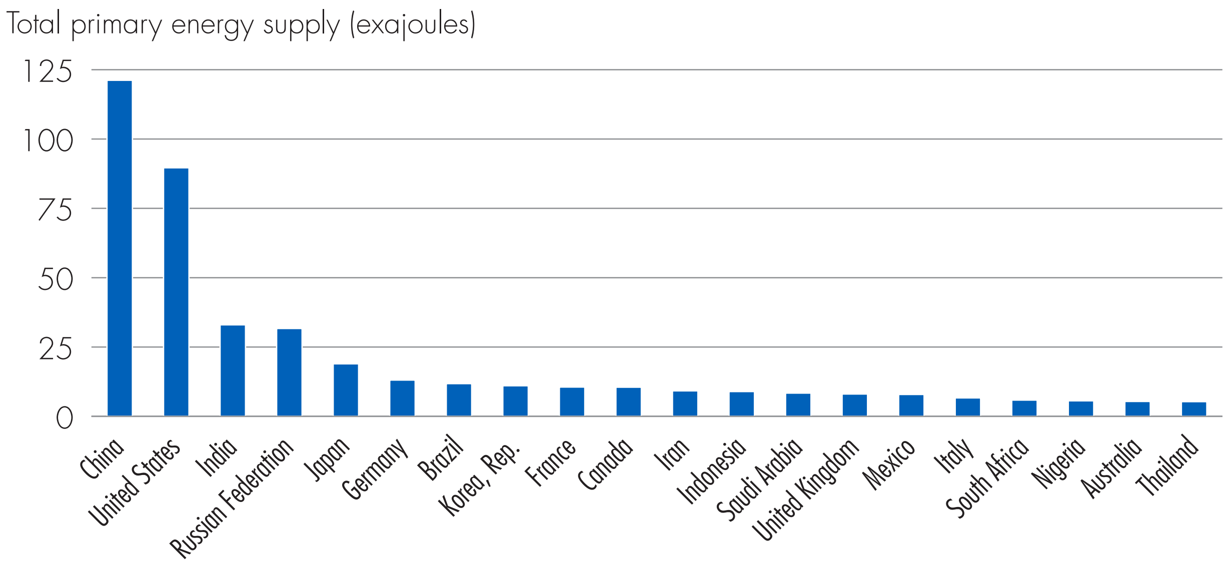
While high-income countries drove the global acceleration in reducing energy intensity after 2010, several large emerging countries—notably Indonesia, South Africa, and Saudi Arabia—also contributed. Russia, the most

Figure O.17. **Rate of improvement in primary energy intensity by region**



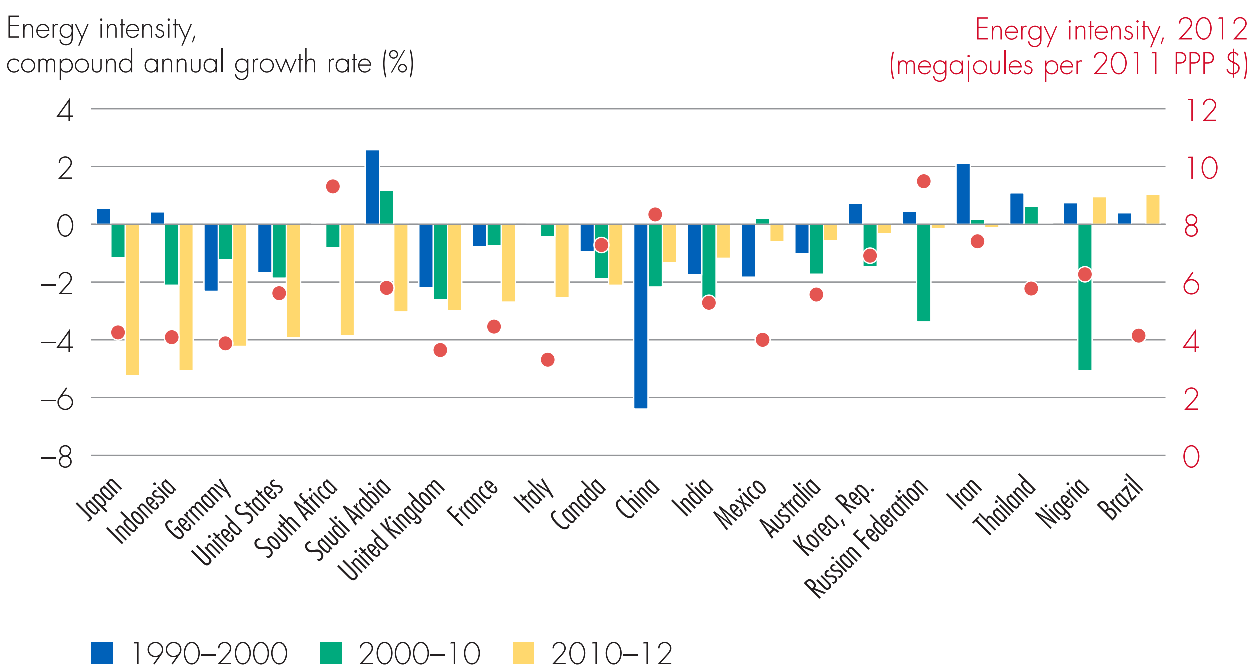
Source: IEA and WDI data.

Figure O.18. **Twenty largest primary energy consumers, 2012**



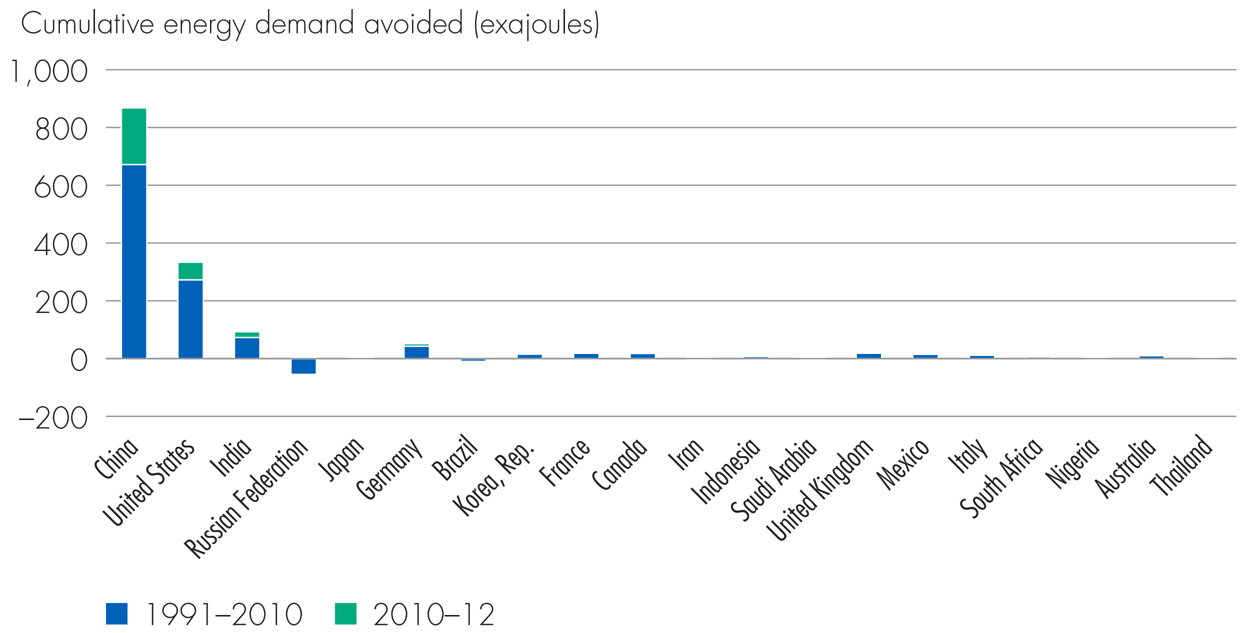
Source: IEA data.

Figure O.19. **Primary energy intensity trends, top 20 primary energy consumers in 2012**



Source: IEA and WDI data.

Figure O.20. **Avoided final energy consumption for top 20 primary energy consumers, 1990–2012**



Source: Energy intensity decomposition analysis based on IEA, WDI, and UN data.

Note: Avoided energy consumption is calculated relative to a base year of 1990.

energy-intensive of the group, showed only a marginal decline. Although during the two-decade base period intensity rose in four rapidly emerging countries—Brazil, Thailand, Iran, and Saudi Arabia—after 2010 only Brazil showed rising intensity. Saudi Arabia saw a major reversal, with intensity dropping by 3 percent a year during the tracking period.

On cumulative avoided energy consumption, many of the largest consumers play roles commensurate with their ranks as consumers (figure O.20). China, the United States, India, and to less extent Germany contributed to global energy savings on a large scale. Russia, because of a sharp rise in intensity in the early 1990s, actually subtracted from avoided energy demand over the period, even though from 2007 it began contributing positively. The contribution from Japan was quite small set against its rank as an energy consumer, as it suffered from low economic growth through most of the period and already had relatively low energy intensity.

Renewable energy

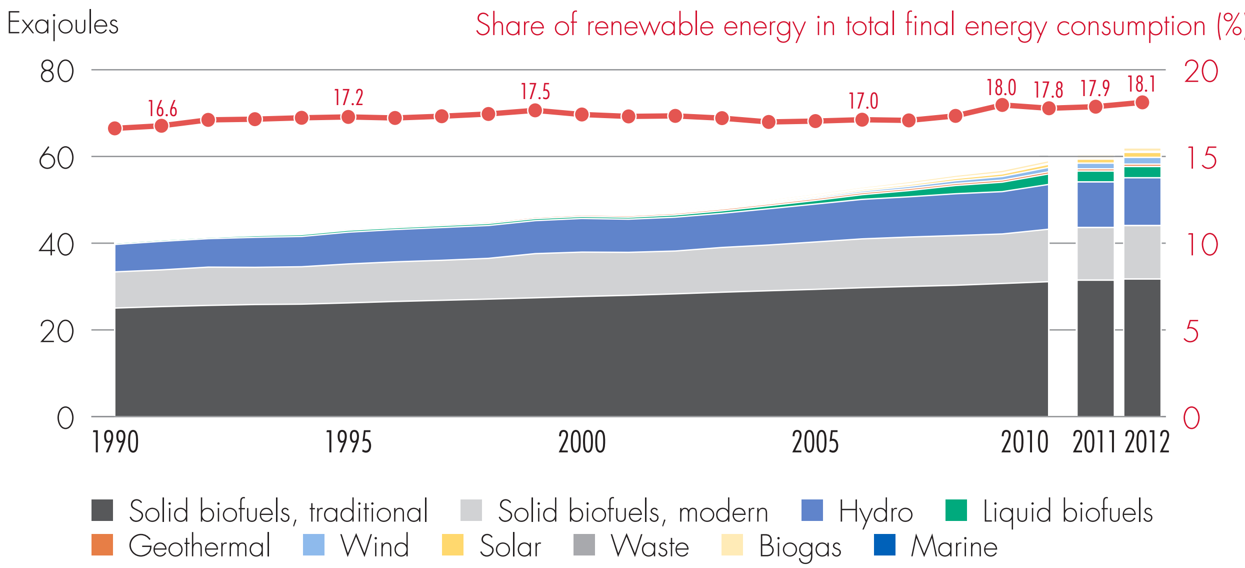
Doubling the share of renewable energy in total final energy consumption

On this third key development objective, the share of RE in total final energy consumption (TFEC) increased from 17.8 percent to 18.1 percent globally in the tracking period (figure O.21). This represents a net increment in RE consumption of 2.9EJ, equivalent to the entire national consumption of Pakistan or Thailand in 2012.

The average annual increase in the share of renewable energy over 2010–12 compares favorably with the previous 20 years. It was equivalent to 0.17 percentage points, up from 0.04 percentage points in the previous decade (figure O.22). But this still falls short of the average annual change of 0.89 percent required to meet the SE4All objective of doubling the renewable energy share from 2010 to 2030.

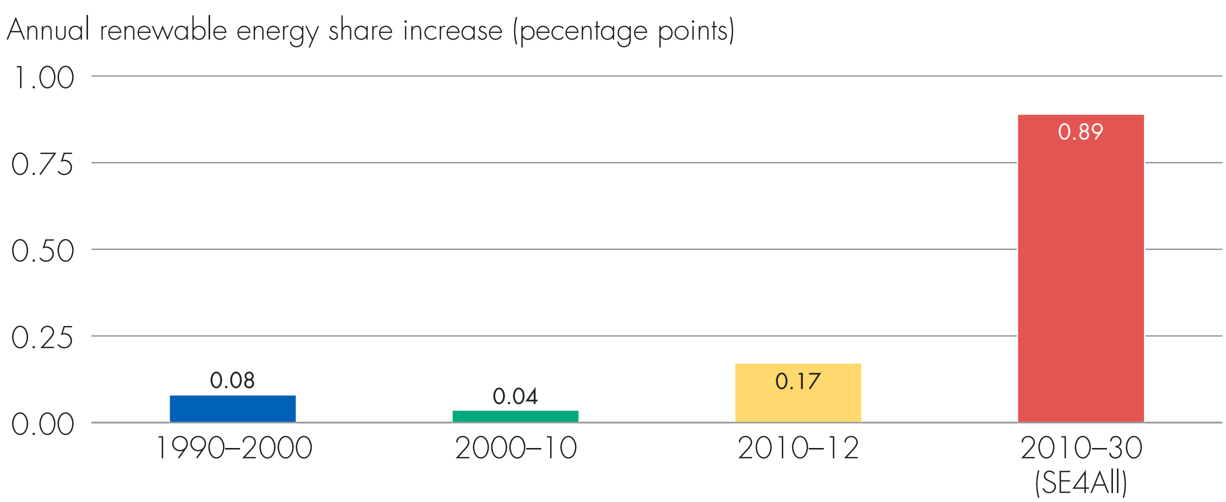
The growth of renewable energy consumption is outpacing the growth of total final energy consumption and the gap

Figure O.21. **Trends and RE share of total final energy consumption by source, 1990–2012**



Source: IEA and UN data.

Figure O.22 **Average annual increase of renewable energy share, actual and required**

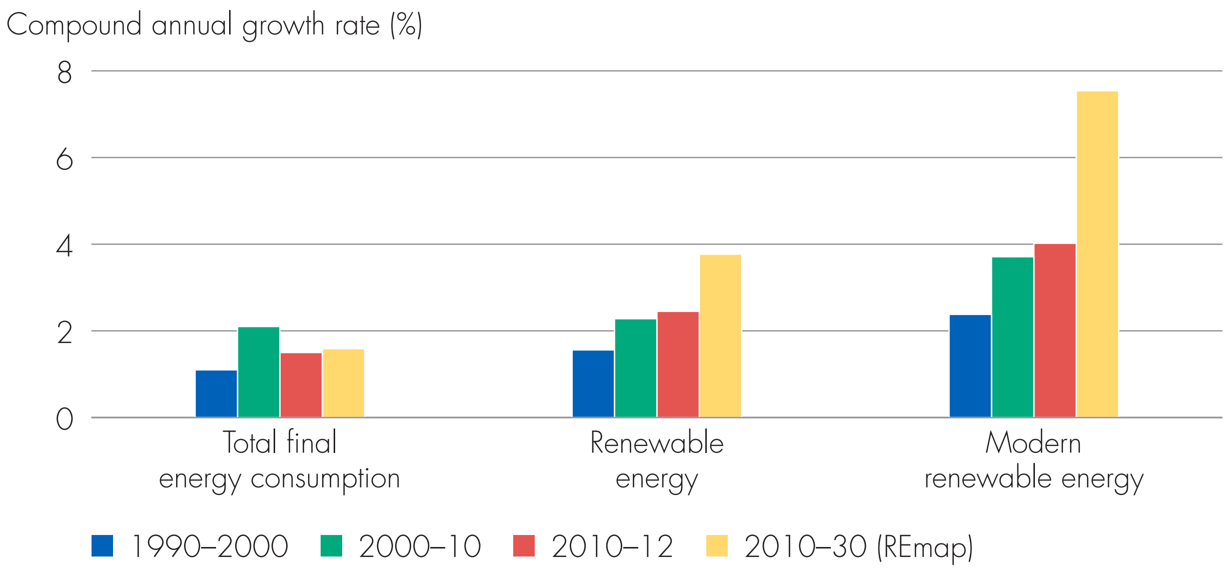


Source: IEA and UN data.

is widening. The compound annual growth rate (CAGR) of TFEC fell from 2.1 percent during 2000–10 to 1.5 percent over the tracking period, while the CAGR of RE increased from 2.3 percent to 2.4 percent (figure O.23). Excluding traditional solid biofuels, the CAGR accelerated from 3.7 percent in 2000–10 to 4.0 percent in 2010–12.[2] Still, IRENA's REmap 2030 study suggests that a renewable energy CAGR of 3.8 percent would be required between 2010 and 2030 to attain the SE4All RE objective, assuming a CAGR for TFEC on the order of 1.6 percent over the same period.[3]

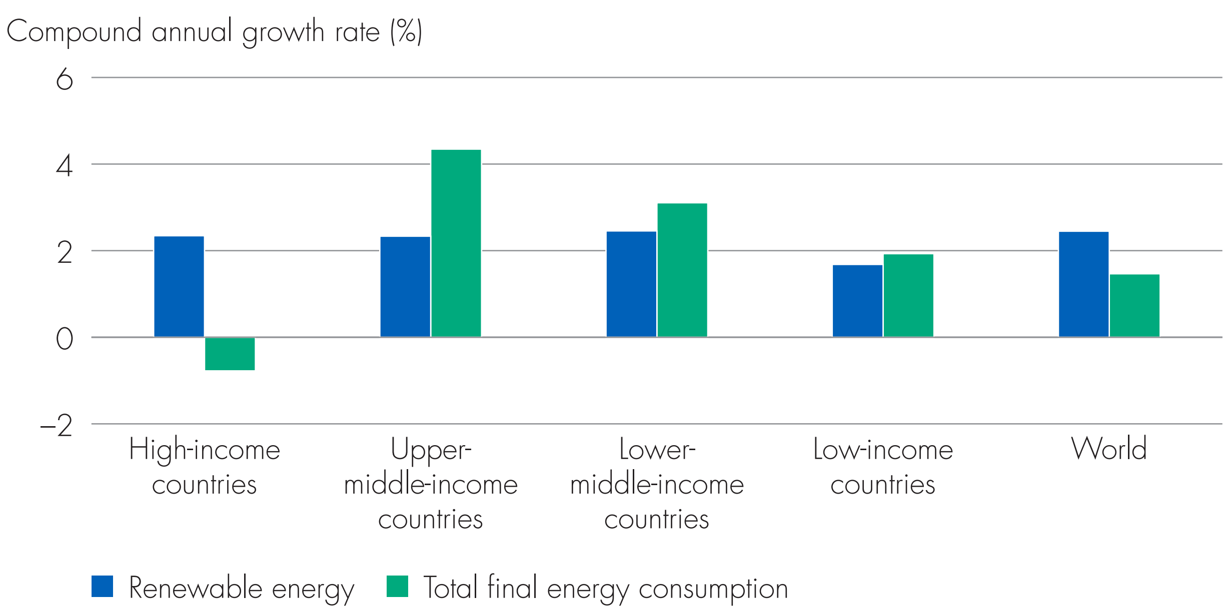
The global slowdown in the growth of TFEC over 2010–12 was mainly attributed to high-income economies where

Figure O.23. **Compound annual growth rate of total final energy consumption and renewable energy final consumption in different periods**



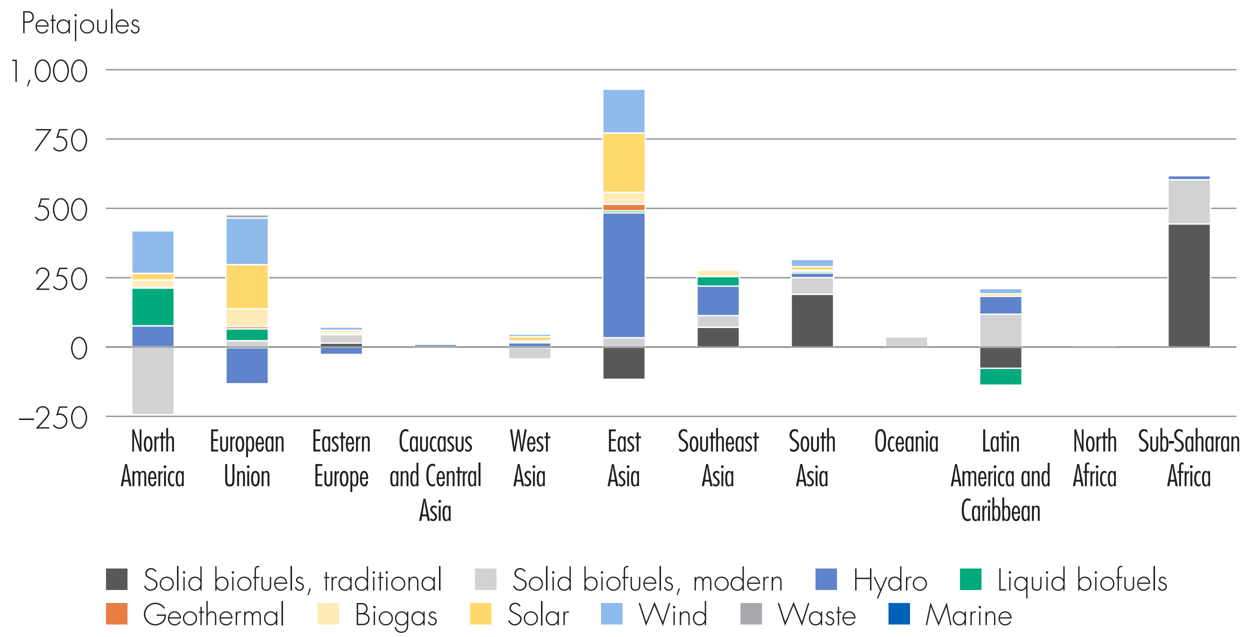
Source: IEA and UN data, 2014; analysis by the International Renewable Energy Agency based on IRENA (2014).

Figure O.24 **Compound annual growth rate of renewable energy consumption and total final energy consumption, 2010–12**



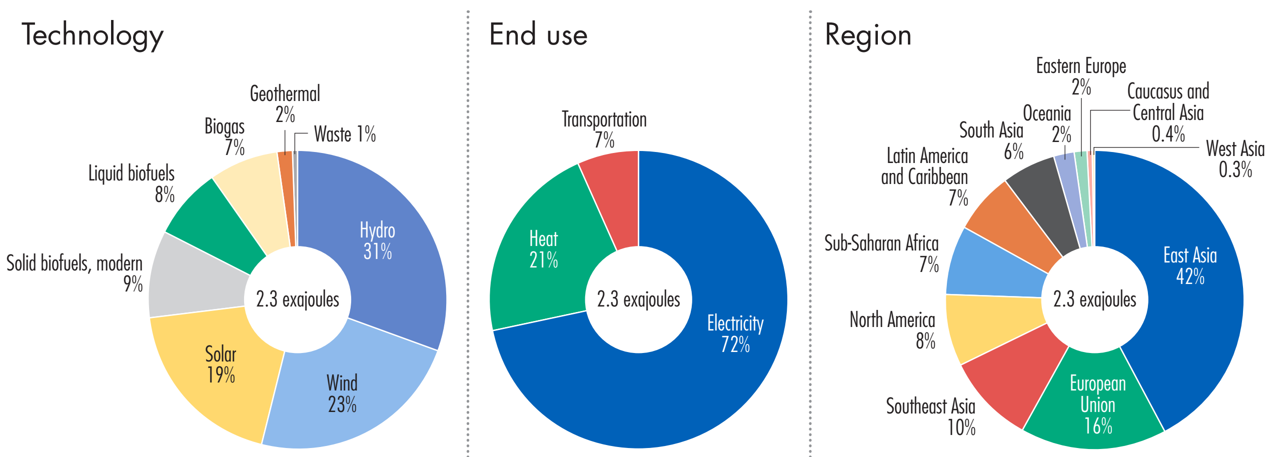
Source: IEA and UN data.

Figure O.25 **Renewable energy additions and retirements by region and resource type, 2010–12**



Source: IEA and UN data.

Figure O.26. **Composition of the net increment of modern renewable energy in total final energy consumption, 2010–12**



Source: IEA and UN data.

TFEC actually fell. The TFEC of middle- and low-income economies still grew faster than renewables' consumption growth in these countries (figure O.24).

The absolute increase of RE consumption over the tracking period was primarily driven by progress in East Asia, and to a lesser extent the EU, Southeast Asia, and North America (figure O.25). RE final consumption also grew rapidly in Sub-Saharan Africa, but this was driven almost entirely by the consumption of solid biofuels for traditional uses. By contrast, East Asia and Latin America showed steep reductions in traditional uses of solid biofuels, consistent with relative progress in the access to non-solid fuels in these regions (see figure O.7).

Excluding solid biofuels used for traditional purposes, the net increase of RE consumption over 2010–2012 is 2.3 EJ. By technology, increases in hydro, wind, and solar resources accounted for roughly three-quarters of the net increase; by end use, increases in electricity generation did the same; and by region, increases in East Asia, the EU, Southeast Asia, and North America also did the same (figure O.26).

Progress on RE partly reflects a significant scale-up in efforts by policymakers. From 2010 to early 2014, 35 more countries introduced RE targets, lifting the total to 144 from 109. Furthermore, 103 new regulatory policy instruments to promote RE were introduced globally in the period, with competitive bidding for grid-connected renewables and net metering for distributed generation by far the most popular. Continual reductions in the cost of key technologies have contributed to progress in RE deployment and a trend toward cost grid-parity in some technologies.

Doubling the share of RE in the global energy mix will depend on the top 20 countries with the largest TFEC (figure O.27). Over the tracking period, 15 of them increased their consumption of modern RE. In China and Nigeria, high growth of TFEC was exceeded by even higher growth of modern RE consumption, increasing the modern renewables share. In India, Russia, Brazil, and Turkey, TFEC grew faster than modern RE consumption, reducing that share.

Summary of progress

There has been positive progress towards sustainable energy, but this progress is not yet on track to meet the 2030 targets. Table O.2 below summarizes the historic and projected values of the main SE4All indicators.

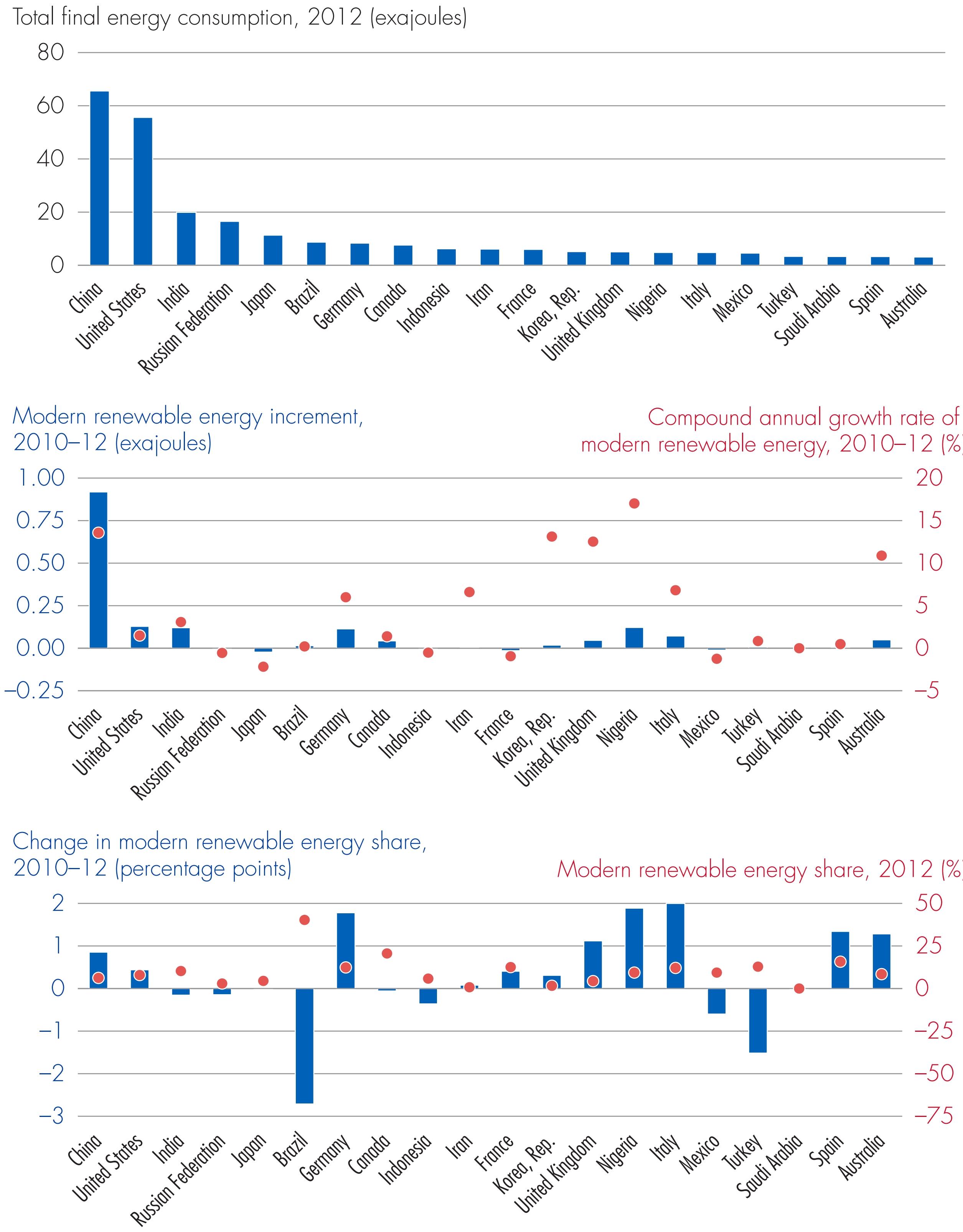
Table O.2. **Summary of progress, 1990–2012, and projected values**

Year	Universal access to modern energy services		Doubling global rate of improvement of energy efficiency	Doubling share of renewable energy in global mix
	Electrification	Cooking	Energy efficiency	Renewable energy
1990	76	47	–1.3	16.6
2010	83	59	–1.3	17.8
2012	84.6	58.4	–1.7	18.1
2030 (projected)	89	72	–2.2[a]	24[a]
2030 (target)	100	100	–2.6	36

Source: Prepared by authors based on World Bank Global Electrification Database 2015, IEA, UN, WDI data (2014).

a. Projections consider the New Policies Scenario of the IEA's World Energy Outlook (2014).

Figure O.27. **Top 20 energy consuming economies: modern renewable energy increment, 2010–12**



Source: IEA and UN data.

Table O.3. **Annual global investment—actual and required ($ billion)**

Annual investment	Universal access to modern energy services	Universal access to modern energy services	Doubling the global rate of improvement in energy efficiency	Doubling the share of renewable energy in the global mix[a]	
Source	Electrification	Cooking	Energy efficiency	Renewable energy	Total
Actual for 2012[b]	9	0.1	130	258	397
Required to 2030[c]	45	4.4	560	442–650	1,051–1259
Gap	36	4.3	430	184–392	654–862

a. This is the range for significantly increasing the share of renewable energy in total final energy consumption.

b. The total assumes 2010 investment in access figures for 2012.

c. Estimates are derived from various sources: Energy access, electrification: *SE4All Finance Committee Report,* World Bank (2014); Energy access, cooking: Energy for All Scenario, *WEO* (IEA, 2012); Energy efficiency: 450 scenario, *WEO* (IEA, 2014); Renewable energy lower bound: *WEO* 450 (IEA, 2014), corresponds to a 29.4 percent renewable energy share in total final energy consumption by 2030; Renewable energy upper bound: REmap 2030 (IRENA, 2014), corresponds to a 36 percent renewable energy share in total final energy consumption by 2030.

Source: Prepared by authors.

Investment gap

To meet the three SE4All energy objectives, *Global Tracking Framework 2013* showed that doubling or tripling historical capital flows would be needed. It estimated that global investment in areas covered by the three objectives was around $400 billion in 2010, and that additional annual investments of at least $600 billion to $850 billion would be required to achieve the three objectives.

Since *GTF 2013* was published, new estimates of actual and required investment have been made for reaching the energy efficiency and RE objectives (table O.3). Actual investments remain near $400 billion, but the required investments rise to around $1,050–1,250 billion.[4] That implies an investment gap of around $650–850 billion and point to a tripling of annual investments to achieve the SE4All objectives.

Taking up this challenge, the SE4All Advisory Board convened a Finance Committee in 2013–14 that brought together private commercial and development banks to further assess the financing gaps and to propose concrete approaches for attracting more capital. The committee identified four broad investment themes that could help mobilize $120 billion in incremental annual investment by 2020: green-bond market development, structures that use development finance institutions' derisking instruments to mobilize private capital, insurance products that remove specific risks, and aggregation structures that bundle and pool for small-scale opportunities.[5]

Energy access

Estimates in the *World Energy Outlook (WEO)* suggest that a fivefold increase in capital is needed—from $9 billion actual investment in 2010 to an annual $45 billion until 2030 to meet the universal access objective.[6,7]

The *WEO* projected cumulative investments of around $320 billion globally in power plants and new T&D lines, according to the IEA's latest New Policies Scenario, in which all investment commitments and policy pronouncements are realized.[8] This translates into an average annual investment of $19 billion to 2030, higher than historical estimates but not yet reaching the levels to attain the SE4All objective of universal access.

For modern cooking solutions, a 44-fold increase in capital is required—from $0.1 billion in 2010 to $4.4 billion annually until 2030—to meet the objective. According to the latest New Policies Scenario to 2030, around $11 billion of cumulative investments are projected in cleaner cooking technologies, such as liquefied petroleum gas (LPG) stoves, improved biomass stoves, and biogas digesters, or $0.6 billion a year. The IEA, in a special edition of *Africa Energy Outlook* (2014), projected investments in access to clean cooking in Sub-Saharan Africa at a cumulative $4.4 billion to 2030. The main component is the cost of improved or alternative cookstoves. It excludes the cost of infrastructure related to LPG, electricity, or natural gas distribution, and covers only the cost of the first stove and half the cost of a second stove, assuming that the path toward such investment becomes self-financing. Around 40 percent of the total is related to LPG cookstoves, 30 percent is for biogas digesters, and 30 percent is for solar cookers and improved biomass cookstoves.

Energy efficiency

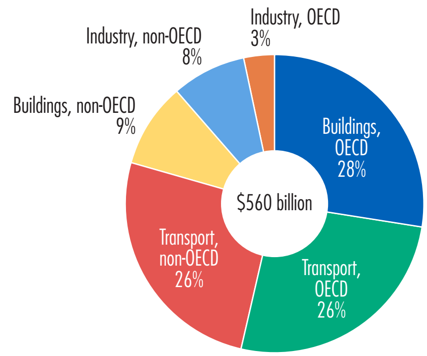
To meet the SE4All objective, a quadrupling of current energy efficiency investment is needed, from about $130 billion in 2012 to an annual average of $560 billion through 2030. Transport is expected to account for slightly more than half the investment due to the sheer volume of new, more efficient cars and trucks projected to be sold and the high investment costs per unit of energy saved compared with other end-use sectors (figure O.28). The share of industrial energy efficiency investment is relatively low at 11 percent because much of the efficiency potential is already embedded, unit investment costs are lower, and most of the efficiency improvement occurs during stock turnover, which is slow.

From a regional perspective, Europe, developing Asia (mainly China and India), and North America dominate energy efficiency investment, accounting for almost 80 percent of the required investment through 2030 (figure O.29). This partly reflects the size of current energy consumption, but is also a consequence of current and planned policies. North America, Europe, and China, for example, are the world's largest car markets and have all adopted stringent fuel-economy standards or emission standards for cars. Several other regions—such as Africa and the Middle East—account for far less investment than their share in final energy consumption, owing to, for example, smaller industrial capital stocks, different space conditioning needs, less cost-reflective energy prices, and the need to build capacity to set and enforce energy efficiency measures.

Renewable energy

Between 2010 and 2012, the global annual investment in RE increased by 13 percent from $228 billion to $258 billion, far short of the near doubling to steer toward the

Figure O.28. **Share of annual average energy efficiency investment in the 450 Scenario by sector and region, 2014–30**



Source: IEA (2014).

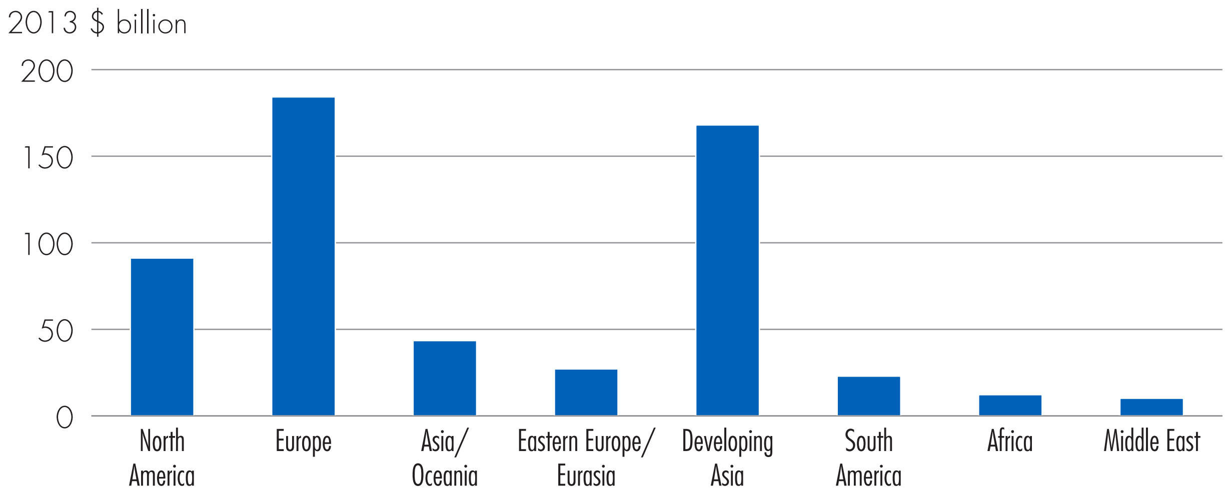
Note: The OECD 450 Scenario in *WEO 2012* assumes different groups of countries adopt binding economywide emissions targets in successive steps, reflecting their economic development and responsibility for past emissions.

450 ppm carbon dioxide concentration target (IEA, 2014) and a more than doubling to achieve the SE4All RE objective as estimated by REmap 2030 (IRENA, 2014).

The 450 Scenario of the *WEO* lays out a trajectory of energy investments in which RE accounts for 29.4 percent of TFEC by 2030.[9] This share lies below the 35.8 percent target of the SE4All agenda, thus the 450 Scenario of RE investment requirements presented here should be taken as conservative. Even so, the 450 scenario requires annual investment of $442 billion, implying a $184 billion investment gap. This gap is spread among regions, except OECD Europe, where annual investment in the last years has exceeded that required in the 450 Scenario (figure O.30). Broad policy commitments and plans announced by countries in the New Policies Scenario do not change the overall picture much, as global investment in that scenario totals $281 billion annually.[10]

REmap 2030 provides a pathway for scaling up renewables that is aligned to doubling the renewables share in TFEC. In REmap 2030, annual investment in renewable energy will have to be on the order of $650 billion, implying a nearly $400 billion investment gap in 2012 and requiring a 2.5-fold increase over 2012's investment volume. As in the *WEO* 450 scenario, the 2012 investment gap is highest in developing Asia (figure O.31). However, REmap 2030 requires relatively higher scale-ups in the economies of the Middle East, Africa, and Latin America.

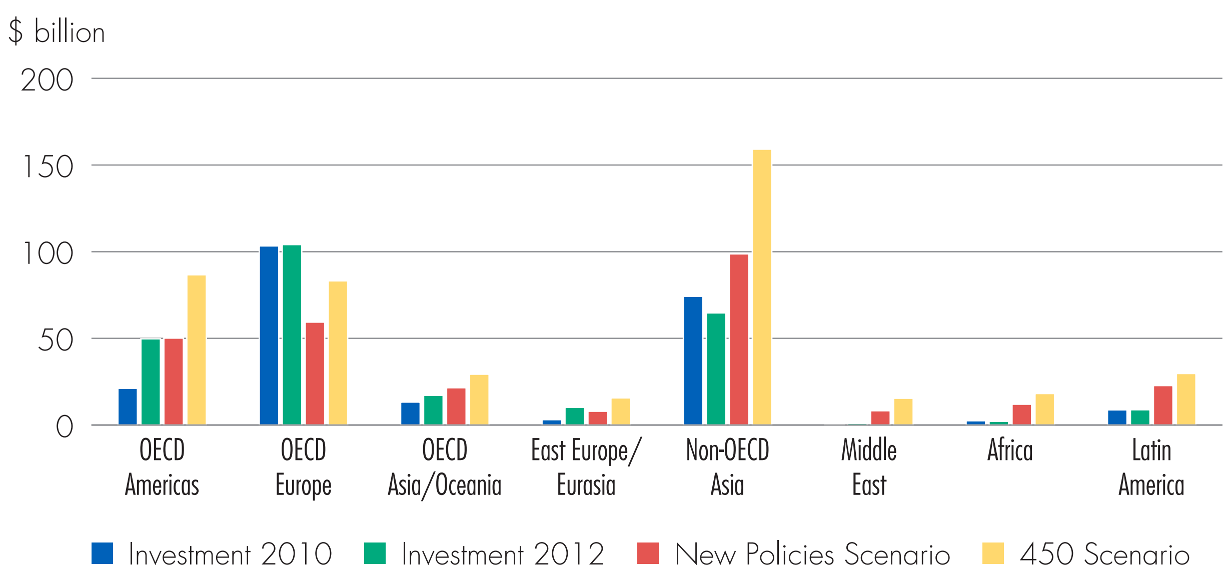
Figure O.29. **Annual average energy efficiency investment in the 450 Scenario by region, 2014–30**



Source: IEA (2014).

Note: The OECD 450 Scenario in *WEO 2012* assumes different groups of countries adopt binding economywide emissions targets in successive steps, reflecting their economic development and responsibility for past emissions.

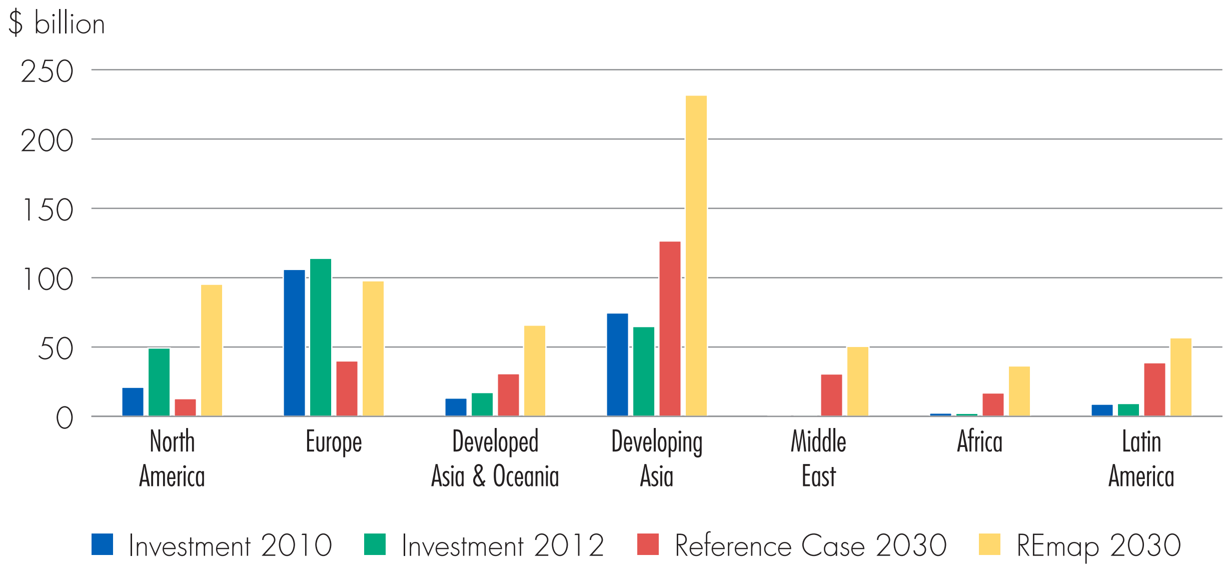
Figure O.30. **Annual renewable energy investment, actual (2010 and 2012) and required by *World Energy Outlook's* New Policies and 450 Scenarios**



Source: IEA 2014.

Note: The regional classification is consistent with the *WEO*.

Figure O.31 **Annual renewable energy investment, actual (2010 and 2012) and required by REmap 2030**



Source: IEA 2014; analysis by the International Renewable Energy Agency based on IRENA (2014).

Note: The regional classification is adapted to align as much as possible with the *WEO*. The Reference Case (IRENA 2014) considers policies in place and currently under consideration.

Both the 450 scenario and the REmap 2030 options analysis predict that more than a third of investment will occur in developing Asia and that the bulk of investment will focus on the power sector. But the pathways differ in their investments in technologies. While the *WEO* predicts wind and then hydro to be the largest recipient technologies of investments, REmap 2030 predicts solar to attract most investment, followed closely by wind (figure O.32). What is clear is that current investment is below that required, and current and planned policies are insufficient to address the gap.

Access to sustainable energy technologies

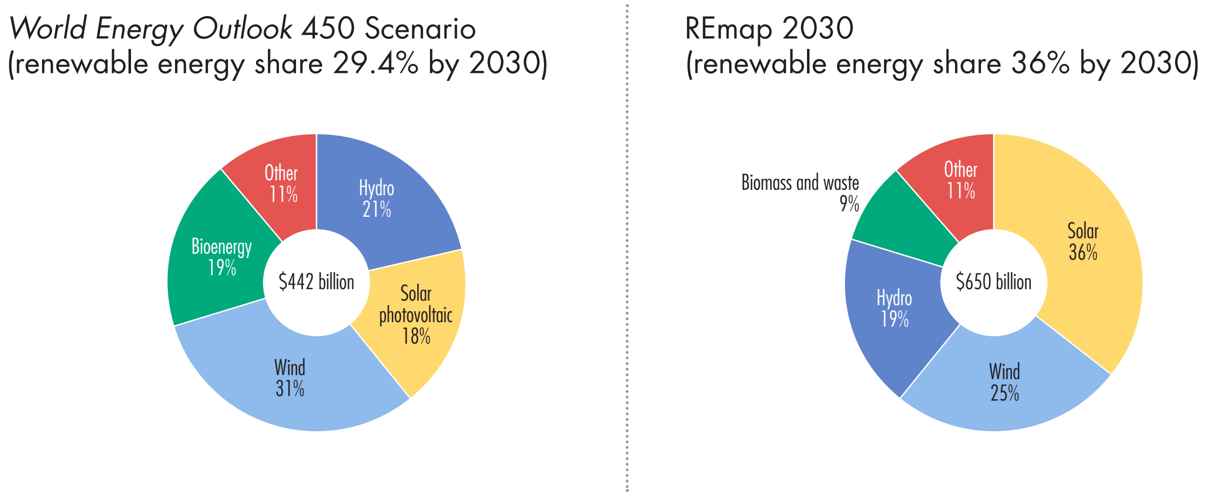
Countries will need to acquire cutting-edge technologies relevant to sustainable energy if they are to attain the three SE4All objectives. An initial perspective on how much countries are acquiring these key technologies comes from data on international trade, a proxy for access to a relatively narrow range of products.[11] Complementing the trade analysis is a review of tariff and nontariff barriers to trade, as well as indicators for scientific journal citations and engineering qualifications, which give a sense of whether countries have the capacity to absorb and apply a technology even if they have access to it.

The trade analysis considers a basket of 12 products relevant to sustainable energy, including solar photovoltaic (PV) cells, light emitting diodes (LEDs), small hydro turbines (capacities below 1 megawatt [MW] and 1–10 MW), wind turbines, biodiesel fuels, insulation materials, fluorescent lamps, heat pumps, reversible heat pumps for air conditioning, electric vehicles, and portable electric lamps and parts of portable electric lamps.[12]

Developing economies' share in this 12-product trade basket grew steeply in absolute terms in the decade 2001–11, although it has stabilized more recently. In 2013, trade in developing countries was about half the trade volume in developed countries (figure O.33). For the technologies selected, China alone accounts for 19 percent of the global trade value and for 56 percent of the developing-economy trade value, mainly due to its large volume of exports for solar PV cells. As groups, developing economies became net exporters and developed economies net importers after 2007.

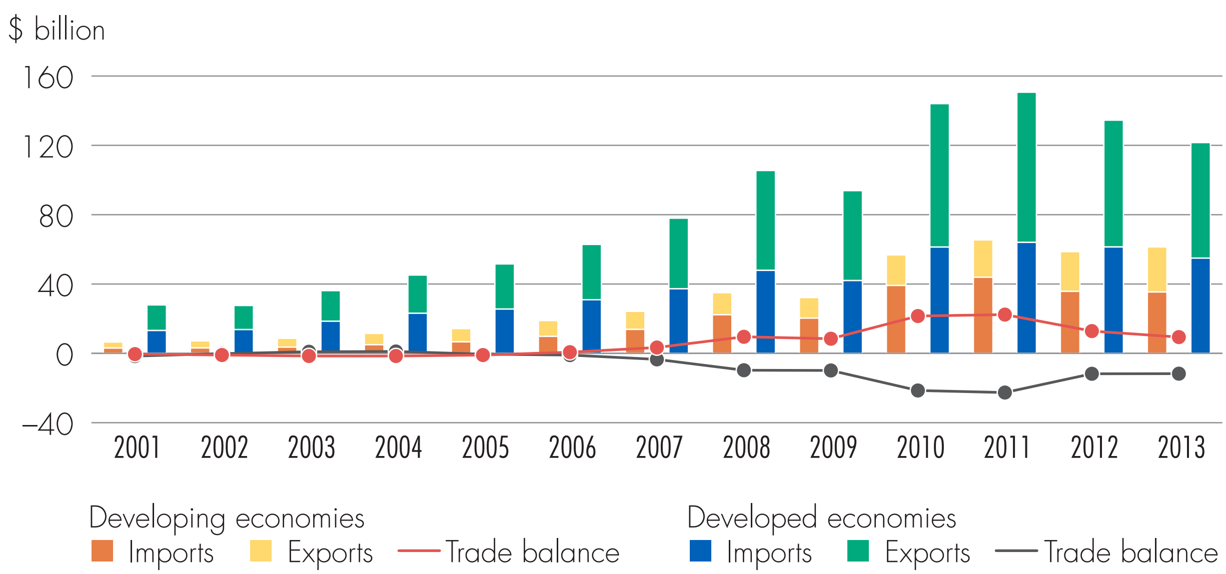
Even though the value of trade for the basket in developing economies is still smaller than that of developed economies, a growing number of countries are trading some of these products (tables O.4, O.5, and O.6). Starting

Figure O.32. **Annual renewable energy investment requirement by technology**



Source: IEA 2014; analysis by the International Renewable Energy Agency based on IRENA (2014).

Figure O.33 **Balance of trade in technologies relevant to sustainable energy, 2001–13**



Source: World International Trade Solutions database (World Bank 2015b).

Note: The 12 products in the trade basket are solar photovoltaic cells, light emitting diodes (LEDs), small hydro turbines (capacities below 1 megawatt [MW] and 1–10 MW), wind turbines, biodiesel fuels, insulation materials, fluorescent lamps, heat pumps, reversible heat pumps for air conditioning, electric vehicles, and portable electric lamps and parts of portable electric lamps.

Table O.4 Trade in products relevant to renewable energy, 2013

Income group (number of countries)	Solar photovoltaic and LEDs HS Code 854140		Wind turbines HS Code 850231		Biodiesel HS Code 382600		Hydro turbines (1–10 MW) HS Code 841012	
	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)
Low income (34)	74	0.18	9	0.47	0	0.00	3	1.82
Lower middle income (50)	70	3.81	18	2.99	2	7.35	14	12.55
Upper middle income (55)	75	33.22	27	18.70	20	10.05	13	49.94
High income (75)	76	62.79	37	77.84	43	82.60	15	35.69
All (214)	74		26		21		12	
Total global trade value ($ billion)		**103.00**		**14.09**		**19.41**		**0.18**

Source: World Integrated Trade Solutions database (World Bank 2015b).

Note: The estimation of the percentage of countries with access to the technology considers only countries with a trade value above US$100,000. The percentage contribution to the total value of trade is based on total amount traded; a similar estimation based on trade as a percentage of GDP is provided in chapter 5 (annex 3) of *Global Tracking Framework 2015*.

Table O.5 Trade in products relevant to energy efficiency, 2013

(%, unless otherwise specified)

Income group (number of countries)	Reversible heat pumps for air conditioning HS Code 841581		Heat pumps HS Code 841861		Fluorescent discharge lamps (CFLs) HS Code 853931		Insulation HS Code 701939, 680610 & 680690		Electric- and gas-powered vehicles HS Code 870390	
	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)
Low income (34)	18	0.47	38	0.22	85	0.69	53	0.23	71	0.93
Lower middle income (50)	36	2.98	58	1.32	82	6.61	65	3.91	66	6.73
Upper middle income (55)	65	36.86	78	10.29	85	48.07	79	18.5	75	6.21
High income (75)	63	59.69	71	88.17	79	44.63	76	77.36	73	86.13
All (214)	50		64		82		70		71	
Total global trade value ($ billion)		**4.98**		**4.31**		**11.64**		**11.26**		**6.80**

Source: World Integrated Trade Solutions database (World Bank 2015b).

Note: The estimation of the percentage of countries with access to the technology considers only countries with a trade value above US$100,000. The percentage contribution to the total value of trade is based on total amount traded; a similar estimation based on trade as a percentage of GDP is provided in chapter 5 (annex 3) of *Global Tracking Framework 2015*.

Table O.6 **Trade in products relevant to energy access, 2013**

Income group (number of countries)	Portable electric lamps with their own source of energy HS Code 851310		Parts of portable electric lamps with their own source of energy HS Code 851390		Hydro turbines (<1 MW) HS Code 841011	
	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)
Low income (34)	88	0.18	12	0.92	0	1.16
Lower middle income (50)	82	3.81	12	6.01	12	8.20
Upper middle income (55)	84	33.22	29	30.04	13	26.28
High income (75)	75	62.79	43	63.03	15	64.35
All (214)	81		27		11	
Total global trade value ($ billion)		**6.99**		**0.15**		**0.18**

Source: World Integrated Trade Solutions database (World Bank 2015b).

Note: The estimation of the percentage of countries with access to the technology considers only countries with a trade value above US$100,000. The percentage contribution to the total value of trade is based on total amount traded; a similar estimation based on trade as a percentage of GDP is provided in chapter 5 (annex 3) of *Global Tracking Framework 2015*.

with RE, although low-income countries (LICs) and lower-middle-income countries (LMICs) accounted, for instance, only for about 4 percent of the global value of trade in solar PV cells/LEDs in 2013, 70–74 percent of countries in these income categories registered trade in this technology. Access to PV cells in LICs increased from two countries to 25 in 2001–13. The proportion of LICs with trade activity in wind turbines and small hydro turbines (1–10 MW) in 2013 was, however, very small, around 9 percent and 3 percent, and no LIC registered trade in biodiesel fuels that year.

In energy efficiency, access to fluorescent discharge lamps (CFLs), insulation materials, and electric- and gas-powered vehicles was acceptable across income levels in 2013, with 85 percent, 53 percent, and 71 percent of LICs trading these products, although again their contribution to the global value of trade was smaller than higher income countries. The number of lower income countries trading heat pumps has increased gradually: in 2013, 38 percent of LICs and 58 percent of LMICs traded these technologies.

In access to electricity, portable electric lamps with their own source of energy serve as a good proxy as they are a direct substitute for kerosene lamps and other forms of traditional lighting. In 2013, 81 percent of all countries had access to this technology. From 2001 to 2013, 29 LICs and LMICs gained access to this type of lamp, when the number of countries in the high-income group remained stable. Trade in parts of portable electric lamps tells a very different story, however, as in 2013 there were just 10 LICs and LMICs trading this product, suggesting that maintenance and repair of these lamps is constrained in lower income countries, which implies higher household energy expenditures.

The trade of small hydropower turbines is low across income groups, notably in LICs. A well-developed RE technology, it can help improve electricity access in rural areas, lower the unsustainable harvesting of solid biofuels, and be part of the solution for scaling up sustainable energy. But no LIC and only 12 percent of LMICs imported more than US$100,000 of this key technology in 2013 (in the 0–1 MW capacity range).[13]

Access to sustainable energy technology is the result of many factors, not just trade but also energy demand, resource potential, market-formation policies, industrial policy (including manufacturing and local-content provisions), customs and trade regulations, cost relative to other options, and access to affordable finance. So, while trade data provide a good proxy for whether the most sophisticated or needed products are crossing boundaries (and reaching beneficiaries), the broader question of access to technologies requires all these factors to be considered, too, including countries' technical capacity for absorbing, adapting, and applying technologies. Data on engineering qualifications and number and quality (citations) of scientific journal papers delivered at country level, which are regarded as good proxies for technical capacity, show that knowledge transfer and training need to be significantly strengthened in lower income countries.

The energy nexus

A discussion of "nexus" issues is part of the *GTF* for the first time. Different from the other three main chapters, chapter 6 is conceptual rather than quantitative, introducing and exploring nexus concepts in four priority areas of development (water, food, human health, and gender) and their links to energy. Energy has links to, and influences, many other areas (such as education), but these four form the initial foray for the *GTF*. Links between most of these areas to energy are well established but often discussed in silos. Chapter 6 considers the existing data and indicators that might be useful for tracking aspects of SE4All's work related to these nexus issues and for highlighting gaps.

The energy interactions with these four areas, closely tied to energy services and energy systems, are fundamental to meeting the objectives of SE4All. Numerous opportunities will arise from more holistic decisionmaking in energy if wider cross-sectoral perspectives can be brought to bear. For instance:

- Renewable energy can be either water intensive or water efficient. PV panels and wind turbines require little water and are generally much more water efficient than conventional sources of electricity. Solar thermal, biomass, geothermal, and carbon sequestration and storage, in contrast, can be "thirsty" sources of electricity, depending on the cooling technologies, and can increase water intensity. Technology choice in clean energy provision can therefore have severe implications for water security. Hydropower depends fundamentally on water, and lower rainfall (perhaps due to greater variability and to climate change) could reduce electricity production from that source.

- Energy efficiency typically has positive and synergistic feedbacks to other resource systems. Efficient use of energy reduces the need for power generation and thus the need for cooling water. Water efficiency is also energy efficiency: using water more efficiently often cuts electricity consumption, as lower water demand reduces the need for pumping and treating water. Similarly, energy efficiency interventions like low-flow showerheads save energy by reducing the volume of water to be heated. Washing machines have become more energy efficient largely by using less water per load. Exploring the co-benefits in water saving tied to energy efficiency, as well as the potential to save energy through water efficiency, can therefore help secure additional benefits.

- Access to energy and to other energy-intensive products, services, and facilities can increase farmer incomes and boost agricultural productivity. Agricultural machinery and inputs such as fertilizers and pesticides can raise yields for farmers. Better access to transportation (roads and freight services) as well as refrigeration and processing facilities can improve market access while reducing spoilage of food. This can increase overall land productivity by reducing field-to-consumer losses and improve farmer incomes. Health, too, gains from sustainable energy services in developing-country community health clinics, through cost-effective and life-saving interventions. These clinics need reliable access to energy for running medical equipment, for storing supplies such as blood, vaccines, and antiretroviral drugs, for staying open after dark, and for helping retain qualified staff. Finally, street lighting may increase women's and girls' mobility after dark and in the early morning and, by improving security, reduce the risk of gender-based violence.[14,15]

All these areas have numerous interwoven concerns, including access to services, long-term maintenance and sustainability, environmental impacts, and price volatility. These issues manifest in different ways in each area, but the impacts are often closely related. Identifying the links early can help in targeting synergies and preempting subsequent potential tensions.

Energy and water

The trade-offs between energy and water have been gaining international attention in recent years as demand for both resources mounts and governments continue to struggle to ensure reliable supplies. About 748 million people still lack access to improved sources of drinking water—nearly half in Sub-Saharan Africa. And more than one-third of the global population—around 2.5 billion people—remain without access to improved sanitation.[16] It is expected that, by 2025, 1.8 billion people will live in countries or regions with absolute water scarcity, and two-thirds of the world's population could be in water-stress conditions.[17]

Energy and water resources are tightly enmeshed: large amounts of water are needed in almost all energy generation, including thermal power plants, hydropower, and biofuels, as well as in extraction of fossil fuels. Conversely, the water sector needs energy to extract, treat, and transport water, run municipal water and wastewater facilities, irrigate land, and desalinate water. Energy and water are both used in producing crops, including those to generate energy through biofuels. This relationship is the energy–water nexus (sometimes the energy–water–food nexus). These interdependencies could complicate solutions and make a compelling case to improve integrated water and energy planning.

Water indicators:

- Reliable and comprehensive data on the energy–water nexus are scarce.
- Indicators must track water withdrawal, consumption, and discharge, over time and space (at power plants).

Energy and food

Assessing the links between energy and food security requires understanding what food security means. The internationally agreed definition is that "Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (Rome Declaration on World Food Security and World Food Summit Plan of Action; World Food Summit 1996). For this definition, food security has four dimensions—availability, access, utilization, and stability—which need to be fulfilled simultaneously.

Energy has a key enabling role in food security and nutrition. It is essential for agricultural processes, including irrigation, and is necessary at every stage of agrifood chains. Energy prices often influence the prices of agricultural inputs. Biofuels in particular are linked to all four dimensions of food security. At household level, better access to modern energy services may increase the quality of food by improving food conservation through refrigeration and by allowing proper cooking.

Food indicators:

- Data exist on inputs to "behind farm-gate" operations, on use of traditional fuels, and on effects of bioenergy development on food supplies and prices.
- Complementary indicators would include energy used to manufacture agrifood chain inputs, energy use beyond the farm-gate, and RE produced along agrifood chains.

Energy and health

Energy is a prerequisite for good health and a source of many serious health risks, notably air pollution, which comes from dirty fuels and inefficient technologies. Less appreciated is that much of it comes from inefficient strategies—for, say, housing, transport, and urban design. Optimizing the health benefits of energy access, efficiency, and use of renewables and minimizing energy-related risks are critical for achieving SE4All's three sustainable development objectives. Outdoor and household (indoor) air pollution are responsible for about 7 million premature deaths annually, making air pollution one of the largest single causes of premature mortality and morbidity worldwide.

Many other health risks are linked to a lack of modern energy access or inefficient energy use. Rudimentary solid fuel cookstoves or kerosene lamps, for instance, can be a factor in domestic injuries, such as burns and poisonings. Energy-inefficient buildings and homes require more heat and power, and vulnerable groups like the elderly also are at higher risk of stroke, heart failure, and other acute events related to extreme weather and heat or cold exposure.[18] Increased incidence of asthmas, allergies, and respiratory illnesses are associated with chronic damp and cold conditions that are more common in energy-inefficient dwellings, particularly affecting the poor, the elderly, and children. In urban areas, physical inactivity and traffic injury rates among pedestrians tend to be higher when public transport is inefficient, leaving people reliant on private motor vehicles that burn more energy and produce more air pollution per unit of travel than efficient rapid transit modes.[19]

Health indicators:

- Existing indicators approximate exposure and burden of disease from indoor and outdoor air pollution. Measurement of electricity access in health care facilities is being developed.

- Efforts should be reinforced to improve indicators on the energy–health nexus, including safety standards for cooking solutions, and exposure rates to indoor air pollution from heating and lighting.

Energy and gender

The energy–gender nexus emerged as a discourse in development at the Beijing Conference in 1995.[20] As highlighted in the 2012 *World Development Report* (*WDR*) and the 2014 *World Survey on the Role of Women in Development*,[21] gender equality is critical for development across all sectors.[22] Access to sustainable energy can liberate men and women from drudgery and free time for leisure, rest, and investing in human capital. However, women in most developing countries suffer more than men from energy deficits and energy poverty.[23]

The energy–gender nexus reflects energy demands based on women and men's roles that are met through energy supply chains of different degrees of formality (from self-collection to commercial provision).[24] At household level, men generally take the final decision about energy access. At macro level, decisions about policy instruments (including incentives to encourage a transition to cleaner energy) require gender analysis and gender budgeting to avoid inadvertent gender blindness or bias in energy policies.[25] Most links of the chain offer entry points for women to be a target group in three areas—time poverty and drudgery reduction, economic empowerment, and health and safety gains.

Gender indicators:

- Existing surveys and databases shed light on the relationships between gender and energy, providing information on time poverty, women's economic empowerment, and mortality and morbidity.

- Quantitative assessments of the differential impacts of energy on women, men, girls, and boys are few.

The data revolution for sustainable development

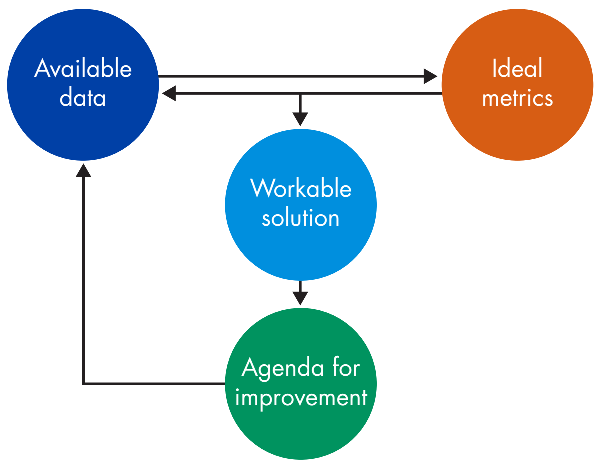
The November 2014 report, "A World That Counts," underscores the pressing need to upgrade capacity and resources to more accurately measure and track the dimensions of sustainable development.[26] Improving data is a development agenda in its own right, and can better focus targeting of existing resources and spur new economic opportunities. Gaps can be overcome through new investment and strengthened capacity.

A new funding stream to support the data revolution for sustainable development should be endorsed. That will require assessing the scale of investments, capacity development, and technology transfer, especially for LICs, and developing proposals for mechanisms to leverage the creativity and resources of the private sector. Funding will also be needed for an education program to improve the capacity and data literacy of the public, information intermediaries, and public servants to break down barriers between people and data.

The *GTF* seeks to catalyze such a data revolution for the energy sector. The philosophy in the first *GTF* was to balance the ideal metric that best captures progress in the energy sector with the constraints posed by the need to use data sets already at hand for all countries in the world, so that tracking could be truly global. That report achieved a workable solution with reasonable and widely available proxy indicators, while acknowledging that they were less than ideal in some ways, and that the *GTF* should simultaneously set an agenda for gradually improving data (figure O.34).

Since 2013, progress has been significant in developing improved metrics for energy access. The first *GTF* proposed and consulted on a conceptual framework for measuring access to electricity and to modern cooking using multitier approaches. The framework went beyond traditional binary measures of presence or absence of an electricity connection or primary use of non-solid fuels, proposing eight attributes of energy supply to determine whether a user has effective access, and to what degree: capacity, availability, reliability, quality, affordability, legality, convenience, and health and safety. Increasing levels of these attributes were required to achieve higher tiers of energy access.

Figure O.34 **Improving measurement and tracking**



Source: Prepared by authors.

This framework has since been elaborated by developing tools for capturing data for energy supply attributes, including a survey instrument that has been piloted in half a dozen country contexts. The results show that this approach is a much more refined way of measuring energy access. For example, Kinshasa city in the Democratic Republic of Congo, which reports a 90 percent access rate under the traditional binary measurement, scores only 30 on a scale of 0 to 100 on the binary metric that reflects all eight attributes of energy supply (box O.1). Similar multitier metrics have also been conceptualized and piloted to measure energy access for household cooking, productive engagement, and community facilities. A global survey based on the multitier approach is planned for 2015.

Other issues of measuring energy efficiency and the sustainability of biomass under RE are equally pressing. Energy efficiency—the relationship between energy inputs and physical outputs—cannot be directly measured at global level. Instead, energy intensity—the amount of GDP produced for every unit of energy consumed—is widely used as an imperfect proxy. Going beyond this would require more detailed disaggregation of data to sectors, subsectors, and individual end-use activities. That would entail both improving the resolution of the national energy balances that characterize where energy is consumed in each country and obtaining complementary information on the physical outputs associated with energy consumption in each sector—for example, freight-kilometers of transportation or square meters of office space. A recent IEA energy-efficiency statistics manual provides a solid methodological basis for doing so.[27] But building capacity for countries to apply this methodology and collect all the supporting data poses a major challenge.

National and international entities already have roles in building capacity to better track energy efficiency. National governments are the only entities with the responsibility and authority to collect and publicly report the statistics to construct national energy efficiency indicators, while international and regional energy organizations are important in developing and promulgating standardized approaches to energy efficiency indicators. For an international initiative like SE4All to produce a set of detailed tracking indicators ultimately requires sufficient information provided by a plurality of the most important countries and organizations, and sufficient resources accompanied by a mandate to sustain a reporting activity.

To go further, tracking requires a consensus-building process that would make decisions—first, on which indicators to pursue to secure meaningful, global tracking indicators, and second, on which key sectors, segments, and activities, as well as countries. This would include identifying the keeper and reporter of global energy efficiency indicators, specifying the range of information needed from countries, identifying bodies that prepare and carry out associated capacity building, and generating the technical assistance to establish and maintain surveying and reporting capacities. This process would also identify the necessary funding, including investment capital, and possible sources.

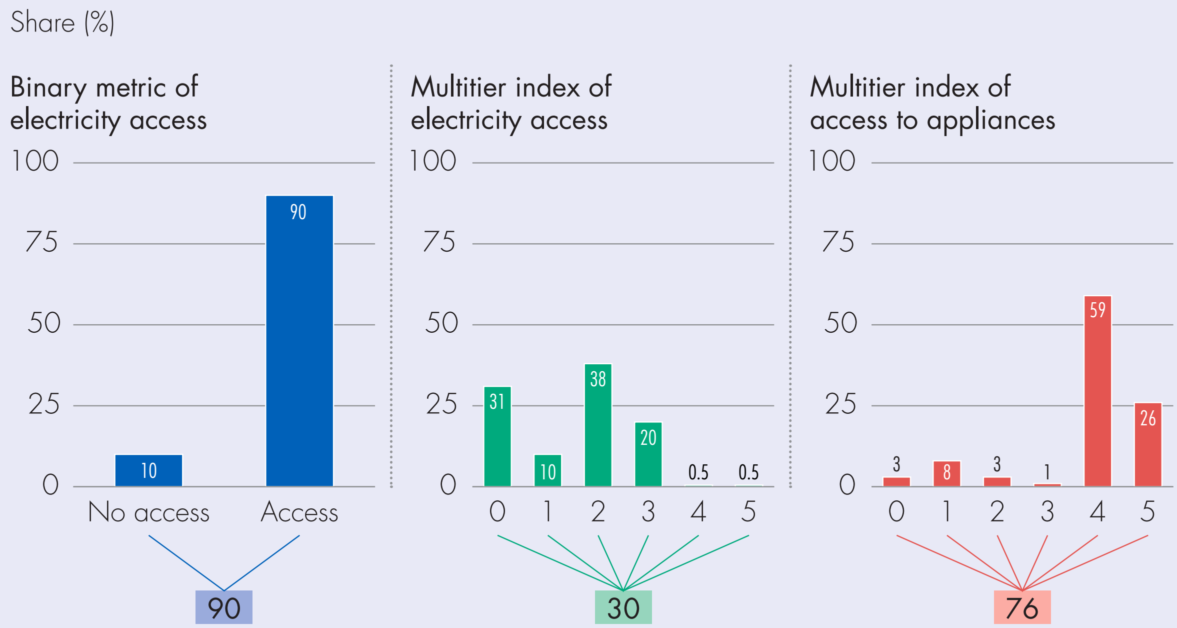
Switching to the sustainability of biomass, about half of what we know as RE takes the form of traditional use, often by households in developing countries for cooking and heating. The volumes used this way are imperfectly estimated at present, and little is known about whether the associated wood and charcoal are harvested and produced sustainably.

Measuring and tracking the sustainable use of solid biofuels—and bioenergy in general—at country level is extremely complex for at least four reasons. First, the assessment of sustainability relates to multiple dimensions (economic, environmental and social) with their own set of indicators. Second, the assessment of sustainability is applied at a "situation" level (zone, project, subregion), such that several assessments are needed for national estimates. Third, because measurement is data-intensive and few data are in the form required for a comprehensive or even pragmatic assessment, harvesting data is intensive and expensive. And fourth, periodic tracking would require

Box O.1 **Pilot Implementation of a Multitier Framework in Kinshasa**

A multitier analysis for Kinshasa demonstrated how an attribute-based multitier approach provides a deeper picture of the state of energy access, helps conduct a gap analysis that points to the reasons for access deficiency, and suggests possible approaches for alleviating them.

Binary or multitier measurement of access to electricity in Kinshasa



The binary measurement indicates that 90 percent of the people in Kinshasa city have access to electricity—implying that only an incremental access challenge remains. The multitier metric presents a very different picture. With an energy supply index of 30 (on a scale of 0 to 100), the city's households have poor access to electricity, despite a high rate of grid connectivity (close to 87 percent). More than three-quarters of the households (79 percent) are on tier 2 or below, and most of the remaining households are on tier 3.

The multitier framework also allows for a gap analysis that examines why households are stuck at lower levels and the interventions that may help them. While about 10 percent of the households do not have a connection, another 21 percent join them on tier 0, despite being grid connected, because they receive less than four hours of supply each day or less than one hour in the evening. Furthermore, 48 percent of households are held at tiers 1 and 2 because of quality of supply issues (low voltage) and less than eight hours of supply a day. Interventions can therefore be more accurately designed to address the access deficiencies that affect each of these sets of households.

Source: Prepared by authors.

an organizational structure and data collection platform that few countries now have.

A pragmatic approach to roughly assessing progress on the sustainable development and use of bioenergy regularly could rely on a mix of proxy, semiquantitative, and qualitative measurements. That mix could include estimating the wood harvested in excess of the incremental growth rate at national level (or estimating the fraction of nonrenewable biomass) with the methodology recently proposed and applied by Bailis and others[28]; assessing and monitoring of bioenergy sustainability at national level using Global Bioenergy Partnership indicators; and estimating the amount or share of land used under certification schemes.[29] The adoption of any of these approaches would require the consensus of, among others, international agencies,

Table O.7 **Challenges in measuring and tracking SE4All objectives and proposed actions for improving data**

	Challenge	Actions
Energy access	Binary measurement of energy, with or without connection, does not capture the nuances of energy supply	A multitier metric for electricity and modern cooking solutions was proposed in *GTF* 2013 to present access as a combination of seven attributes of energy supply. Preparations are under way to launch a global access survey that will ramp up the ability to evaluate energy access. New frameworks for productive uses, community facilities, and small-lighting solutions, presented in this *GTF*, will be pilot-tested to ensure the reliability of results before global roll-out.
Energy efficiency	Energy efficiency, the relationship between energy inputs and physical outputs, would require a set of more-disaggregated data across countries than energy intensity	A consensus-building process could choose key sectors, end-use activities, and countries for which to develop more meaningful global tracking indicators. It would prioritize indicators, specify required information, and identify needed technical assistance and financial resources.
Renewable energy	Measurement and tracking of the sustainable use of solid biofuels is based on the assumption that all solid biomass consumed in developing economies is used in a traditional way	International organizations and statistics groups, and national governments, have initiated steps to agree on methodologies to progressively account for the sustainable use of solid biofuels in energy statistics. A roadmap of actions that considers approaches already piloted could include: *Short term:* Use proxy, semiquantitative, and qualitative measurements, including proportion of land following established good practice and share of land under certification schemes. Emerging methodologies allow the fraction of wood fuel (firewood and charcoal) used in a nonrenewable or unsustainable way to be quantified, based on spatially explicit assessments. *Medium term:* The assessment and monitoring of bioenergy sustainability could be progressively conducted at national level in high-impact countries using Global Bioenergy Partnership indicators, though not annually due to the complexity and funding needs. Thus periodic tracking would be more challenging under this approach.
	Other data and methodological constraints	Definitions and data collection in distributed renewable energy power generation for grid-connected and off-grid systems need to be improved. With regards to renewable energy policy, it would be desirable to convert existing targets into a common metric to allow the estimation of an aggregate global target.

Source: Prepared by authors.

international statistics groups, and national governments. Table O.7 summarizes the challenges in measuring and tracking the SE4All objectives and the wider agenda for improving data availability and quality.

The Open Working Group on Sustainable Development Goals of the UN General Assembly adopted a document proposing 17 sustainable development goals (SDGs) and 169 targets (United Nations 2014).[30] SDG 7 on Energy—Ensure access to affordable, reliable, sustainable, and modern energy for all—includes the following targets and means of implementation (7a and 7b):

- *Target 7.1* By 2030, ensure universal access to affordable, reliable, and modern energy services.
- *Target 7.2* By 2030, increase substantially the share of renewable energy in the global energy mix.
- *Target 7.3* By 2030, double the global rate of improvement in energy efficiency.
- *Target 7a* By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology.
- *Target 7b* By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries and small island developing states.

The indicators in *GTF 2015* correspond closely to the targets articulated by the Open Working Group.

Notes

1. Worldwide, roughly one-third of total primary energy supply is attributable to energy production, conversion, refining, transmission, and distribution. The remaining two-thirds is final energy consumption in end uses.
2. Analyzing the net increment with and without the contribution of traditional solid biofuels—which include primary solid biofuels and charcoal—is important as they are assumed to be used in a non-sustainable way by the residential sector in developing economies. It is expected that the attainment of the SE4All objective of universal access to modern energy will reduce the consumption of solid biomass used for traditional purposes and therefore make the SE4All objective on renewable energy easier to achieve. Chapter 5 discusses in more detail the challenge of defining and measuring bioenergy. Renewable energy resources that exclude solid biofuels for traditional uses are here referred to as modern renewable energy resources.
3. REmap 2030 (IRENA 2014) is an energy options analysis that provides a roadmap toward doubling the share of renewable energy in TFEC between 2010 and 2030.
4. Actual investment fell from $417 billion in 2010 to $397 billion in 2012, largely reflecting IEA methodological updates in calculating energy efficiency investments. This decline in energy-efficiency investments was partly offset by an increase of $30 billion in RE investment.
5. World Bank and others 2014.
6. http://www.worldenergyoutlook.org/publications/weo-2014.
7. *WEO;* IEA 2014.
8. IEA 2014.
9. IEA 2014.
10. IEA 2014.
11. Products are identified at the six-digit level of the Harmonized System (HS) subheadings of the Harmonized Commodity Classification and Coding System (UN COMTRADE database).
12. The product known as a photosensitive semiconductor device (HS Code 854140) aggregates both photovoltaic cells (whether or not assembled in modules or made up into panels) and LEDs.
13. There is growing consolidation of companies manufacturing hydro turbines globally: in 2013 just five countries accounted for 65 percent of exports of small hydro turbines (China, Germany, Austria, the United States, and Italy). Very few developing countries have developed value chains for manufacturing small turbines, and those that have generally have little production capacity and a narrow range of capacity scales. Only one LIC and two LMICs export small hydropower turbines (India, Democratic Republic of Congo, and Sri Lanka).
14. Cecelski and others 2005.
15. Doleac and Sanders 2012.
16. WHO/UNICEF 2014.
17. WWAP 2012.
18. Röbbel 2011.
19. Hosking 2011.

20. Clancy and others 2011.
21. UN Women 2014.
22. World Bank 2012.
23. Defined as an absence of sufficient choice in accessing adequate, affordable, reliable, clean, high-quality, safe, and benign energy services to support economic and human development (Clancy and others 2003; UNIDO/UN Women 2013).
24. Detailed reviews of the energy–gender nexus may be found in Clancy and others (2011), Köhlin and others (2011), and World Bank (2005).
25. Clancy 2009.
26. Produced by an Independent Expert Advisory Group on a Data Revolution for Sustainable Development for the UN Secretary-General; IEA 2014b.
27. Independent Expert Advisory Group 2014.
28. Bailis and others 2015.
29. Bailis and others 2015.
30. United Nations 2014b.

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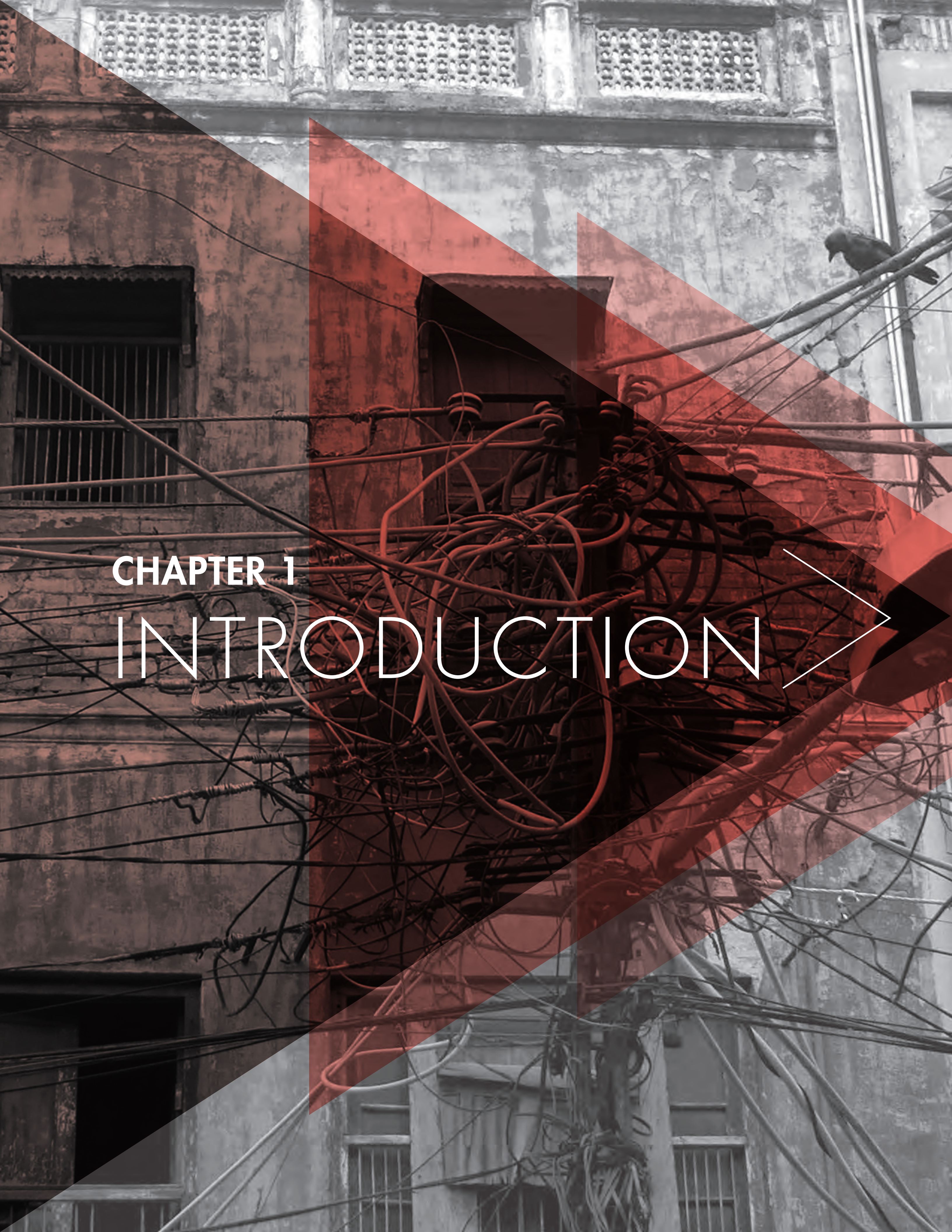


CHAPTER 1

INTRODUCTION

Introduction

In 2011, the United Nations General Assembly set three global energy-related objectives for 2030: ensure universal access to modern energy services, double the global rate of improvement in energy efficiency, and double the share of renewable energy in the global energy mix. It subsequently announced 2012 and 2014–24 as the year and decade of Sustainable Energy for All (SE4All). Some 102 countries have formally opted into the SE4All initiative, of which 83 are developing economies, and numerous corporations and agencies have pledged tens of billions of dollars in support.

Sustaining the momentum to achieve these objectives requires a means to chart global progress to 2030. In 2013, the World Bank/Energy Sector Management Assistance Program and the International Energy Agency, with 13 other agencies, launched a framework for regular global reporting based on feasible, rigorous methodological approaches and a set of indicators that offer scope for progressive improvement.

The first edition of the SE4All *Global Tracking Framework* report (*GTF 2013*) performed several tasks. It established a consensus-based methodology and identified concrete indicators for tracking global progress toward the three objectives. It presented a data platform drawing on national data records of more than 180 countries that account for more than 95 percent of the global population. And it documented changes in the indicators over 1990–2010, generating a baseline for assessing progress over 2010–30.

This second edition, *GTF 2015*, updates progress over 2010–12 and assesses whether it has been fast enough to meet the 2030 objectives. It also analyzes changes by sector, country, and technology.

GTF 2015 explores additional and complementary themes: It provides further analysis of the investment required to attain the SE4All objectives, examines how much countries have accessed the technology and knowledge needed to move toward sustainable energy for all, and identifies the improvements needed in data collection and capacity building for a more nuanced and accurate picture of progress.

Lastly, *GTF 2015* explores and introduces "nexus concepts" focusing on links between energy and four priority areas: food, water, gender, and human health. While the links between energy and these areas are generally well established, they are often presented in an isolated fashion. The analysis describes the nature of interdependencies and cross-sector dynamics, and it identifies gaps in existing data and indicators for tracking the nexus relations.

The nexus analysis brought in eight new international organizations to work with the partners preparing *GTF 2015*. As with the first edition, this *GTF* has gone through international public consultation and expert peer review. This formal process ensured a wide consensus on the content and quality of the analysis and conclusions.

The SE4All GTF is one of four activities aimed at measuring and tracking progress in sustainable energy under the SE4All initiative (figure 1.1): Readiness for Investment in Sustainable Energy (RISE) is an index based on a suite of indicators that assess the existence and quality of strategic, legal, and regulatory frameworks at country level to promote private investment in sustainable energy. The multitier frameworks for measuring energy access propose metrics based on attributes of energy and its usability across households, productive engagements, and community facilities to measure the multifaceted nature of energy access. And the State of the Energy Access report on just that at country and program level, documenting progress, best practice, and lessons learned, based on formal development analytics and socioeconomic impact assessments.

The four activities are interrelated and together allow a comprehensive assessment of trends, emerging practices, and progress toward the SE4All objectives.

GTF 2015 is structured into two sections. The first focuses on tracking core indicators to verify progress toward the SE4All objectives, with chapters on each of the

Figure 1.1 **How the GTF links to other SE4All initiatives**

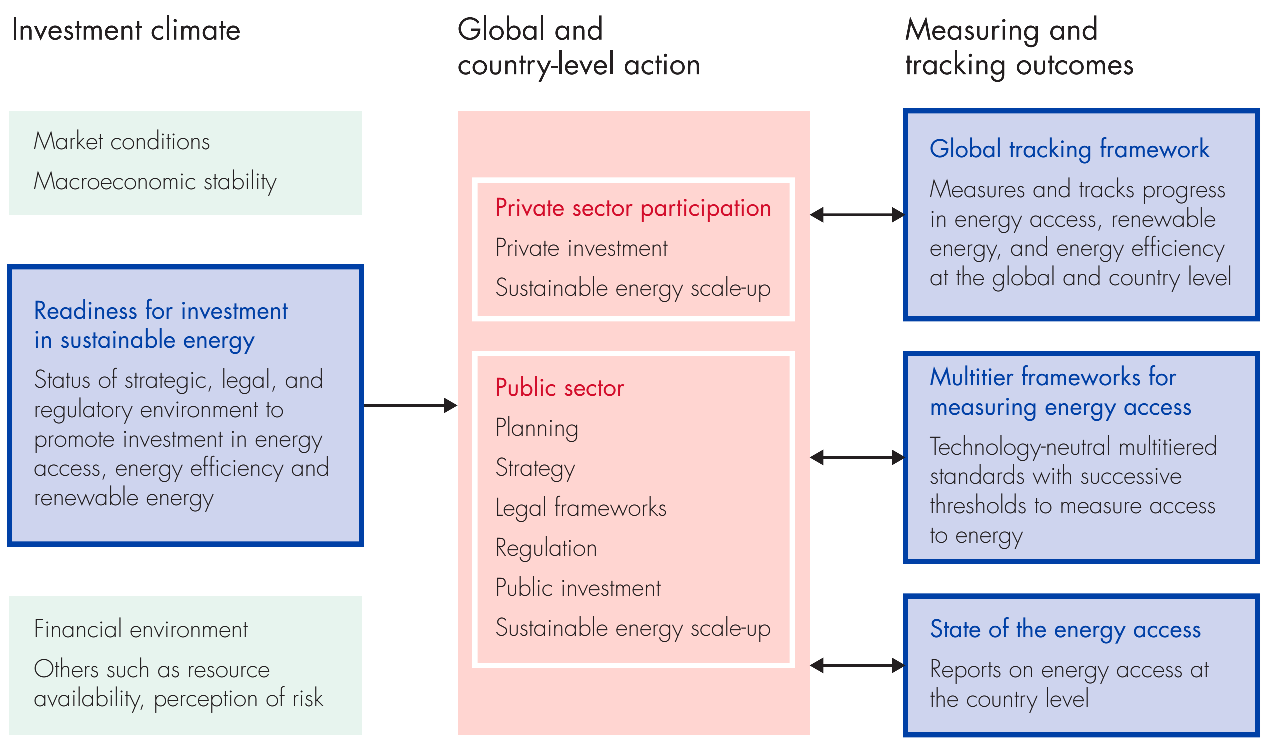


Table 1.1 **Targets (7.1–7.3) and means of implementation (7a–7b)**

Number	Sustainable Development Goal
7.1	By 2030, ensure universal access to affordable, reliable, and modern energy services.
7.2	By 2030, increase substantially the share of renewable energy in the global energy mix.
7.3	By 2030, double the global rate of improvement in energy efficiency.
7a	By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency, and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology.
7b	By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries and small island developing states.

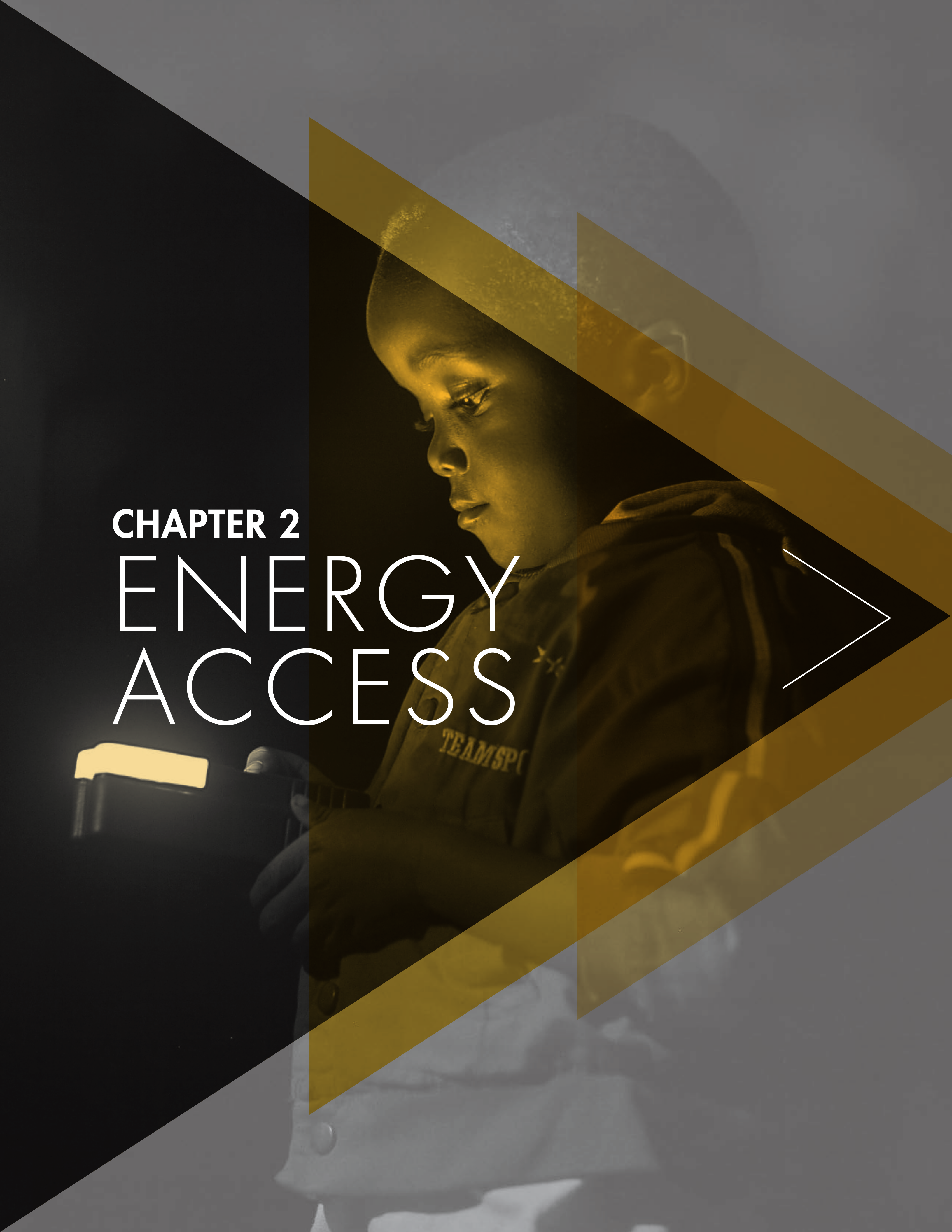
three areas: energy access, energy efficiency, and renewable energy. The second has two chapters, one on methodological improvements emerging for measuring and tracking the SE4All indicators and one on the nexus relations.

The three objectives are closely aligned to the energy targets proposed by the Open Working Group on Sustainable Development Goals of the United Nations General Assembly in its report of November 2014.[1] Goal Number 7, on energy, is to ensure access to affordable, reliable, sustainable, and modern energy for all, and has five targets and means of implementation (table 1.1).

The SE4All GTF consortium will continue to report progress toward the SE4All objectives every two years, and it is hoped that the work and emerging experience of the activity contributes to the measurement and tracking efforts of Sustainable Development Goal Number 7.

Note

1. United Nations. 2014. Open Working Group Proposal for Sustainable Development Goals; Open Working Group of the General Assembly on Sustainable Development Goals. New York: Division for Sustainable Development. https://sustainabledevelopment.un.org/content/documents/1579SDGs%20Proposal.pdf.



CHAPTER 2
ENERGY ACCESS

Energy access

Highlights

The global electricity access deficit in 2012 was about 1.1 billion people—down from around 1.2 billion people in 2010—representing about 15 percent of the population. About 87 percent of those lacking access lived in rural areas, and 88 percent lived in Sub-Saharan Africa and South Asia.

During the tracking period, 2010–12:

- The global electrification rate rose from 83 percent in 2010 to 85 percent in 2012, an increase of 222 million people. Incremental global access growth was overwhelmingly in urban areas, with only 46 million in rural areas, including about 36 million in South Asia, followed at a distance by Sub-Saharan Africa and Latin America and the Caribbean.

- Access expansion more than kept pace with the population increase. Of the 222 million, 85 million people in excess of population growth gained access.

- Annual growth in access (net of population) was 0.6 percent, much higher than growth over the base period (1990–2010) of 0.1 percent and much closer to the target growth rate for reaching universal access by 2030 of 0.7 percent. Among the two highest access-deficit regions in 2010–12, South Asia reported the highest rate at 1.6 percent, but Sub-Saharan Africa only 0.03 percent.

- Nine of the 20 high-impact access-deficit countries reported access growth that was faster than the average global rate of 0.6 percent.

About 2.9 billion did not have access to non-solid fuels as a primary source for cooking purposes, equivalent to 41 percent of the global population, in 2012. About 84 percent of them live in rural areas, and about two-thirds in Sub-Saharan Africa and South Asia.

During the tracking period:

- The global access rate rose from 58 to 59 percent, with an increase of 123 million people. India and China showed the greatest absolute population increase on this measure. The incremental access growth was entirely in urban areas.

- Global annual growth was a negative 0.1 percent, the same rate as in the base period. East Asia reported the highest annual growth rate, 0.4 percent.

- Only India and China among the 20 high-impact access-deficit countries reported access growth higher than the global rate.

Reaching universal access by 2030 will bring in about $19 billion annually in the New Policies Scenario of the International Energy Agency (IEA 2014a), still less than the about $49 billion required, but higher than historical annual investments of $9 billion.

The global annual investment needed for electricity access could be between $2 billion and $55 billion depending on the "tier" of access (section 5). Countries can reach universal access through various paths, choosing tiers based on their political and financial realities. Therefore if countries aspire toward higher access, the investment need could vary between tiers 1 and 5 access by multiple times.

Introduction

Access to clean, modern, sustainable energy is critical for improving the health and livelihoods of billions of people around the world. There is growing evidence linking socioeconomic benefits with access to a reliable and affordable supply of electricity. For example, with adequate lighting and a reliable supply of electricity in the evening, children can read and do homework longer, families can listen to the radio, watch television, or generate income. Adding to these social benefits are health benefits: many alternative lighting sources, like kerosene lamps, emit a dull light and are a major source of pollution, harming the health of household members and the local environment.

Like electrification, the sustained adoption of clean and affordable cooking solutions can improve the health and well-being of hundreds of millions around the world. The household air pollution emitted from such inefficient energy use is a major source of health risk and premature mortality, particularly among women. The concentrations of small particulate matter in solid fuel used at home can be a multiple of ten times—if not a hundred times—higher than the recommendations of the World Health Organization (WHO). Such high concentrations pose major risks for diseases like childhood pneumonia, heart disease, cancers, and chronic respiratory diseases among the poorest populations, with little or no access to health care. In 2012, WHO estimated that over 4 million premature deaths were attributable to the household air pollution created from a primary reliance on solid fuels for cooking.

Primarily for these reasons, the first objective of Sustainable Energy for All (SE4All 2014) is to achieve universal energy access to modern energy by 2030. Two tracking indicators were adopted, drawing on readily available data: "percentage of population with electricity access" and "percentage of population with primary reliance on non-solid fuels." However, these binary access metrics have shortcomings, and so the GTF Multitier Framework capturing attributes of energy supply was built to address them (chapter 5). A medium-term agenda has been drawn up for data that have the potential to serve as a key source for identifying factors holding back energy access.

This chapter has four more sections. Sections 2 and 3 report on progress of electrification and of non-solid fuels, mainly over the 2010–12 tracking period. Section 4 discusses the scale of challenge remaining to achieve the SE4All universal access objective. Section 5 reviews the investment requirements, unveiling a new tool, the "Access Investment Model", which focuses on how countries can choose to achieve universal access through various tiers of the GTF Multitier Framework.

Tracking electrification

The indicator to track electrification is the percentage of population with access to electricity. This indicator is underpinned by the World Bank's (2015) Global Electrification database,[1] updated to include the 2012 electrification rates to go alongside the three data points for 1990, 2000, and 2010. The database, covering 212 countries, measures household connections, and therefore generally relies on household surveys (demographic and health

Box 2.1. **Disparities in World Bank and IEA databases on global access deficits**

The difference in the global access deficit between IEA's Energy Access Deficit and the World Bank's Global Electrification database is close to 200 million (the World Bank records the lower figure). For the majority of countries access rates are similar, but not in a handful of large countries (box table 1).

There are pros and cons of relying on official estimates that draw on utility connections (IEA) or household surveys (World Bank). Some utility data fail to capture highly decentralized forms of electrification in rural areas and illegal access to electricity in urban areas, while household survey data can be plagued with sampling errors and inconsistencies and unreliability of responses. However, as the SE4All objective is to measure the population's use of electricity, household surveys as the primary source are preferred.

Differences in country electrification estimates, IEA and World Bank

Country	Population without electricity (millions) (*WEO* 2014)	National electrification rate (%) (*WEO* 2014)	Population without electricity (millions) (World Bank 2014)	National electrification rate (%) (World Bank 2014)	Source (World Bank 2014)	Difference in population (millions)
Indonesia	60	76	10	96	DHS (2012)	50
Pakistan	56	69	11	94	DHS (2013)	45
India	304	75	263	79	NSSO (2012)	40
Nigeria	93	45	75	56	DHS (2013)	18
Philippines	29	70	12	88	DHS (2013)	17
Myanmar	36	32	25	52	Estimate	11

Source: WEO 2014 (IEA 2014a); World Bank 2014.

surveys, censuses, living standards measurement surveys, etc.). For missing data points, modeled estimates based on a regression specification are used.[2] The other comparable access database is the IEA's Electricity Access database.[3] A number of discrepancies between the two databases exist, underscoring the need to improve data collection (box 2.1).

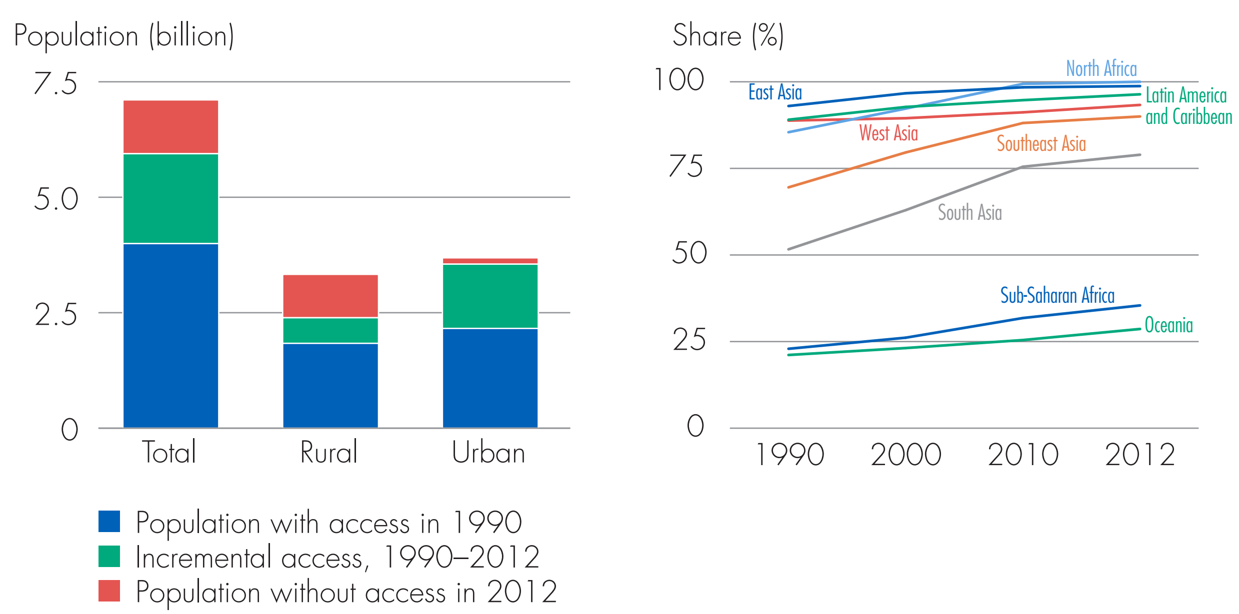
Over 1990–2012, electrification rose from 76 to 85 percent, covering 1.9 billion people. Regionally, the most dramatic increase was in South East Asia and South Asia. Sub-Saharan Africa and Oceania continued lagging behind. Electrification in rural areas rose from 61 to 72 percent, and in urban areas from 94 to 96 percent. This absolute expansion slightly exceeded the population increase, as the global population grew by 1.7 billion (and the urban population by 1.4 billion). In rural areas, the access increase was 555 million versus a population increase of 308 million (figure 2.1).

During the 2010–12 tracking period, global electrification rose from 83 to 85 percent, for an increase of 222 million people. Incremental access growth was overwhelmingly in urban areas (figure 2.2), with only 46 million in rural areas—about 36 million in South Asia, followed far behind by Sub-Saharan Africa and Latin America and the Caribbean. Among countries, India was the largest contributor with around 55 million gaining electrification, followed by Nigeria with around 18 million—the two largest access-deficit countries.

Access expansion more than kept pace with the population increase during the tracking period. Of the 222 million gaining access, 85 million exceeded population growth. However, the performances of the two highest access-deficit regions—South Asia and Sub-Saharan Africa—were vastly different: South Asia provided electricity to 54 million people over its population increase, but Sub-Saharan Africa barely kept pace, adding just about half a million people over the population increase (figure 2.3). In fact, the performance of urban and rural areas in Sub-Saharan Africa is also a study in contrasts: in urban areas, access growth exceeded population increase by 25 million; in rural areas, it fell short by 23 million.

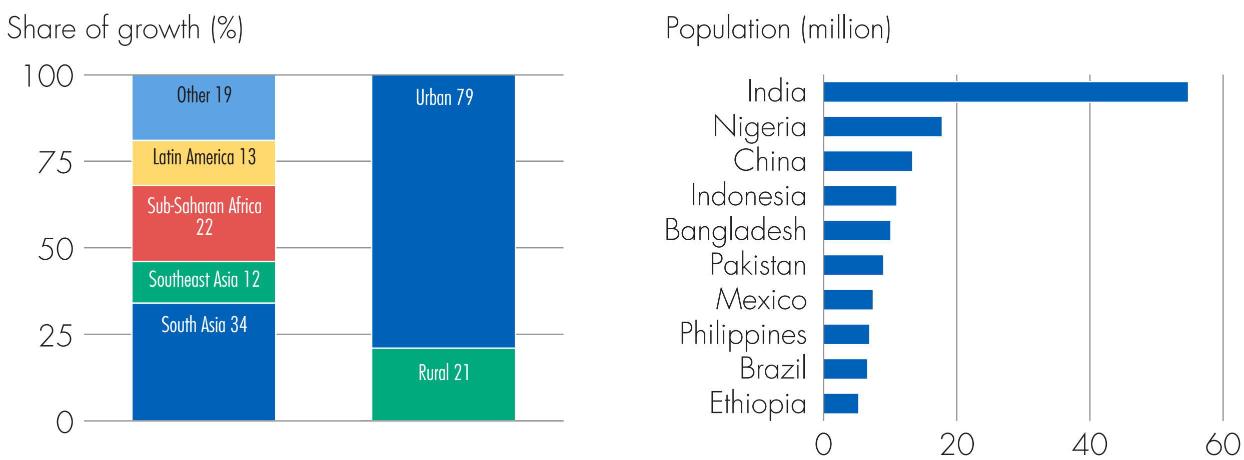
India experienced the highest net increase, 43 million people, with new access above population growth during the tracking period. About 55 million people were electrified against the growth in population of 12 million, giving a net annual increase of 21 million. Nigeria followed with a 3.7 million net annual increase. A group of eight countries (Argentina, Bangladesh, Brazil, China, Indonesia,

Figure 2.1. **Electrification rate, 1990–2012**



Source: World Bank Global Electrification database 2015 (World Bank 2015).

Figure 2.2. **Global electricity access growth, 2010–12**



Source: World Bank Global Electrification database 2015 (World Bank 2015).

Pakistan, Philippines, and Vietnam) had net annual increases of more than 1 million.

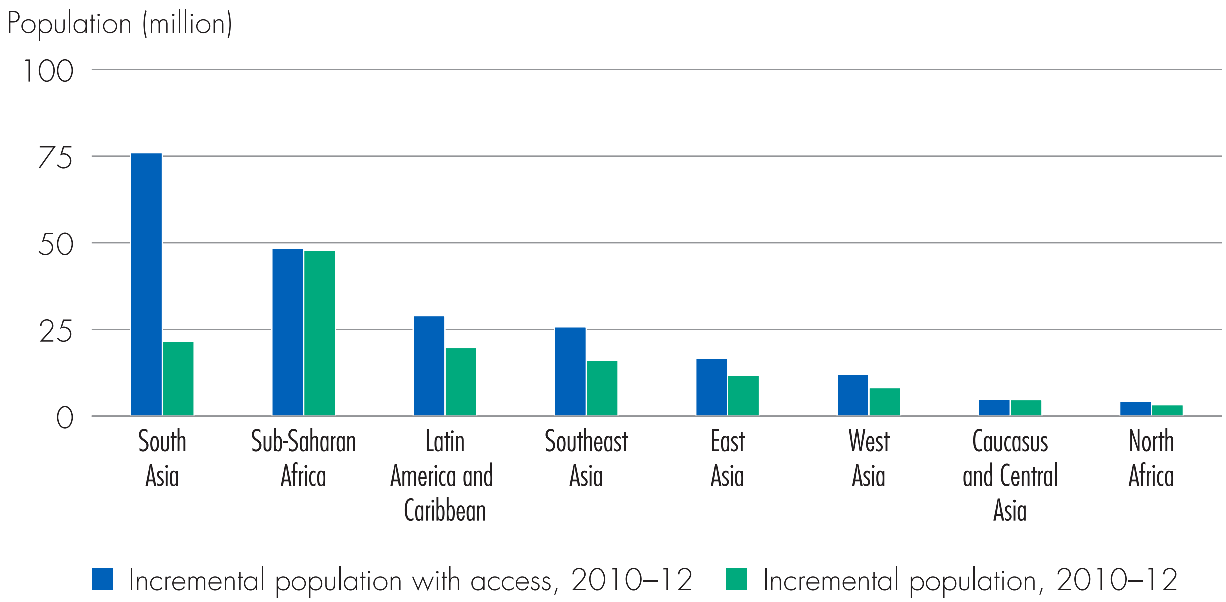
The electricity access deficit in 2012 was about 1.1 billion people—down from about 1.2 billion people in 2010—or about 15 percent of the global population in some 200 million households. About 87 percent of those lacking access lived in rural areas, and 88 percent were in Sub-Saharan Africa and South Asia. The unelectrified urban rate was small, at 139 million people, largely in Sub-Saharan Africa. Sub-Saharan Africa accounted for 55 percent of the total access deficit, with 589 million people. The rest was around the world, but with a sizable proportion in Southeast Asia (figure 2.4).

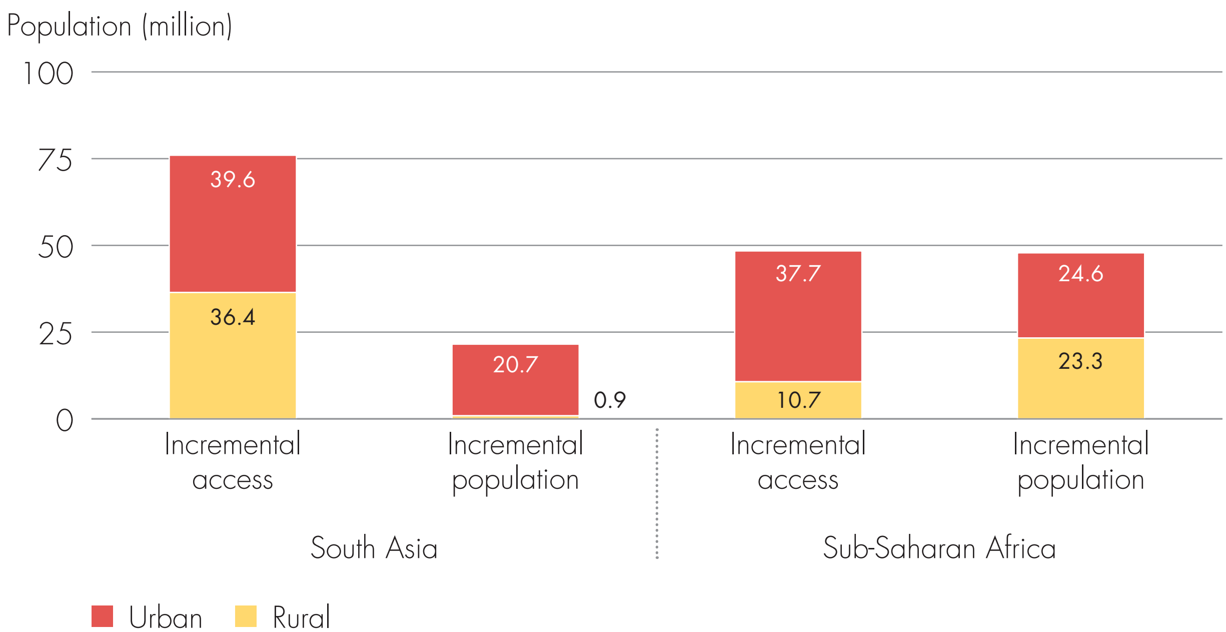
Among the regions, electrification in 2012 varied from 29 percent in Oceania to 35 percent in Sub-Saharan Africa and to near universal access in the Caucasus and Central Asia, East Asia, North Africa, and developed countries. Oceania may have the lowest rate, but also has only 7 million people without electricity. More urbanized and higher-income regions typically exhibit higher rates. North Africa, East Asia, Southeast Asia, and the Caucasus and Central Asia are clustered, demonstrating a sharply higher rate than other developing regions. West Asia and Latin America are to some extent outliers that report by far the highest income and urbanization rates (that is, growth in urban share) among developing regions, yet have lower electrification than East Asia and North Africa. South Asia also stands out with electrification around double that in Sub-Saharan Africa and Oceania, both with comparable incomes and urbanization rates (figure 2.5).

A group of top 20 high-impact countries, accounting for 83 percent of the global access deficit, is key to achievement of the universal access objective. India alone had a little less than one-third of the global deficit (263 million), followed by Nigeria and Ethiopia (figure 2.6). In this group, 13 are in Sub-Saharan Africa. Another group of top 20 countries is those with the lowest electrification rates, comprising about 316 million people. Nine countries, all in Sub-Saharan Africa, overlap the two groups: Burkina Faso, Democratic Republic of Congo, Kenya, Madagascar, Malawi, Mozambique, Niger, Tanzania, and Uganda. While progress in the former group is essential in meeting the universal access goal, a focus on the latter is essential for human development and economic productivity.

Average electrification rates mask differences among income quintiles. Among the two top 20 groups, 14 countries are examined more deeply to assess inequality in access among the top 60 percent of the population and the bottom 40 percent, based on data from the latest household surveys. In most of these countries, even the top 60 percent in urban areas do not enjoy near universal electrification—the closest is Cambodia at 86 percent (figure 2.7). The difference in access between the richer 60 percent versus the poorer 40 percent is also stark in many countries. In urban areas, the gap between access of the top 60 percent and bottom 40 percent is more than 50 percentage points in Mozambique, Uganda, Rwanda,

Figure 2.3. **Electricity access and population growth, 2010–12**



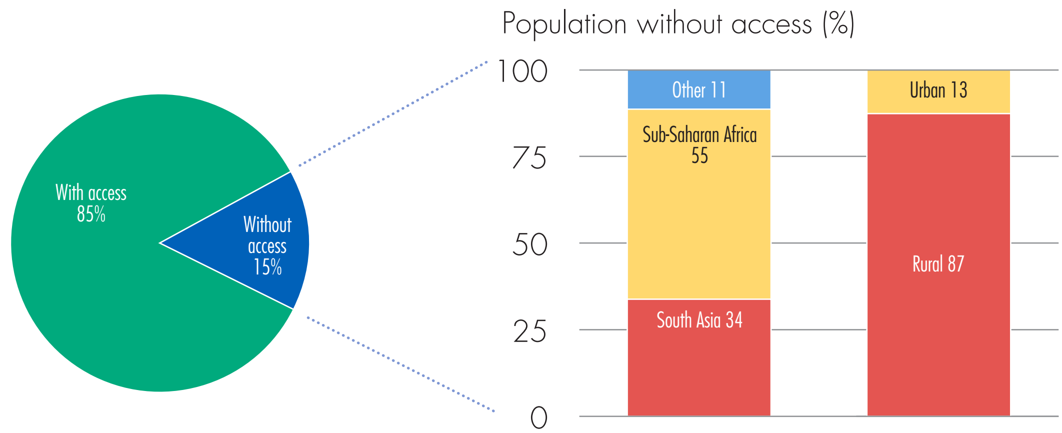


Source: World Bank Global Electrification database 2015 (World Bank 2015).

and Angola. (The other extreme is Ethiopia.) In rural areas, the inequality is less pronounced, partly because overall access is low. Even then the gap can be very wide, and is highest in Angola at 40 percentage points. The access rate in the bottom 40 percent in rural areas is less than 5 percent in 11 of the 14 countries, and the situation is similar in urban areas in South Sudan, Malawi, and Rwanda—the bottom 40 percent have barely any access to electricity.

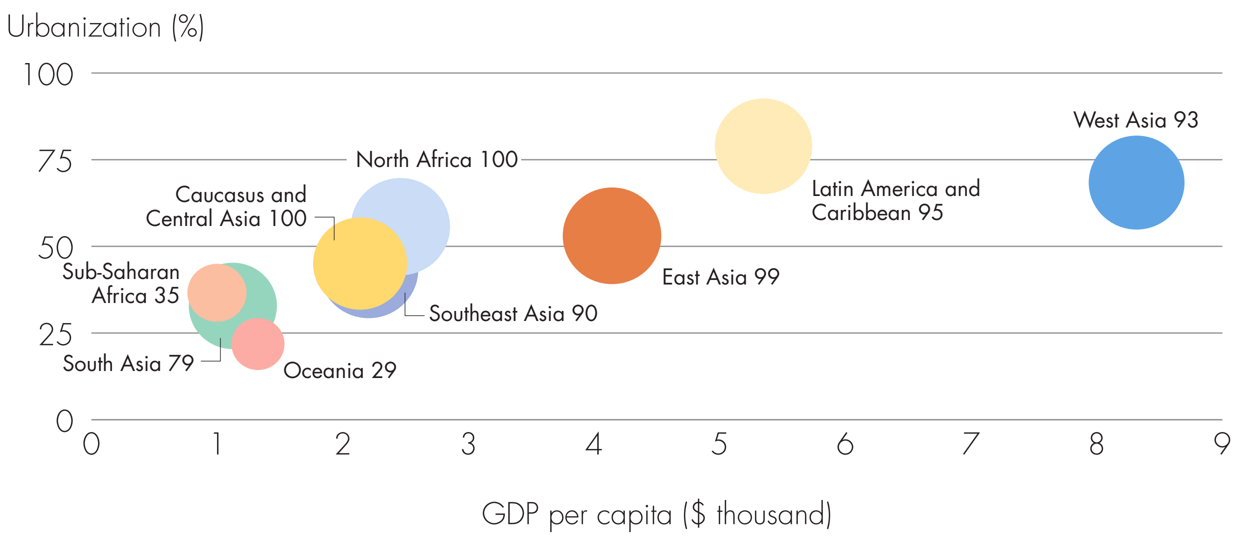
Lower electrification is associated with higher inequality. The concentration index (CI)[4]—a common measure of inequality—suggests that electrification is concentrated more among the rich than the poor as CIs for all

Figure 2.4. **Electricity access deficit, 2012**



Source: World Bank Global Electrification database 2015 (World Bank 2015).

Figure 2.5. **Regional electrification rate in 2012, by urbanization and income**



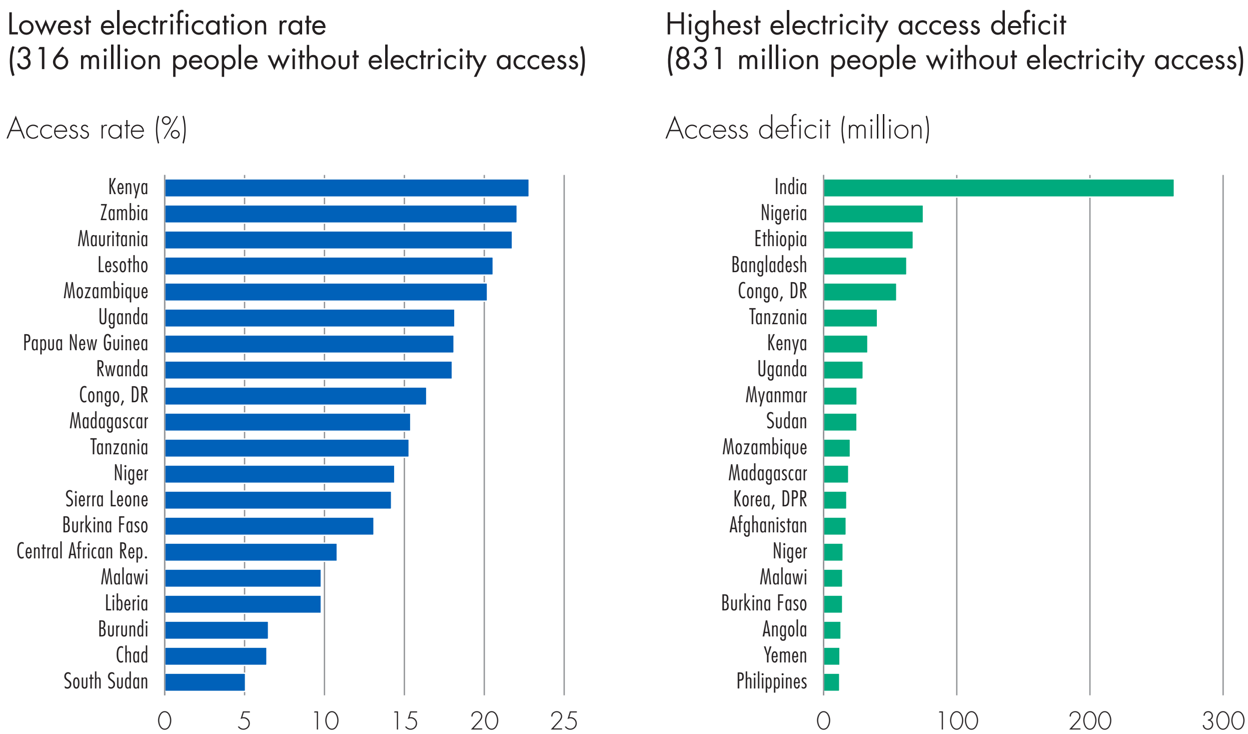
Source: World Bank's Global Electrification database, 2015 (World Bank 2015).

Note: Size of bubble reflects electrification by region.

the selected counties are positive. Inequality is worst in Rwanda, Tanzania, Malawi, and Mali (figure 2.8), where the index is more than 0.6. Further, inequality is worse among countries with low electrification rates, such as Malawi, Rwanda, Tanzania, and South Sudan. The correlation between the CI and electrification is –0.5. Inequality is less among countries with higher electrification, like Pakistan, India, and Mexico. Afghanistan and Côte d'Ivoire are exceptions with relatively low access and low CI—they have performed well in creating more equitable electricity access.

Over the tracking period, annual access growth accelerated to 0.6 percent from base-period growth (1990–2010) of 0.1 percent. Growth is calculated as the ratio between the absolute net increase (access less

Figure 2.6. **Top 20 countries: Highest electricity access deficit and lowest electrification rate, 2012**



Source: World Bank Global Electrification database 2015 (World Bank 2015).

population) and population at the end of the period (annex 1). This way the access performance of a country is normalized with respect to its population. Every region improved in the tracking period from the base period. South Asia reported the highest annual access growth in 2010–12 at 1.6 percent, followed by West Africa with 0.9 percent over 2010–12. The largest access-deficit region—Sub-Saharan Africa—showed a mere 0.03 percent annual growth, just above the population increase, but still better than its negative growth in the base period (figure 2.10).

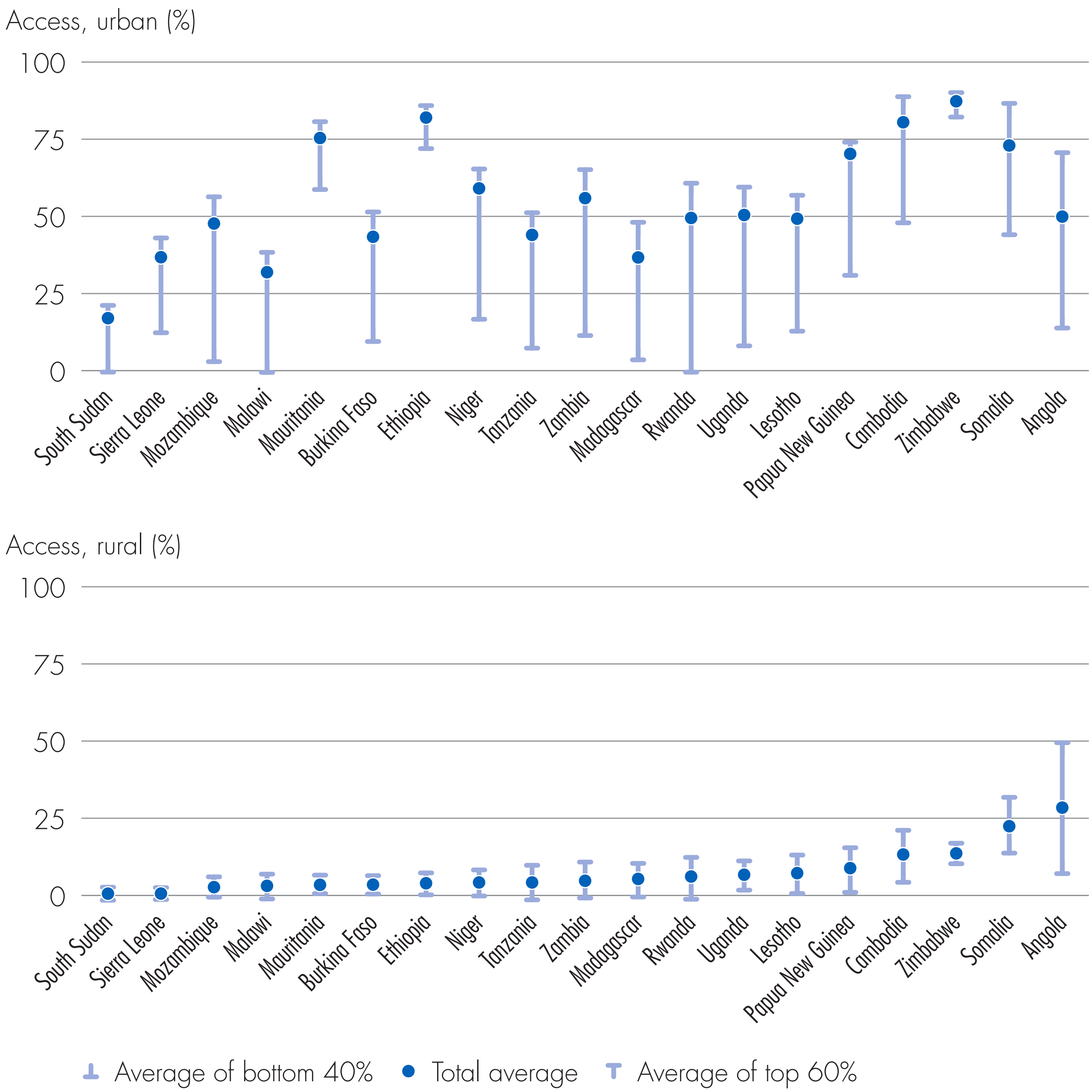
Looking ahead, progress toward the universal access objective is closely tied to the performance of the high-impact countries. Among the top 20 access-deficit countries, nine have been unable to keep up with population growth; Afghanistan and Nigeria register the highest growth rate at about 2.6 and 2.2 percent, and India registers 1.7 percent (figure 2.9). Overall, 75 developing countries achieved an annual growth rate of at least the global growth rate of 0.6 percent during the tracking period; 79 are still below this rate, home to about 440 million people without electricity.

Unless all countries move according to their individual target of universal electrification, the global access target cannot be met. If global access expansion continues at the same pace as in the tracking period (0.6 percent—figure 2.11) until 2030 in developing countries, global electrification could reach universal access by 2030. However, some countries will need to ramp up their performance sharply as universal access is a country-level target.

Tracking non-solid fuels

The indicator to track access to modern cooking solutions is the percentage of population primarily relying on non-solid fuels for cooking. This binary indicator is underpinned by the WHO Household Energy database,[5] which regularly reports on the percentage of the population primarily relying on solid fuels for cooking (the population without access to non-solid fuels). In 2014, WHO updated its estimates for 191 countries using a nonparametric statistical model based on data from over 750 household surveys (Bonjour et al., 2012).

Figure 2.7. **Inequality in electricity access between the top 60% and bottom 40% of the population**

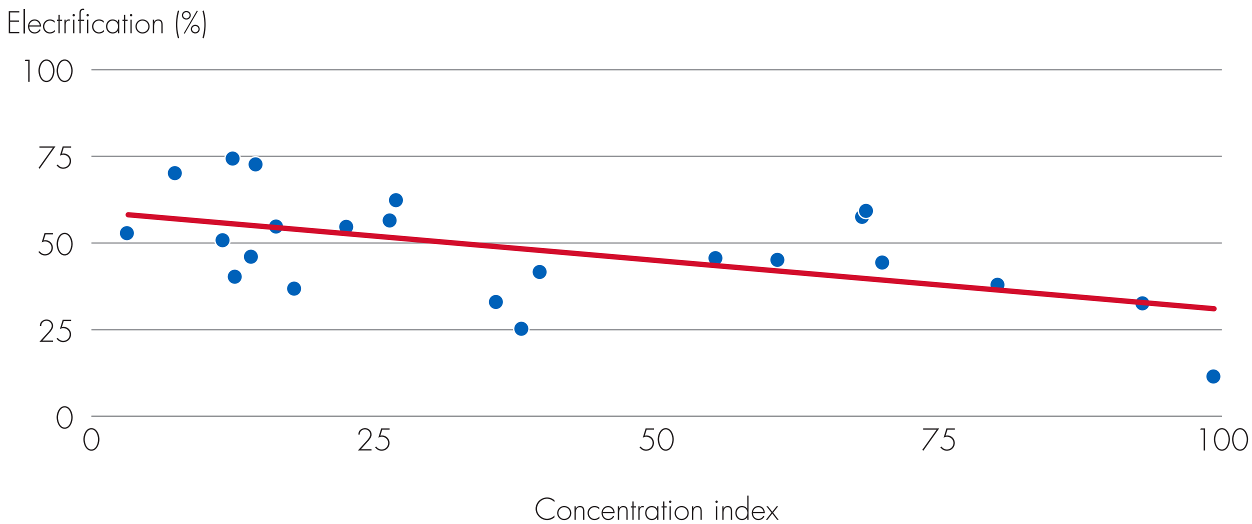


Source: Household surveys.

But current global data collection focuses on the primary fuel used for cooking and fails to collect data on the type of device or technology used. A recent WHO publication[6] highlights the importance of the technology, too, for public health. Its guidelines recommend what fuels and technology (stove, lamp, and so on) combinations in the home are clean and discourage use of coal and kerosene (a non-solid fuel) in the home. With the rollout of the GTF Multitier Framework paired with the technical recommendations in the WHO guidelines, access to modern cooking solution in the home will be defined as “access to clean fuels and technologies” rather than “access to non-solid fuels.” This shift will help ensure that health and other “nexus” benefits (chapter 6) are better counted, and thus realized.

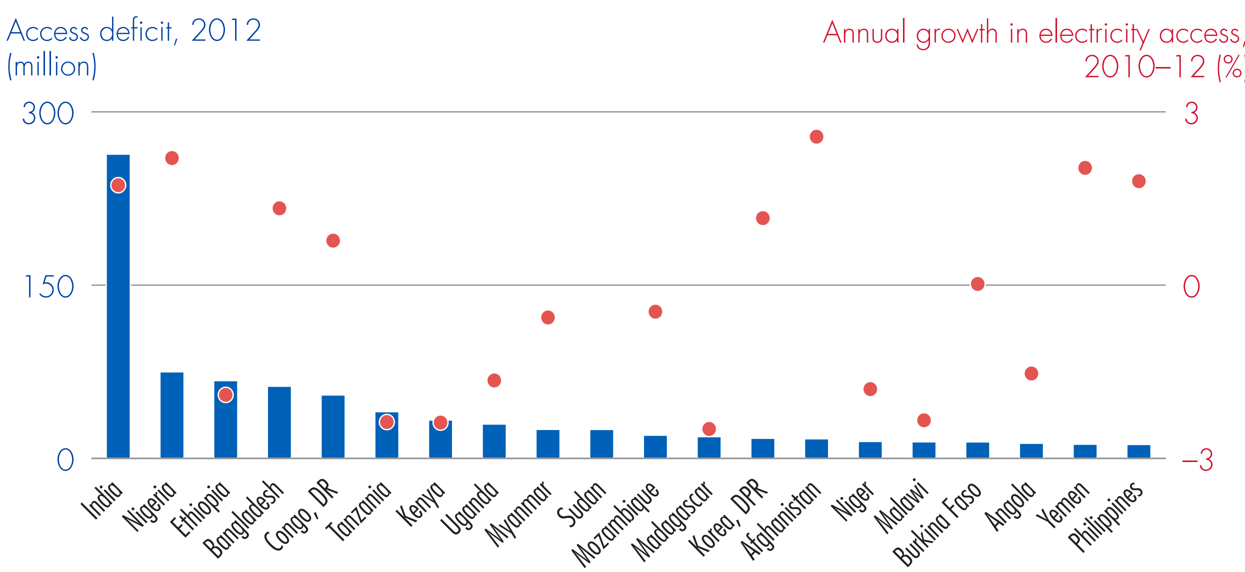
Over 1990–2012, the global non-solid fuel access rate rose from 48 to 59 percent. In rural areas (where access is lowest) it increased from 22 to 27 percent, in urban areas

Figure 2.8. **Concentration index and electrification rate**



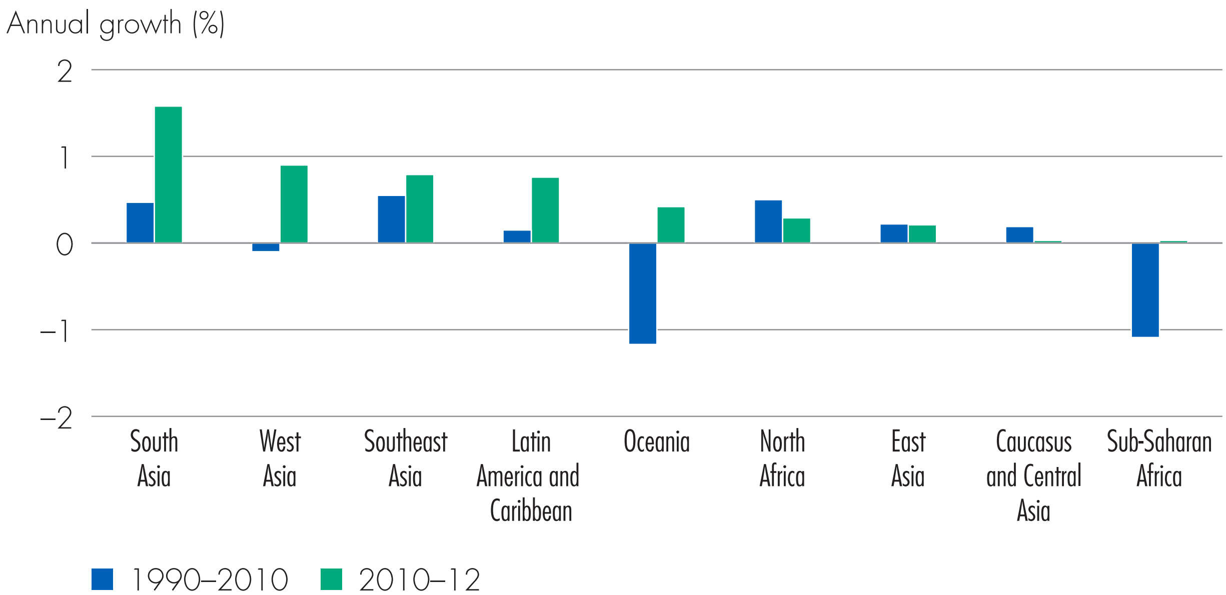
Source: Household surveys.

Figure 2.9. **Top 20 access-deficit countries: Electricity access deficit, 2012, and annual growth in electricity access, 2010–12**



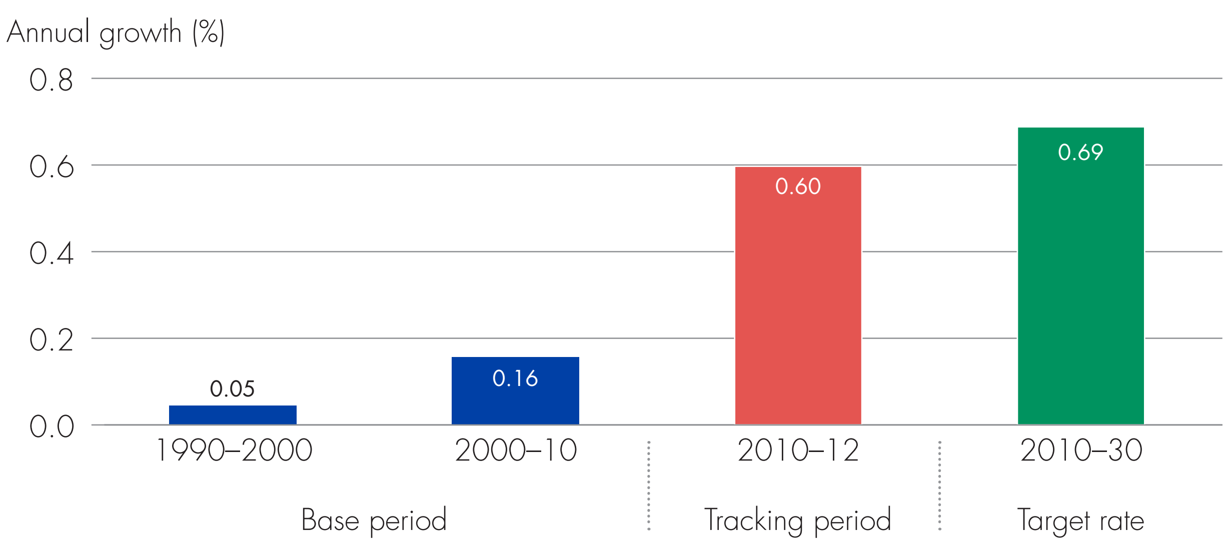
Source: World Bank Global Electrification database 2015 (World Bank 2015).

Figure 2.10. **Annual growth in electricity access, base and tracking periods, by region**



Source: World Bank Global Electrification database 2015 (World Bank 2015).

Figure 2.11 **Annual growth in electricity access, historical and target**



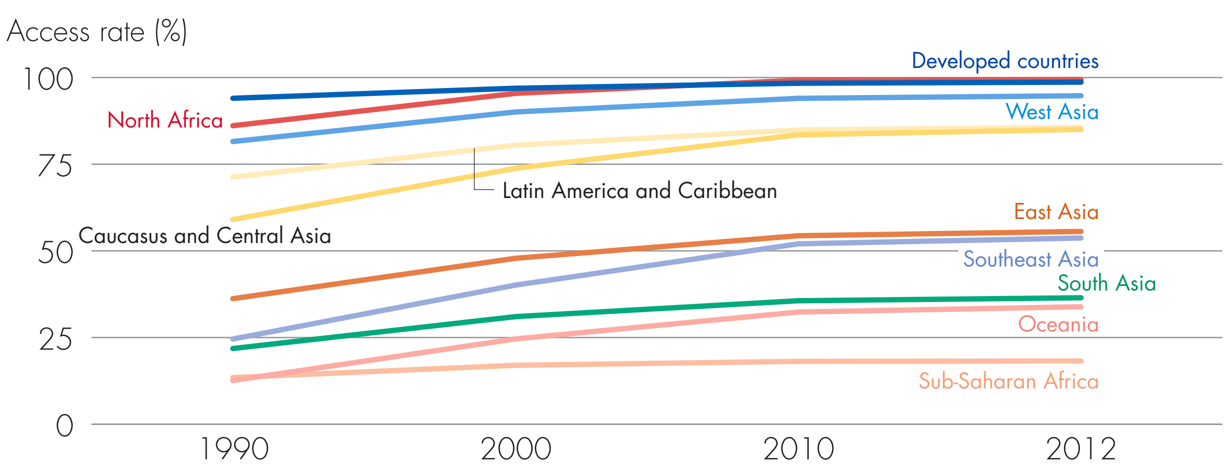
Source: World Bank Global Electrification database 2015 (World Bank 2015).

from 70 to 87 percent. The Caucasus and Central Asia, East Asia, and South East Asia turned in impressive performances (figure 2.12).

Over 2010–12, the access rate edged up from 58 percent[7] to 59 percent, an increase of 123 million, including 22 million in China, 14 million in India, and 11 million in Indonesia (figure 2.13). India and China—previously the two largest access-deficit countries—also showed the greatest progress in the absolute number of people gaining access to non-solid fuels. The incremental access growth was entirely in urban areas.

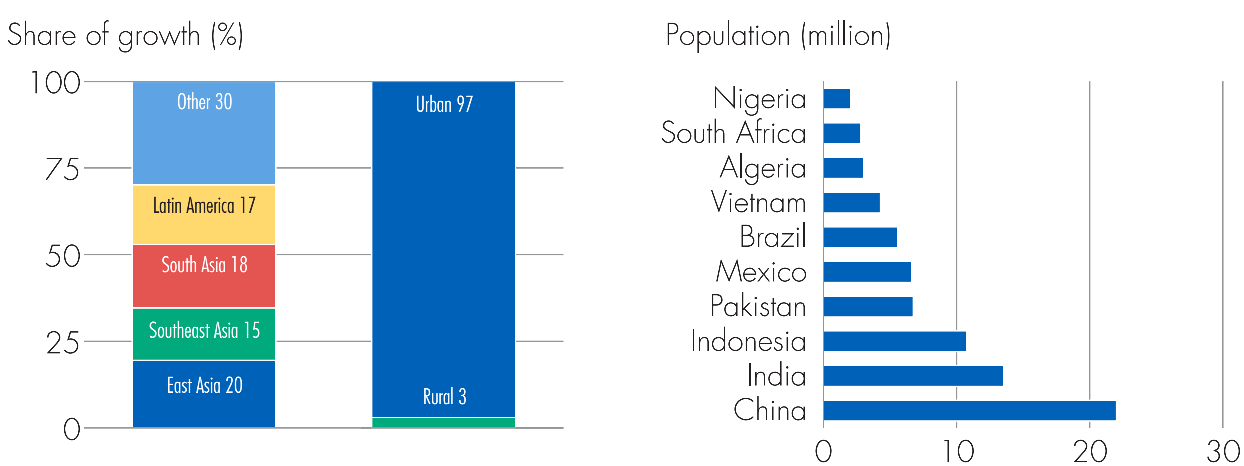
The natural growth in population during the tracking period exceeded the growth in the population with access to non-solid fuels. The global population grew by 138 million—145 million in urban areas set against a 7 million decrease in rural areas—outpacing the growth in energy

Figure 2.12. **Regional access to non-solid fuels, 1990–2012**



Source: WHO Household Energy database 2015 (WHO 2015).

Figure 2.13. **Global non-solid fuels access growth, 2010–12**

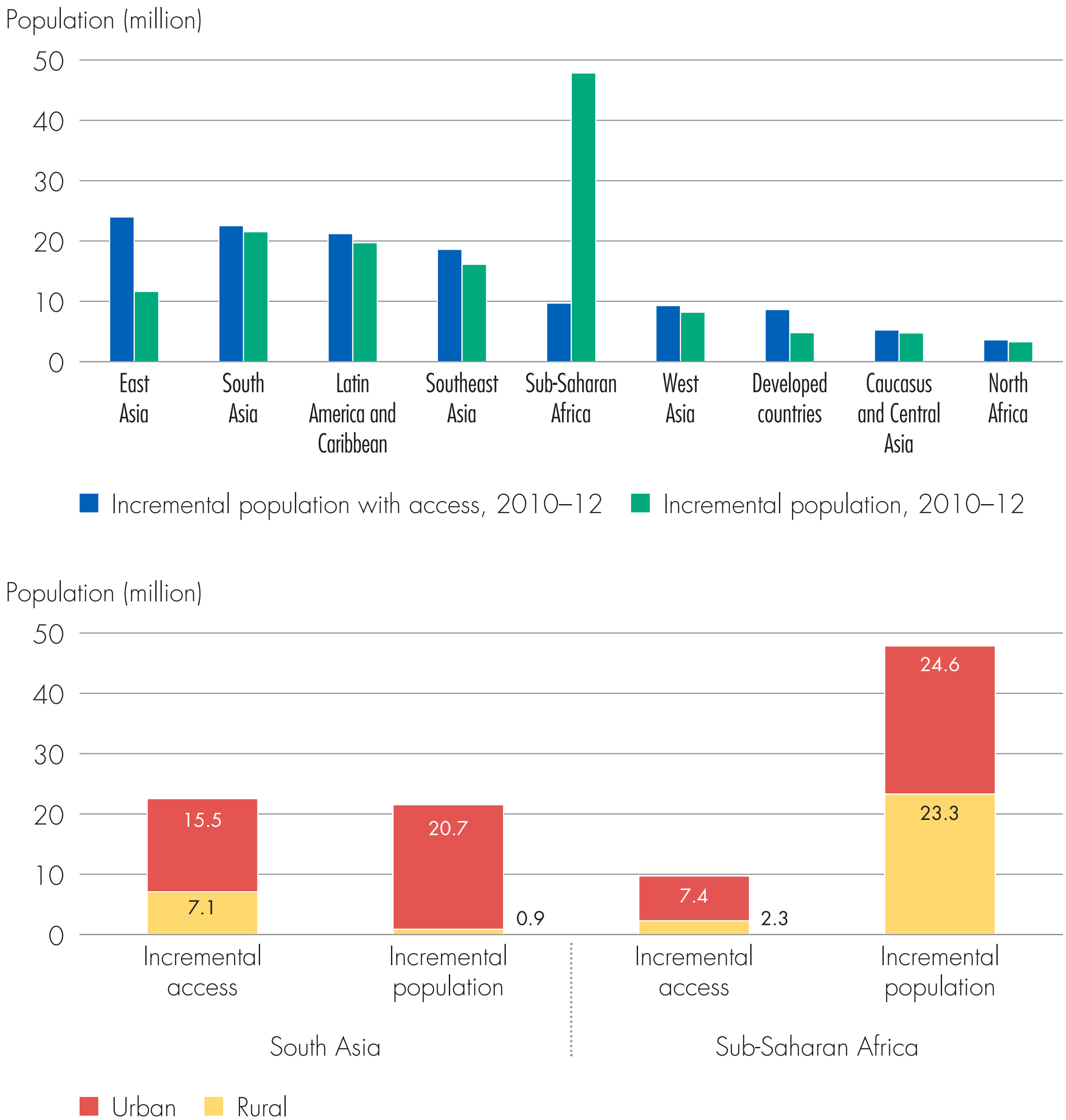


Source: WHO Household Energy database 2015 (WHO 2015).

access—123 million. This gap is notable in Sub-Saharan Africa, where the population increased by 48 million but only 9 million gained access to non-solid fuels. In all other regions, the increase in access exceeded or matched population growth, notably East Asia with a net gain of about 12 million people (figure 2.14).

In 2012, about 2.9 billion lacked access to non-solid fuels for cooking, or around 41 percent of the global population. Some 84 percent of the population lacking access to non-solid fuels are in rural areas. South Asia and Sub-Saharan Africa account for around two-thirds of the population without access, East Asia one-fifth. The access

Figure 2.14. **Non-solid fuel access and population growth, 2010–12**

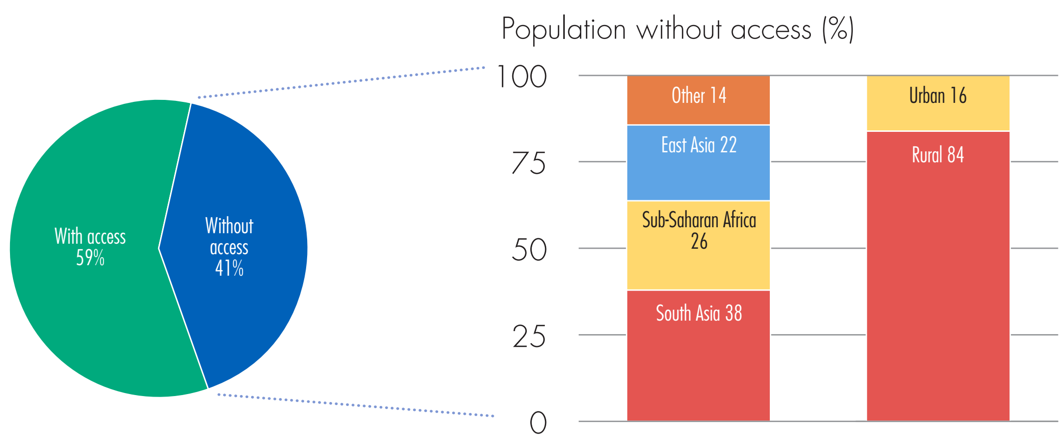


Source: WHO Household Energy database 2015 (WHO 2015).

rate varies considerably, from 18 percent in Sub-Saharan Africa to 34 percent in Oceania and to near-universal access in the West Asia and high-income countries. South Asia—access rate 36 percent—is home to about 1.1 billion people who cook primarily with solid fuels, followed by Sub-Saharan Africa and East Asia, which together add another 1.4 billion (figure 2.15).

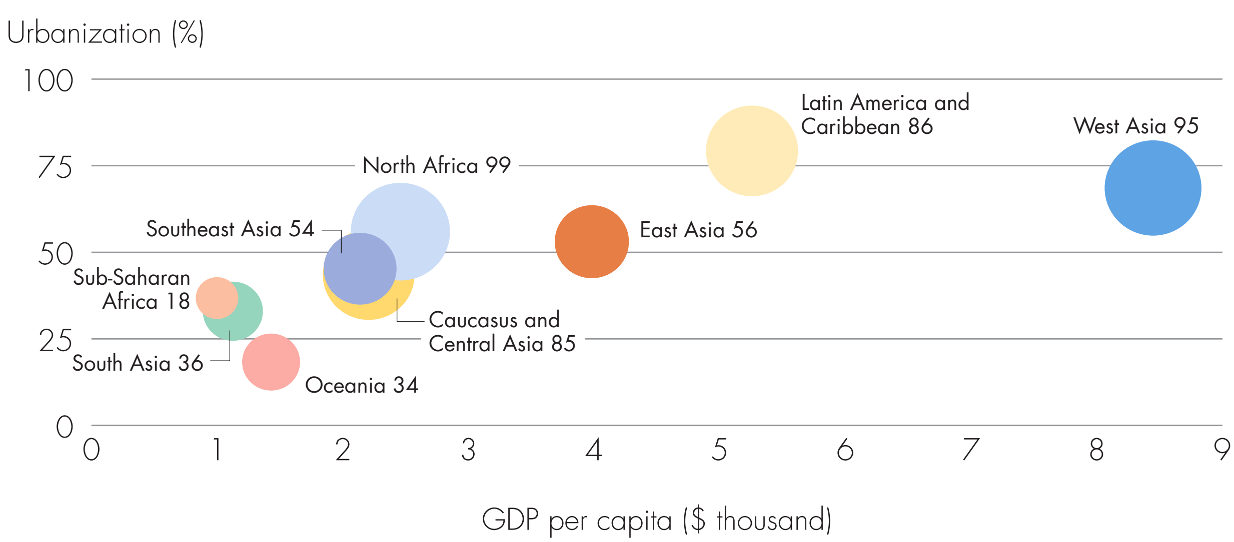
The average non-solid fuel access rate varied from 18 percent in Sub-Saharan Africa to 34 percent in Oceania to near-universal access in the North Africa, Latin America and the Caribbean, and developed countries. Of the eight developing regions, three have an access rate of less than 50 percent (figure 2.16). More urbanized and higher-income regions typically exhibit higher non-solid

Figure 2.15. **Global non-solid fuel access deficit, 2012**



Source: WHO Household Energy database 2015 (WHO 2015).

Figure 2.16. **Regional non-solid fuel access rate in 2012, by urbanization and income**



Source: WHO Household Energy database 2015 (WHO 2015).

fuel access rates. North Africa, Southeast Asia, and the Caucasus and Central Asia are clustered together, demonstrating a sharply higher access rate than other developing regions.

The top 20 countries with the absolute highest access deficit account for 83 percent of the global deficit. Nine are in Sub-Saharan Africa, four in South Asia, two from East Asia, and four from Southeast Asia (figure 2.17).

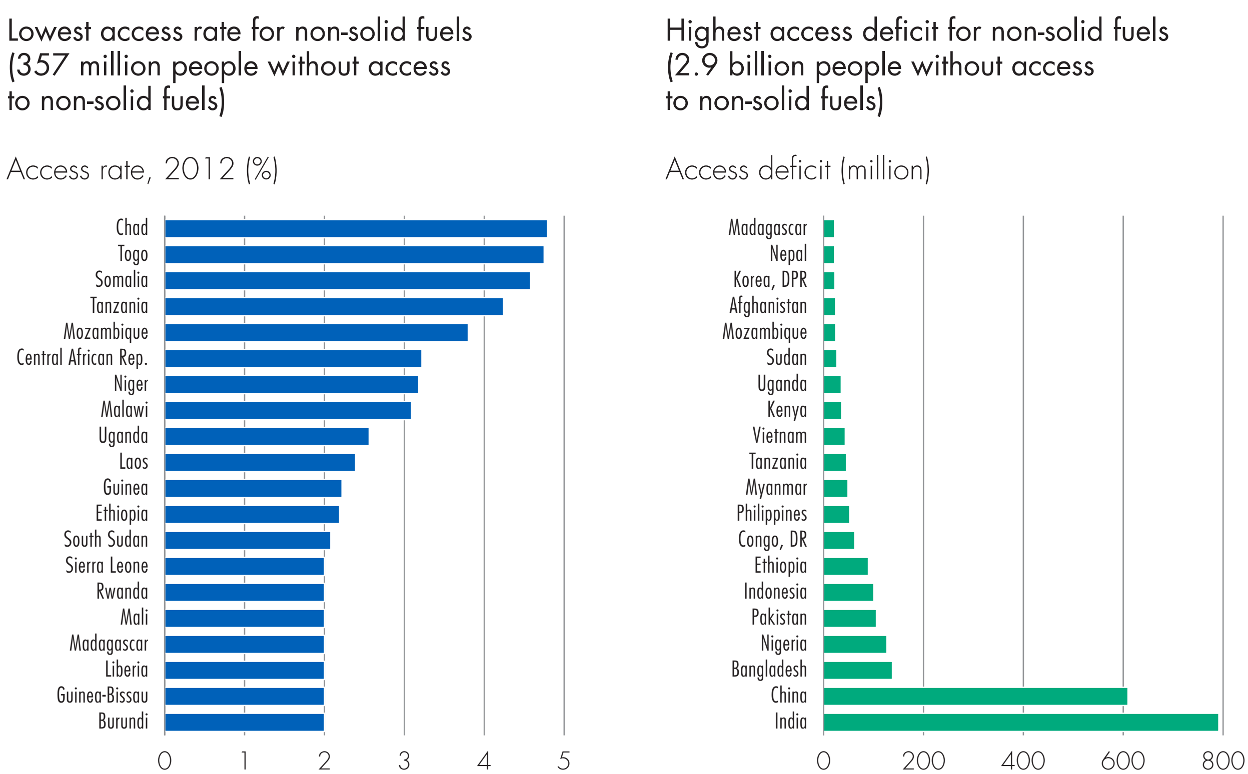
Another group of 20 countries have the lowest non-solid fuel access rate. Seven of them—all in Sub-Saharan Africa—have rates of 2 percent or less; all the other countries in this group are from the region, Laos (Lao PDR) aside. These 20 countries add up to about 357 million people who lack access to non-solid fuels for cooking (12 percent of the total access deficit).

A handful overlaps between these two groups: Ethiopia, Madagascar, Mozambique, Tanzania, and Uganda. While the former group is more important to meet the global goal, a focus on the latter is important for human development and economic productivity.

Differences in access rates between the richer 60 percent of the population and the poorer 40 percent are stark in many countries. The gap is 66 percentage points in Nepal's urban areas and more than 40 percentage points in Côte d'Ivoire, Ghana, and Cambodia (figure 2.18). Inequality is less pronounced in rural areas, except in Nigeria, Nepal, and Zambia, partly because the overall national access rates are so low. Access in the bottom 40 percent is less than 5 percent in 13 of the 17 countries.

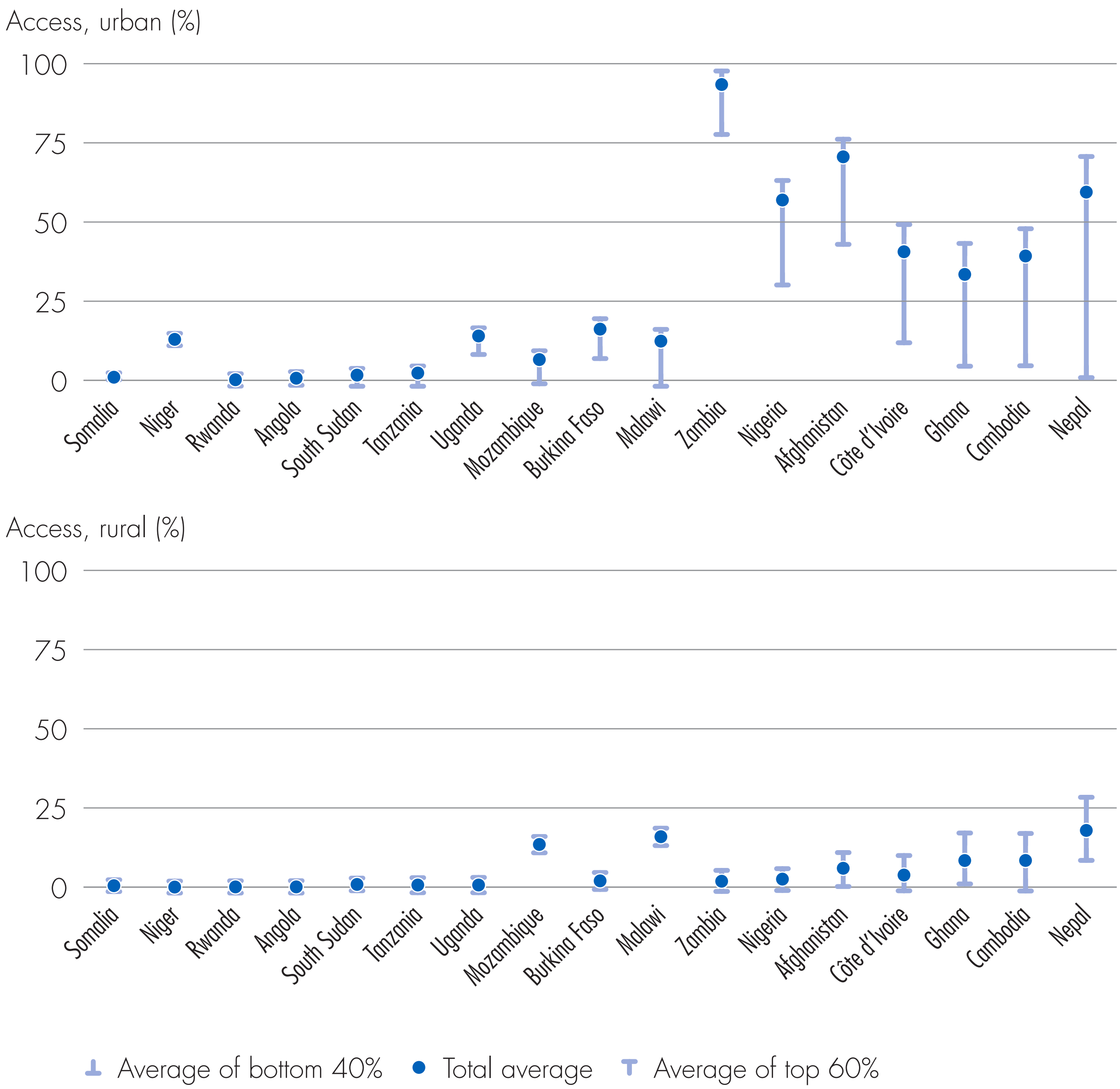
The gap between the rich and poor is wider in access to non-solid fuels for cooking than electrification. All the CIs[8] are greater than zero, suggesting that the richer populations are more likely to have access to non-solid cooking fuels than poorer households, particularly in countries with the lowest access rates, like Malawi and Tanzania. In contrast, countries with the highest access rate have less inequality in access among the income quintiles.

Figure 2.17. **Top 20 countries—lowest access rate and highest access deficit, non-solid fuels**



Source: WHO Household Energy database 2015 (WHO 2015).

Figure 2.18. **Inequality in access to non-solid fuels between the top 60% and bottom 40% of the population**

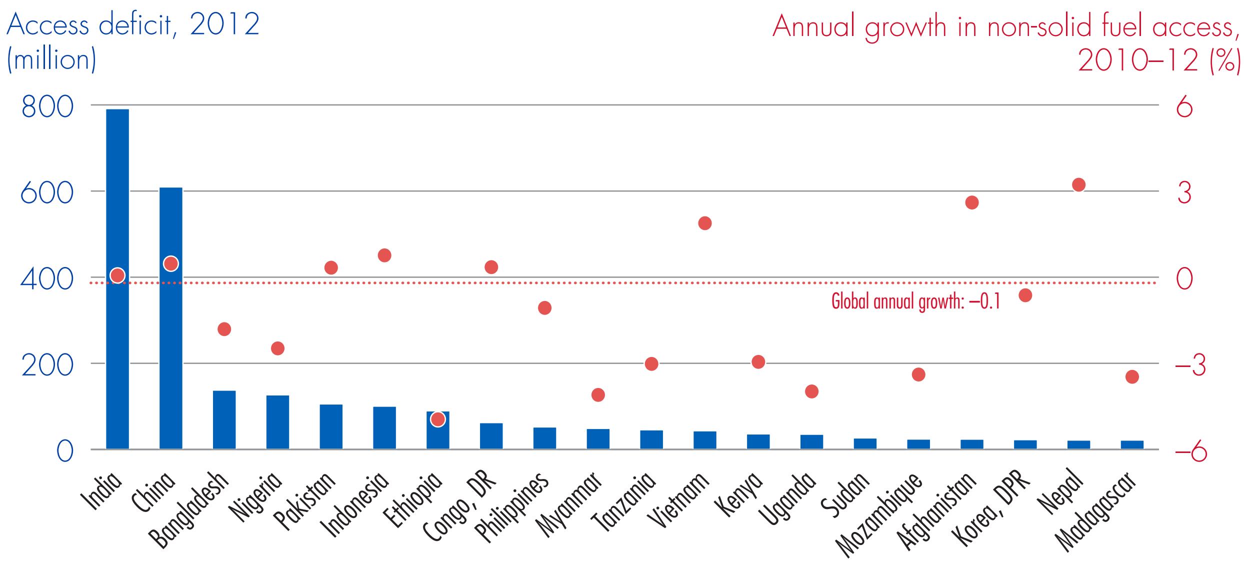


Source: Household surveys.

Increasing the access rate globally will rely on progress of the high access-deficit countries. This is evident in the experiences of China, India, and Indonesia, which report access expansion shifting millions of households to non-solid fuel use. But even then, India and China's annual growth was only about 0.5 percent. Among the top 20 access-deficit countries, Nepal had the highest annual growth of 3.2 percent (figure 2.19).

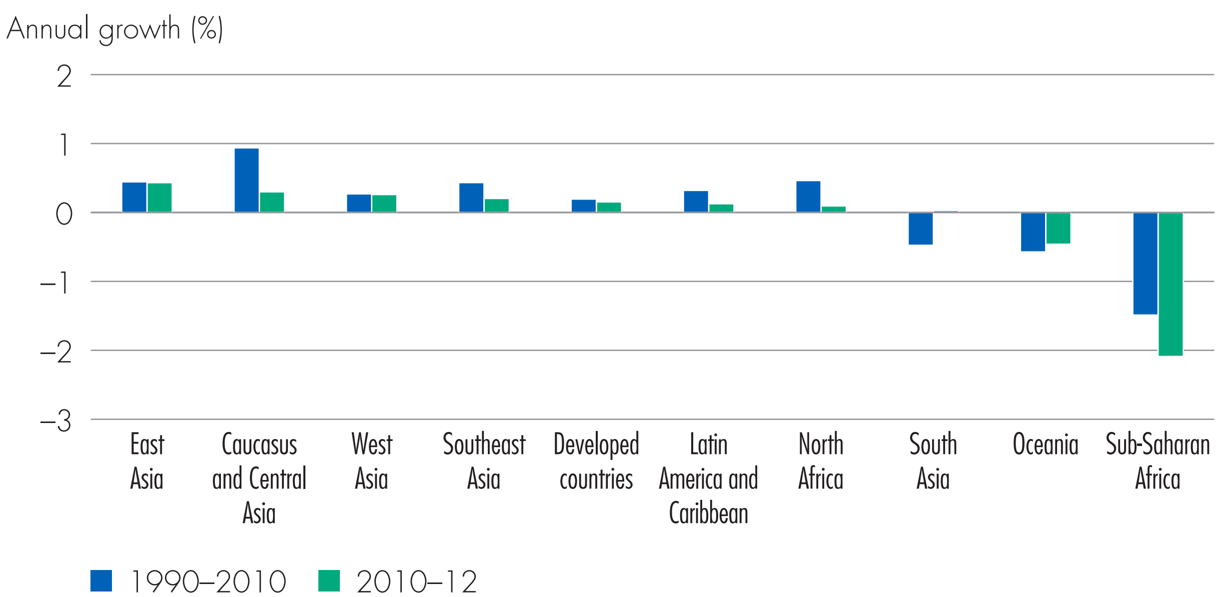
Over the tracking period, global annual growth was a negative 0.1 percent, the same rate as in the base period (1990–2010). (Growth is calculated the same way as for electricity access.) Among developing countries only, annual access growth in the tracking period was even worse, at a negative 0.2 percent, the same as during the base period. In the tracking period, East Asia reported the best rate at 0.4 percent annually, Sub-Saharan Africa the worst with an annual decline of 2.1 percent. South Asia may have turned the corner (figure 2.20).

Figure 2.19. **Top 20 access-deficit countries: Non-solid fuel access deficit, 2012, and annual growth in non-solid fuel access, 2010–12**



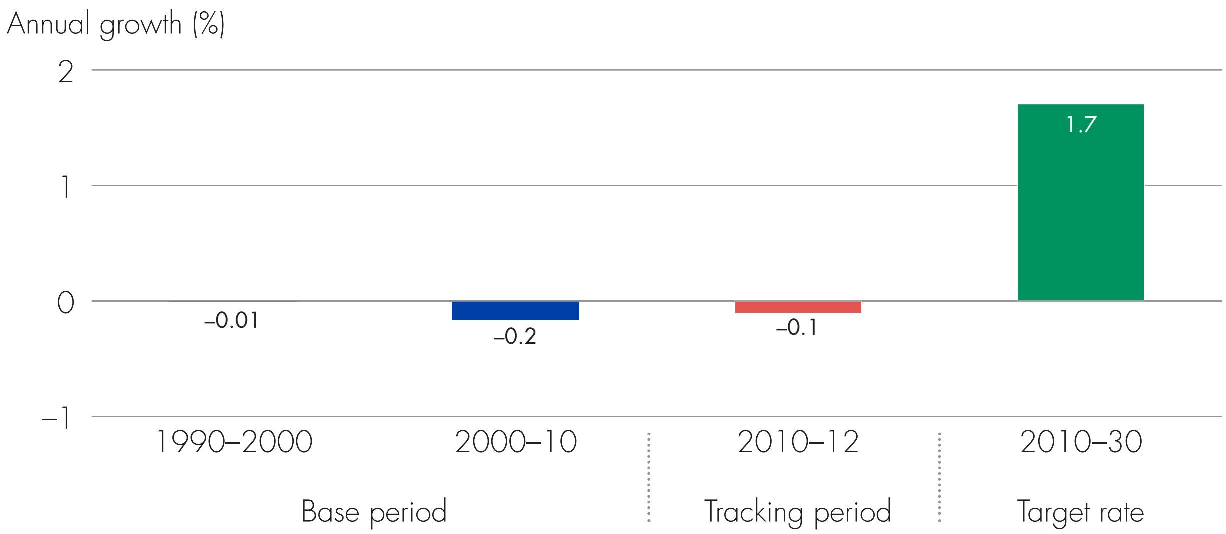
Source: WHO Household Energy database 2015 (WHO 2015).

Figure 2.20. **Growth in non-solid fuel access: Base and tracking periods, by region**



Source: WHO Household Energy database 2015 (WHO 2015).

Figure 2.21 **Annual growth in access to non-solid fuels: Historical and target**



Source: WHO Household Energy database 2015 (WHO 2015).

Access growth needs to accelerate to achieve the SE4All goal of universal access to modern cooking by 2030. Annual growth needs to be 1.7 percent globally and 1.9 percent among developing countries over 2010–30 to attain the goal by 2030 (figure 2.21). This requires dramatic improvements in focusing policies and resources.

The scale of the challenge with a focus on Sub-Saharan Africa

Electrification

The number of people without access to electricity is projected to decline to around 950 million people in 2030, or 11 percent of the global population at that time in the New Policies Scenario of the World Energy Outlook (WEO) 2014 (IEA 2014a). This scenario reflects a continuation of current policies and cautious implementation of proposals, even if they are yet to be formally adopted. The caution stems from the many institutional, political, and economic obstacles, as well as at times a lack of detail on announced intentions and a lack of foreknowledge on how well they are likely to be implemented.

The projections draw on the IEA's WEO 2014 global databases on electricity access and the traditional use of solid biomass for cooking as its baseline.[9] They are underpinned by the World Energy Model (box 2.2). But as seen (box 2.1), there are material differences in electricity estimates between the IEA's global databases and the World Bank's Global Electrification database. This means that the World Energy Model's 2012 baseline for those without access to electricity is 1.3 billion people and that its baseline for those without access to modern cooking facilities is 2.7 billion.

About 1.7 billion people will gain access to electricity by 2030, but much of this gain will be offset by population growth (figure 2.22). Those attaining electricity access will reach a range of consumption levels by 2030—equivalent, in turn, to a range of tiers in the GTF Multitier Framework (chapter 5)—ranging from defined minimum consumption in urban and rural areas to consumption above the regional average at that time. The number of people without electricity access will decrease in all regions by 2030 except Sub-Saharan Africa, where it will be in decline by then, but still higher than in 2012. Given that this region will account for around two-thirds of the global population without access to electricity in the New Policies Scenario by 2030, it receives close review in the rest of this section.

Around 540 million people are projected to gain access to electricity in Africa by 2030 in the New Policies Scenario, 500 million of them in Sub-Saharan Africa. But around 635 million in Sub-Saharan Africa are projected to remain without electricity by this date, leaving a huge gap in the global energy system (figure 2.23) and revealing that

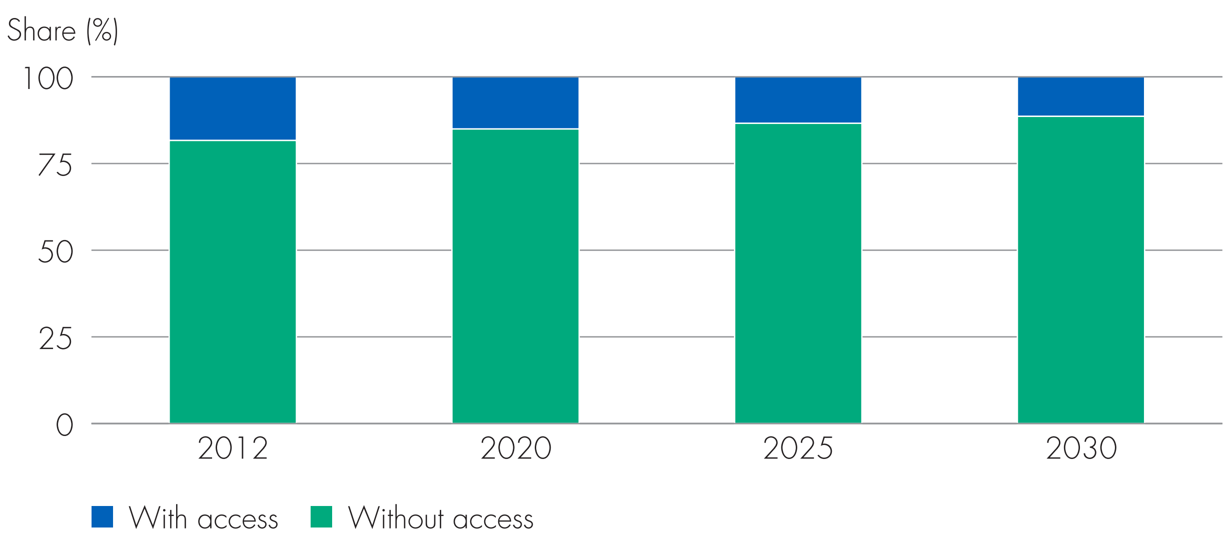
Box 2.2. **World Energy Model: Methodology**

The projections come from the IEA's World Energy Model, a large-scale simulation model to replicate how energy markets function. It is data intensive, covering the whole global energy system. Much of the data on energy supply, transformation, and demand, as well as energy prices, come from the IEA's own databases on energy and economic statistics, with further data from a wide range of external sources. Updated every year and developed over many years, the model consists of three main modules: final energy consumption (covering residential, services, agriculture, industry, transport, and non-energy use); energy transformation including power generation and heat, refinery and other transformation; and energy supply.

Within the World Energy Model, projections for access to electricity and to modern cooking solutions are based on separate econometric panel models that regress the electrification rates and rates of reliance on biomass over many variables at the regional level. Investment requirements, fuel demand, and carbon dioxide emissions are based on the regional power generation mix for electricity access, whereas for clean cooking a set of assumptions about clean cookstoves is used.

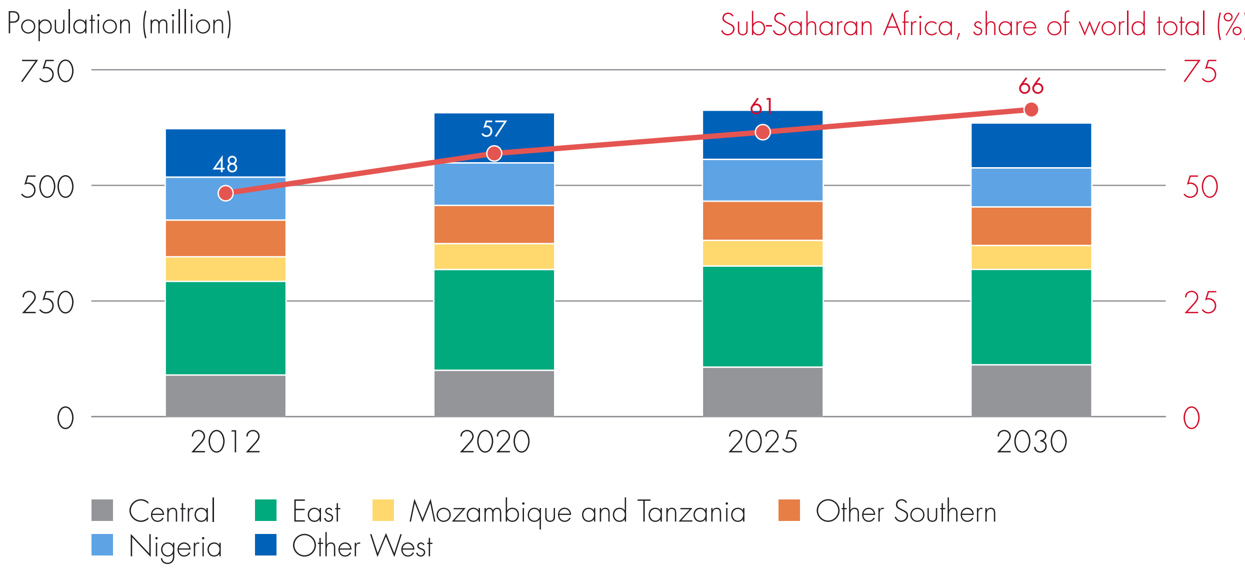
The panel models are run under the following economy and population assumptions: world gross domestic product (purchasing power parity) grows by an average of 2.7 percent a year over 2012–30, with the rate of growth slowing gradually over time as the emerging economies mature. The rate of economic growth varies by region. The rates of population growth assumed for each region are based on United Nations projections (UNDP 2012), and world population is projected to grow from an estimated 7.0 billion in 2012 to 8.4 billion in 2030. In line with the long-term historical trend, population growth slows over the projection period. Almost all the increase in global population is expected in countries outside the Organisation for Economic Co-operation and Development, mainly in Asia and Africa.

Figure 2.22. **Share of world population with and without access to electricity: New Policies Scenario**



Source: *World Energy Outlook 2014* (IEA 2014a).

Figure 2.23. **Population without access to electricity by subregion in Sub-Saharan Africa: New Policies Scenario**



Source: *World Energy Outlook 2014* (IEA 2014a).

Note: Subregions are derived from those used by the United Nations and existing regional power pools (bodies set up to strengthen regional power sector integration across Africa). For members of more than one pool, such as Tanzania, a decision has been taken to assign it to just one subregion, driven mainly by analytical considerations specific to this study, and so may not be consistent with other groupings (such as Africa's regional economic communities). For more detail on the regional breakdown, see IEA's (2014b, 21) *Africa Energy Outlook*.

current and expected efforts still fall short of meeting universal access by 2030.

Contributory factors include the current state of electricity infrastructure, the type and extent of expected investment in the various parts of the power sector, and the huge geographic size of many African countries. Demographic trends are also important, with Sub-Saharan Africa expected to continue recording steep population growth and, unlike many other parts of the world, an increase in the rural population. By 2030, around 80 percent of the Sub-Saharan population without access to electricity will live in rural areas, where providing electricity is much harder than in urban areas.

But the size of the challenge should not obscure the progress being made, aided by numerous national and multilateral initiatives. At present, population growth is outpacing electrification, but projections point to this trend reversing in the mid-2020s. The pace of change is fastest among the urban population, where the number of people without access is cut by more than half.

Nigeria brings new electricity access to more people than any other country in Africa, reducing the absolute number of those without access by around 10 percent by 2030 despite massive population growth. Other parts of West Africa see continued progress in raising electrification rates, and the subregion as a whole reaches 65 percent in 2030.

The access problem is more persistent in Central Africa, with almost two-thirds of the subregional population expected to remain without access in 2030. East Africa achieves the fastest pace of access growth, with Ethiopia, Kenya, and Rwanda leading the way; but a large part of the rural population here, too, remains without access. In South Africa, the government aims to reach 97 percent electrification—defined as universal access—by 2025 through a mix of on- and off-grid technologies (mainly solar home systems). This target is achieved by 2030 in the New Policies Scenario.

The type of access provided depends on country-specific factors, including the type of policies and financing for access projects, the current state and coverage of transmission and distribution systems, the status of plans to extend the grid, and the capacity and financing to realize these plans. Alongside policy-related considerations, actual costs are strongly affected by population density in the areas without access. For areas with high concentrations—urban areas or larger settlements—on-grid supply is typically the most cost-effective. Indeed, urban populations gaining access in the projections do so entirely via the grid because of the relatively low cost of additional connections and because the fixed costs of extending the grid are spread over a larger amount of electricity consumed (box 2.3).

Grid extensions are expected to remain largely within the domain of the public authorities and utilities, relying on a combination of self-financing from within the power sector (if the tariff structure allows for a degree of cross-subsidization), government budgetary allocations, and funding from international donors. The spread of decentralized access also involves other public entities, such as rural electrification agencies, and a range of nongovernmental organizations and private entities, as well as local communities.

Beyond a certain distance from the grid, the cost of extending it becomes prohibitive, tipping the balance in favor of mini-grids or off-grid systems (figure 2.24). Higher density settlements favor mini-grids. The main technologies are diesel generators or RE technologies—solar photovoltaic (PV), small hydropower, and small wind systems. The attractiveness of renewable technologies is much higher when costs are considered on a life-cycle basis, but finance must be available to meet the relatively high upfront outlay, which—even as costs come down—remains far above that required for a diesel generator. There are also potential synergies between technologies: hybrid systems

Box 2.3. **With or without a grid? The dynamics of expanding electricity access in Nigeria and Ethiopia[10]**

The most cost-effective way to expand electrification varies widely between countries and within countries themselves in Sub-Saharan Africa. It also changes over time as incomes and consumption patterns change. A detailed spatial analysis for Nigeria and Ethiopia illustrates how a range of factors—including population density, tariffs for grid-based electricity, technology costs for mini-grid and off-grid systems, and the final cost of diesel at point of consumption—affect the optimal mix of grid-connected, mini-grid, and off-grid generation options.

In Nigeria, higher population density and more widespread coverage by the transmission grid tend to favor on-grid supply as the most cost-effective route to electricity access (box figure). In the New Policies Scenario, this is the principal means by which the electricity rate is increased to around 70 percent by 2030. In areas where grid extensions are not cost-effective, mini-grids tend to provide the preferred solution. In Ethiopia, too, a significant proportion of the population lives in areas that can be best connected through the grid. But the overall population density of Ethiopia is half that in Nigeria, meaning that mini-grid and, especially, off-grid facilities are much more prominent.

Optimal split by grid type in Nigeria and Ethiopia, based on anticipated expansion of main transmission lines

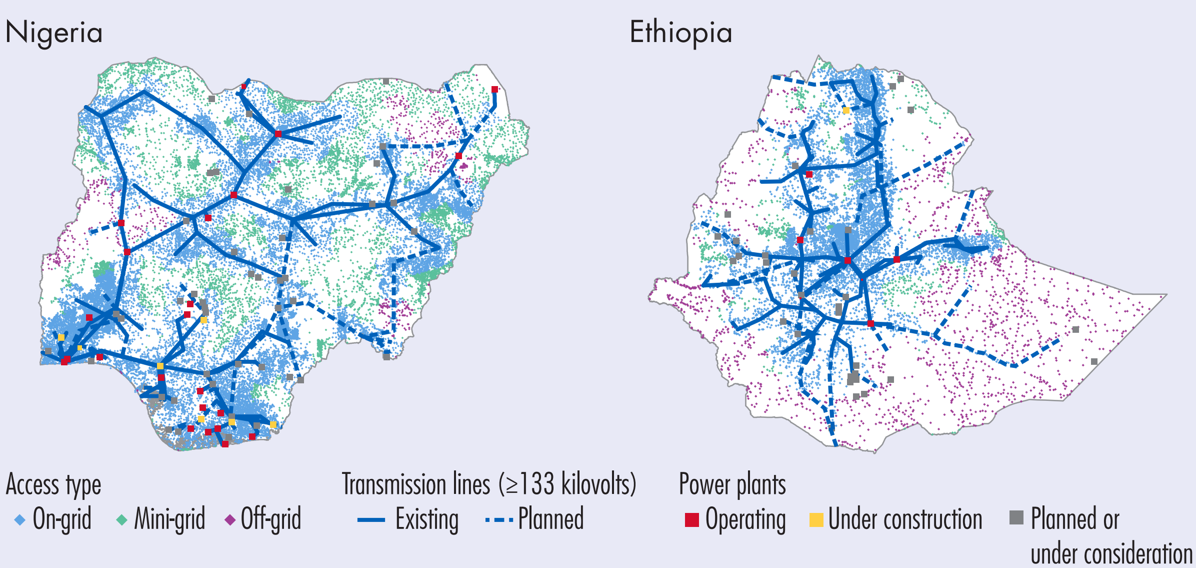
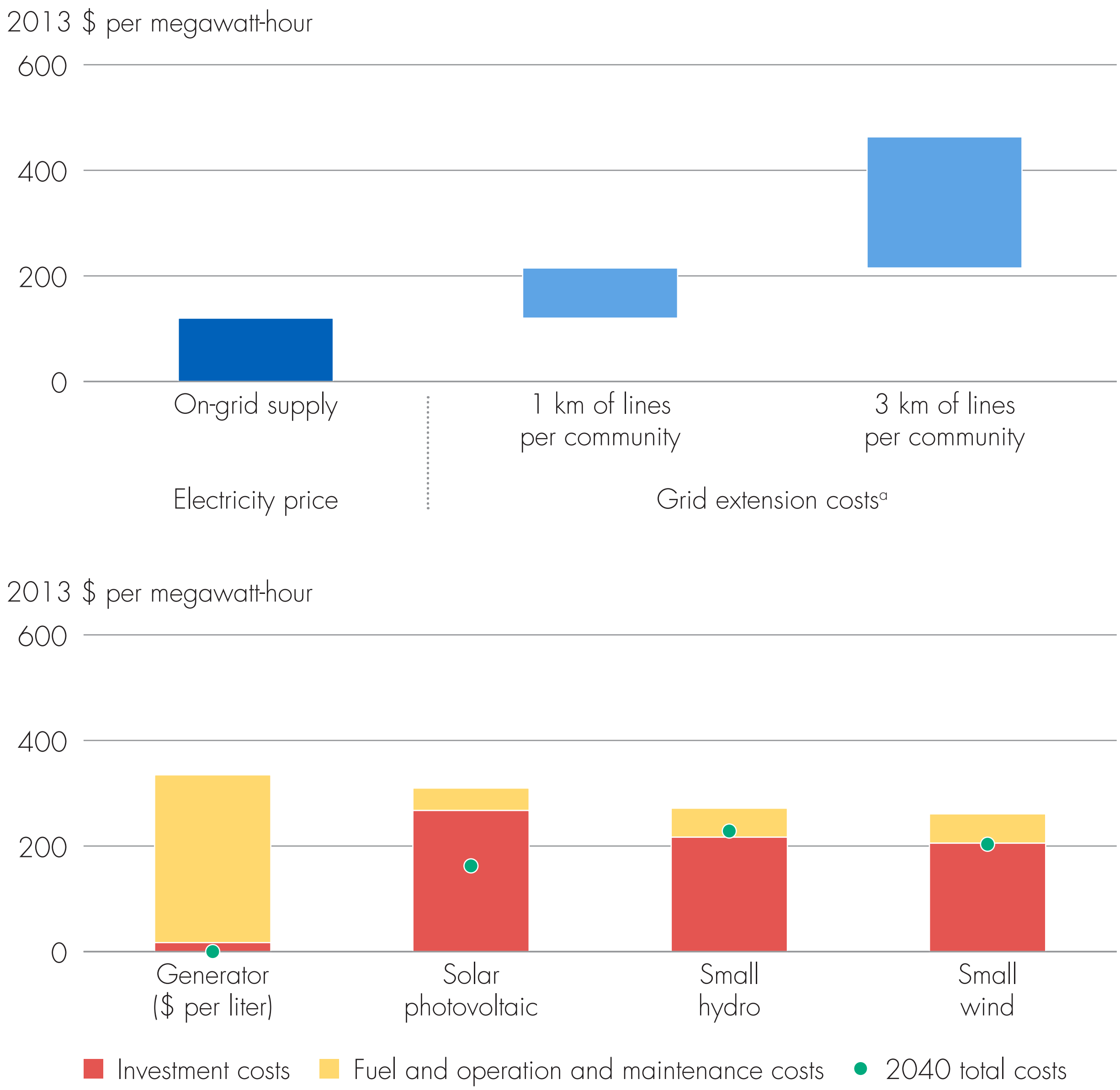


Figure 2.24. **Indicative levelized costs of electricity for on-grid, mini-grid, and off-grid technologies in Sub-Saharan Africa, 2012**



a. Costs of grid extension are calculated as the average cost of extending a medium-voltage grid a certain distance (1 km, say) to each community on a levelized cost basis.

Source: *Africa Energy Outlook* (IEA 2014b).

Note: Costs are indicative and will vary widely by local conditions such as electricity tariffs, population density, and the delivered cost of diesel. The quality of service for the technologies also varies: additional investment in batteries or back-up power may be needed to compensate for the variability of renewables or intermittent grid supply.

combining fossil fuel and renewable-based power generation (such as diesel and solar PV) can bring considerable flexibility and higher reliability of supply.

Non-solid fuels

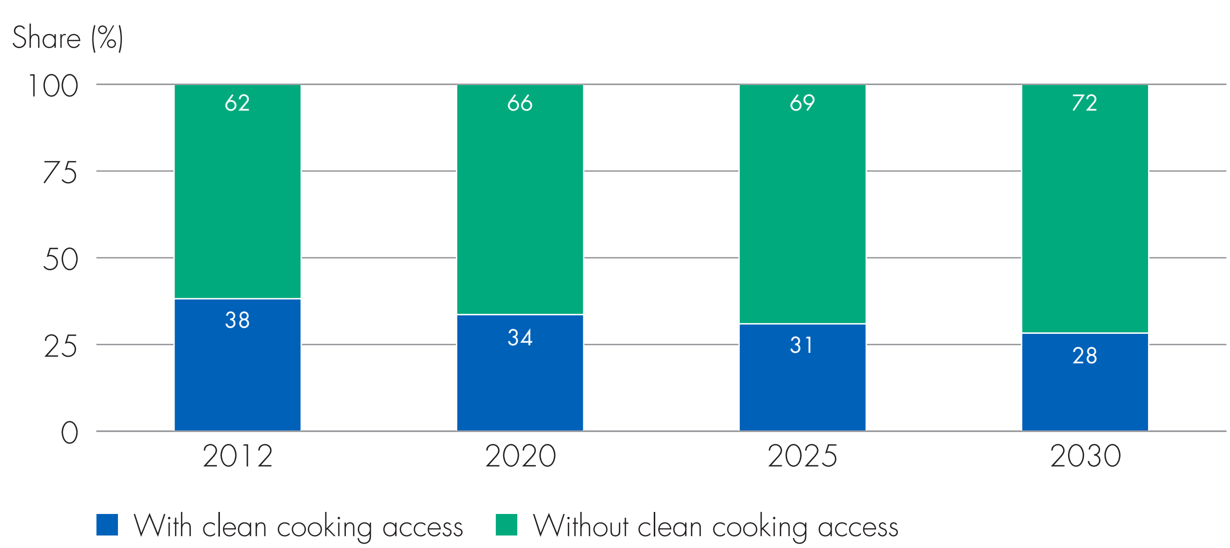
Worldwide, the number of people without modern cooking solutions is projected to decline to 2.4 billion people in 2030 in the New Policies Scenario, around 200 million fewer than in the projections of the Global Tracking Framework 2013, but still 28 percent of the global population by then (figure 2.25). The number of people without modern cooking facilities is still far higher than the number of people without electricity, suggesting that a large swathe of the population has electricity but continues to cook using solid biomass and traditional stoves. Around 1.6 billion people are projected to gain access to modern cooking solutions between 2013 and 2030 in the New Policies Scenario, averaging 110 million people a year.

In Sub-Saharan Africa, around 80 percent of residential energy demand is for cooking, compared with around 5 percent in countries of the Organisation for Economic Co-operation and Development. This is mainly due to households prioritizing energy for cooking within very restrictive budgets (when paid for) and the low efficiency of cookstoves (typically 10–15 percent efficiency for a three-stone fire, as against 55 percent for a liquefied petroleum gas [LPG] cookstove). Estimates of the amount of fuelwood consumed by households differ markedly, within and between countries, which has a huge impact on estimates of total solid biomass use (figure 2.26).

The correlation between high levels of solid biomass use for cooking and high levels of poverty in much of Sub-Saharan Africa can give rise to a perception that an increase in average incomes will lead to a fall in the traditional use of solid biomass, as use of other fuels increases. However, this is not borne out by historical trends: in Sub-Saharan Africa, outside South Africa, GDP per capita has increased by 3 percent on an annual average basis since 1995, and population by 2.7 percent a year. But the number of people without access to clean cooking facilities has still increased by 2.4 percent a year. That is, the population relying on traditional use of solid biomass has tracked population growth closely, despite rising incomes.

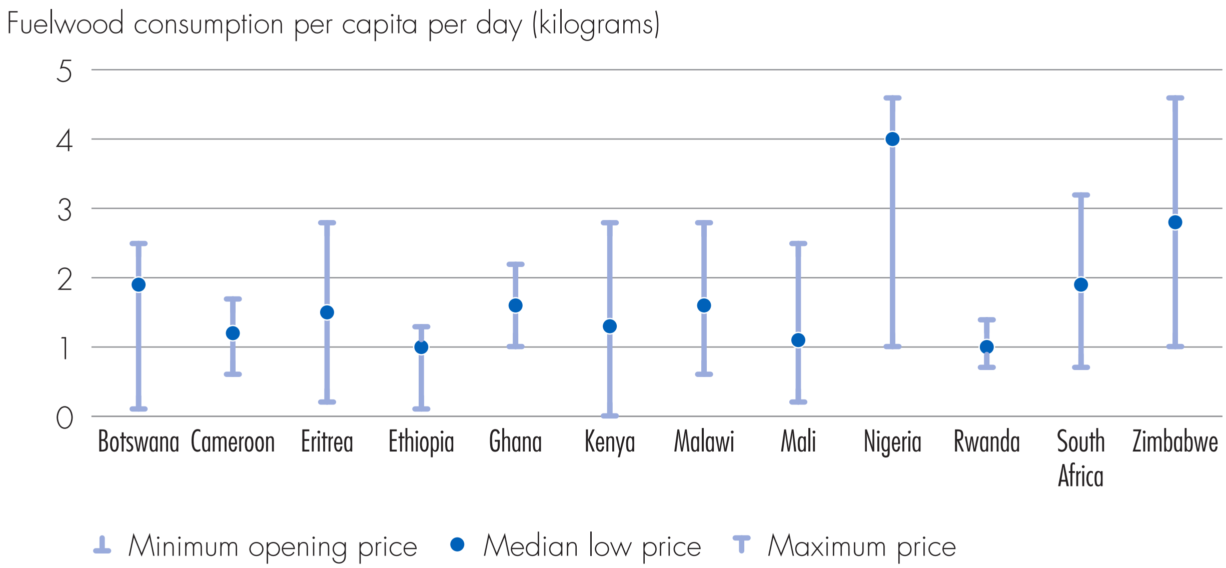
In the New Policies Scenario, the number of people in Sub-Saharan Africa without access to clean cooking increases to around 760 million by 2030. With a rising population, this means, more positively, that around 660 million people have access to clean cooking facilities in 2030, which is an improvement over today. Examining the trends by subregion, the number of people without access in East Africa decreases by around 30 million by 2030 (figure 2.27). Without the shift to more efficient use of biomass, the risks

Figure 2.25. **Share of world population with and without access to modern cooking solutions: New Policies Scenario**



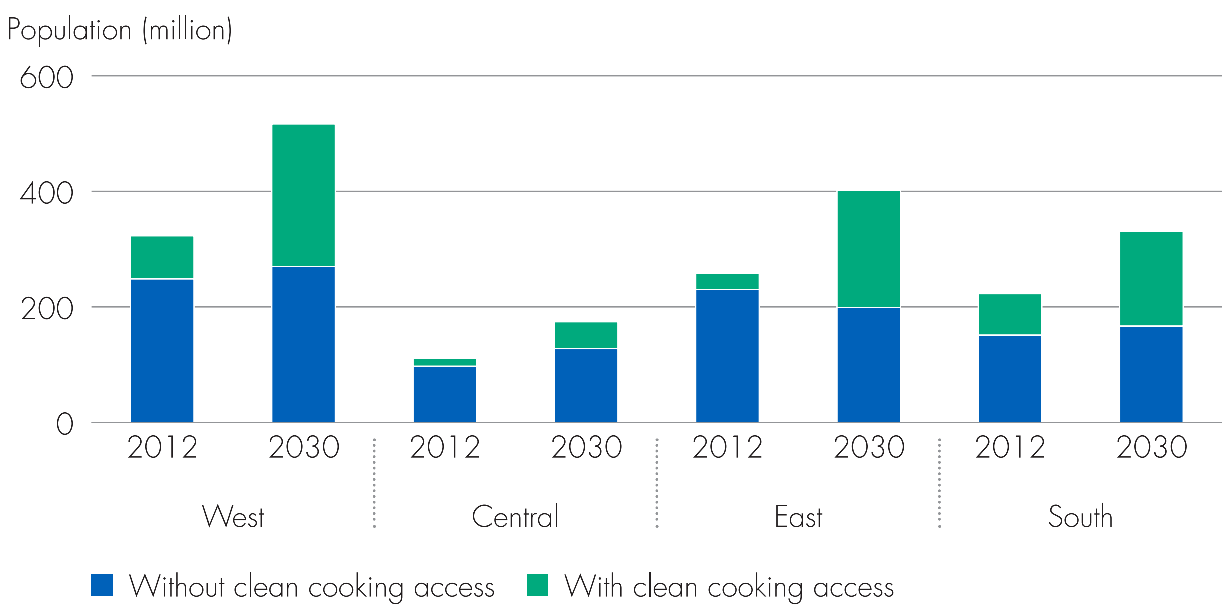
Source: *World Energy Outlook 2014* (IEA 2014a).

Figure 2.26. **Fuelwood consumption per capita a day, selected African countries**



Source: *Africa Energy Outlook* (IEA 2014b).

Figure 2.27. **Sub-Saharan Africa: New Policies Scenario**



Source: *Africa Energy Outlook* (IEA 2014b).

to an already depleting forest biomass stock would be much higher in East Africa, especially around urban areas where high demand for solid biomass and lack of regulation of the charcoal industry are blamed for 10–20 percent of the deforestation in these areas (GIZ, 2014). By contrast, in Central Africa, where forest biomass is more plentiful (and therefore relatively cheap), the population without access increases by around one-third.

What factors can raise access to clean cooking facilities if economic development and income growth do not automatically lower traditional use of solid biomass? In practice, numerous considerations besides income are in play—particularly relative prices, availability of alternatives, and scarcity of forest biomass—in availability and price of fuelwood, or the time required to collect it. In some cases, an increase in solid biomass prices makes alternative fuels competitive. This is particularly likely in urban areas, where charcoal can be more costly than or around the same cost as other cleaner alternative fuels. In Sub-Saharan Africa, the projections reveal important distinctions between urban and rural populations in the type of access gained from 2013 to 2030, and between different regions. Within urban areas, most of those gaining access do so by switching to other fuels, with LPG the best placed.[11] The share of urban households outside South Africa relying on traditional cookstoves decreases from 65 to 35 percent over the projection period. In rural areas, where household energy use stays dominated by solid fuels, those gaining access do so almost entirely via improved biomass cookstoves.

The projected level of investment in access to clean cooking in Sub-Saharan Africa reaches a cumulative $4.4 billion over the period to 2030. The main component is the cost of improved or alternative cookstoves (table 2.1). (The cost of infrastructure related to LPG, electricity, or natural gas distribution is not included.) Cookstoves require replacement, but only the cost of the first stove and half of the cost of a second stove is included in the projection, reflecting an assumed path toward such investment becoming self-financing.[12] Around 40 percent of the total is related to LPG cookstoves, 30 percent biogas digesters, and 30 percent solar cookers and improved biomass cookstoves.

Investment requirements

WEO 2014 (IEA 2014a) estimates about $19 billion of annual investments globally to 2030 in power plants and new transmission and distribution lines to increase electricity access in the New Policies Scenario. This is higher than historical estimates but not yet reaching the levels required to attain the goal. It will require greater clarity and consultation over the pace and direction in which the main electricity grid will be extended. For cooking, WEO 2014 estimates about $0.6 billion of annual investments globally to 2030 in cleaner cooking technologies,

Table 2.1. **Technology characteristics of different cooking options**

	Investment cost ($)	Efficiency (%)	Daily hours for cooking	Consumption per household (tons of oil equivalent per year)
Traditional cookstoves				
Charcoal	3–6	20	2–4	0.5–1.9
Fuelwood, straw	0–2	11	2–4	1.0–3.7
Alternative cookstoves				
Kerosene	30	45	1–3	0.1–0.2
LPG	60	55	1–3	0.08–0.15
Electricity	300	75	1.2–2.4	0.07–0.13
Biogas digester	600–1,500	65		
Improved cookstoves				
Charcoal	14	26	1.5–3	0.4–1.5
Fuelwood	15	25	1.9–3.8	0.5–1.6

Source: *Africa Energy Outlook* (IEA 2014b).

including LPG stoves mainly in urban areas, and improved biomass stoves and biogas digesters largely in rural areas.

All previous estimates find that a significant scale-up in investments is required from current levels and from expected levels based on current and announced policies (table 2.2). Unsurprisingly, the large majority of these additional investments are required in Sub-Saharan Africa and developing Asia. For electricity, additional investments in grid electrification are required to meet the needs of fast-growing urban populations, although mini-grid and off-grid solutions are expected to take up a hefty share of investments in remote areas where extension of the main grid would not be the most economically attractive approach. New business models involving, for instance, prepayment or pay-as-you-go for a certain level of service have been used in some countries and can be commercialized by the private sector. The scale of investments required to realize universal access to modern cooking solutions by 2030 is, in some cases, assumed to be much smaller than for electricity, but progress is still slow, and clean cookstoves need to be further disseminated through different channels, such as concessional financing and microfinance.

A non-comprehensive review of the access investment estimates (Bazilian et al., 2014) published over the last decade highlights that the models and assumptions behind these calculations sometimes lack transparency, and those that are transparent reveal the following limitations:

- Most studies focus solely on capital costs and do not explicitly consider recurrent costs like fuel or operation and maintenance (O&M).
- Investment needs are disaggregated by region but not by country.
- Some approaches lack an explicit breakdown between generation, transmission, and distribution costs.
- Per capita demand assumptions imply that the world's poor will continue to live in poverty and demand small amounts of electricity over 2010–30.

Table 2.2. **Estimates of investment needs to reach universal access**

Goal	Investment needs estimates ($ billion/year)		Period	Source
	Electricity	Cooking		
Universal electricity access	45		2011–30	SE4All (2014) Finance Committee
Universal energy access	12–279	18–41	2010–30	Bazilian et al. (2014)
Universal energy access (incremental)[a]	65–86		2011–30	Pachauri et al. (2013)
Universal energy access	44.5	4.5	2011–30	IEA (2012)
Universal energy access	15	71	2010–30	IIASA (2012)
Universal energy access	48		2010–30	Dobbs et al. (2011)
Universal energy access	35–40[b]	39–64[c]	2010–30	AGECC (2010)
Universal electricity access	~55			Saghir (2010)
Universal electricity access	42.9		2005–30	World Bank Group (2006)

Source: Adapted from Bazilian et al. (2014).

a. Pachauri et al. (2013) calculate the incremental cost above current trends to achieve universal EA by 2030 in rural areas only; reported in 2005 dollars.

b. Based on IEA (2009).

c. Estimates include the capacity development costs of multiple supply options in $ billions/year: improved cookstoves (11–31), biogas (30–40), and LPG (7–17).

- Most approaches do not distinguish between the shares of grid extension, mini-grid, and off-grid systems from one region to the next and fail to isolate the costs of various technologies from one region to the next.

- Studies exclude the impact of geography and population density on costs.

This report unveils a new country-level investment needs model called the Access Investment Model (AIM), developed to provide greater clarity on the scale of the access challenge based on the multi-tier access framework for electricity (World Bank 2013). This model has been used to estimate the investment required to achieve different levels of electricity access among countries with high access deficits. The assumptions of AIM are detailed in annex 2.

This model draws on two previous modeling efforts. Bazilian et al. (2014) present a methodology for estimating regional electricity-access investment needs that incorporates capital and recurrent costs as well as transmission and distribution costs by using the total levelized cost of each generation technology; that simulates low, medium, and high scenarios of per capita consumption (in efforts to move beyond household demand and perpetual conditions of poverty, and to incorporate basic productive activities); and that makes separate energy mix assumptions for generating electricity in mini-grid and off-grid settings. Similarly, in preparation for the June 2014 release of the SE4All Finance Committee Report, in which the World Bank Group, Bank of America Merrill Lynch, and the Brazilian Development Bank (BNDES) have assessed the investment and innovative financing required to achieve SE4All's three global energy goals, the World Bank developed a global electricity access investment needs model that disaggregates investment required in each country; assumes growth in per capita electricity demand over the model horizon; uses Bazilian et al.'s formulation for generation, transmission, and distribution, capital and recurrent costs; and specifies the shares and costs of electrification technologies per region.

AIM builds upon these estimates to develop a transparent global model, based on country data, with the following features and capabilities:

- *Electricity access tiers.* The multi-tier measurement of EA provides the flexibility of choosing from a range of target-setting approaches. In one such approach, targets may be set by assigning the minimum EA tier that must be delivered to every consumer. Such targets will depend on the baseline situation in a selected geographic area, its development status, the most pressing needs of its population, and the budget. For example, countries in which a high proportion of the population lacks electricity in any meaningful form might set a target of moving people from tier 0 to tier 1 to ensure basic lighting services, whereas countries in which most people already have some form of access to electricity could focus on moving people into tier 4 or 5. These five access tiers are incorporated into AIM to help policy makers understand the cost implications of providing varying degrees of access, which will also assist countries develop national EA targets.

- *Improved demand representation.* Three elements of demand are modeled: (i) as described above, there are varying levels of access that translate into differing levels of electricity demand. The power and energy requirements of each access tier are explicitly modeled and incorporated; (ii) research and experience shows that demand typically increases over time due to the gains from increased productivity afforded by EA. AIM users can specify and alter the evolution of demand over time by defining the rate at which households move from one tier to the next; and (iii) industrial and commercial demand growth is also captured as it is important to represent the power sector transformation needed to support basic productive uses and community services, and a move to a more vibrant and equitable global economy.

- *Improved supply cost formulation.* For each of the access tiers described above, capital and recurrent costs for generation, transmission, and distribution are explicitly defined (where applicable) for each region and, if possible, each country. A portfolio of supply options for each region (or country), electrification method, and tier are specified.

- *Scenario and sensitivity analysis.* The future is highly unpredictable: demand may shift unexpectedly; cost estimates may need to be improved or updated as prices change; and each country may set separate energy-access tier targets. AIM therefore allows users to test scenarios and conduct sensitivity analysis.

AIM is a transparent tool that can be used by governments and stakeholders. However, it is not meant to provide more than a first-order estimate of the magnitude of the investment challenge and a snapshot of the possibilities for expanding access. It is available on request so that governments can simulate scenarios that best embody the strategy and access pathway to universal electricity most appropriate for their social and political aspirations. Governments are encouraged to change and improve input parameters—demand estimates, transmission and supply costs, population density in regions—as well as use the output of the tool to guide more detailed planning efforts when developing SE4All Investment Prospectuses (as Rwanda, for instance, is doing).

The case of Tanzania is used here to simulate the provision of universal access via different access scenarios. The electricity access rate in 2010 was 16 percent, with urban access of 46 percent and rural access of only 4 percent. Five scenarios are explored to move the unconnected households into access tiers.

- Scenario 1: all new access connections are tier 1
- Scenario 2: all new access connections are tier 2
- Scenario 3: all new access connections are tier 3
- Scenario 4: all new access connections are tier 4
- Scenario 5: all new access connections are tier 5

It is assumed that universal access is reached by 2030 via grid, mini-grid, and off-grid (single-user) supply options depending on the level of access provision (figure 2.28, top panel shows rates for Scenario 3). While AIM enables users to specify growing demand of newly connected households, for illustrative purposes it is assumed that demand remains constant over time.

Grid power supply is assumed to evolve based on the 2012 Update to Tanzania's Power System Master Plan (TANESCO, 2012) (figure 2.28, bottom panel). Mini-grid power supply is assumed to comprise solar (27 percent), micro-hydro (37 percent), and diesel (36 percent), and the primary sources for off-grid systems are solar PV and diesel generation.

Cumulative costs of electricity access provision range from $1.5 billion to $42 billion for Tanzania, reflecting the tremendous difference in costs for national access tiers and rural and urban households. The lower bound is Scenario 1 and the upper bound Scenario 5, indicating investment ranging from 5 to 150 percent of 2012 GDP (in current $)—a huge challenge for Tanzania. This equates to average annual investment needs of $65 million to $2.1 billion (figure 2.29). The average cost per capita each year ranges from $2 to $215 depending on the supply technology (table 2.3).

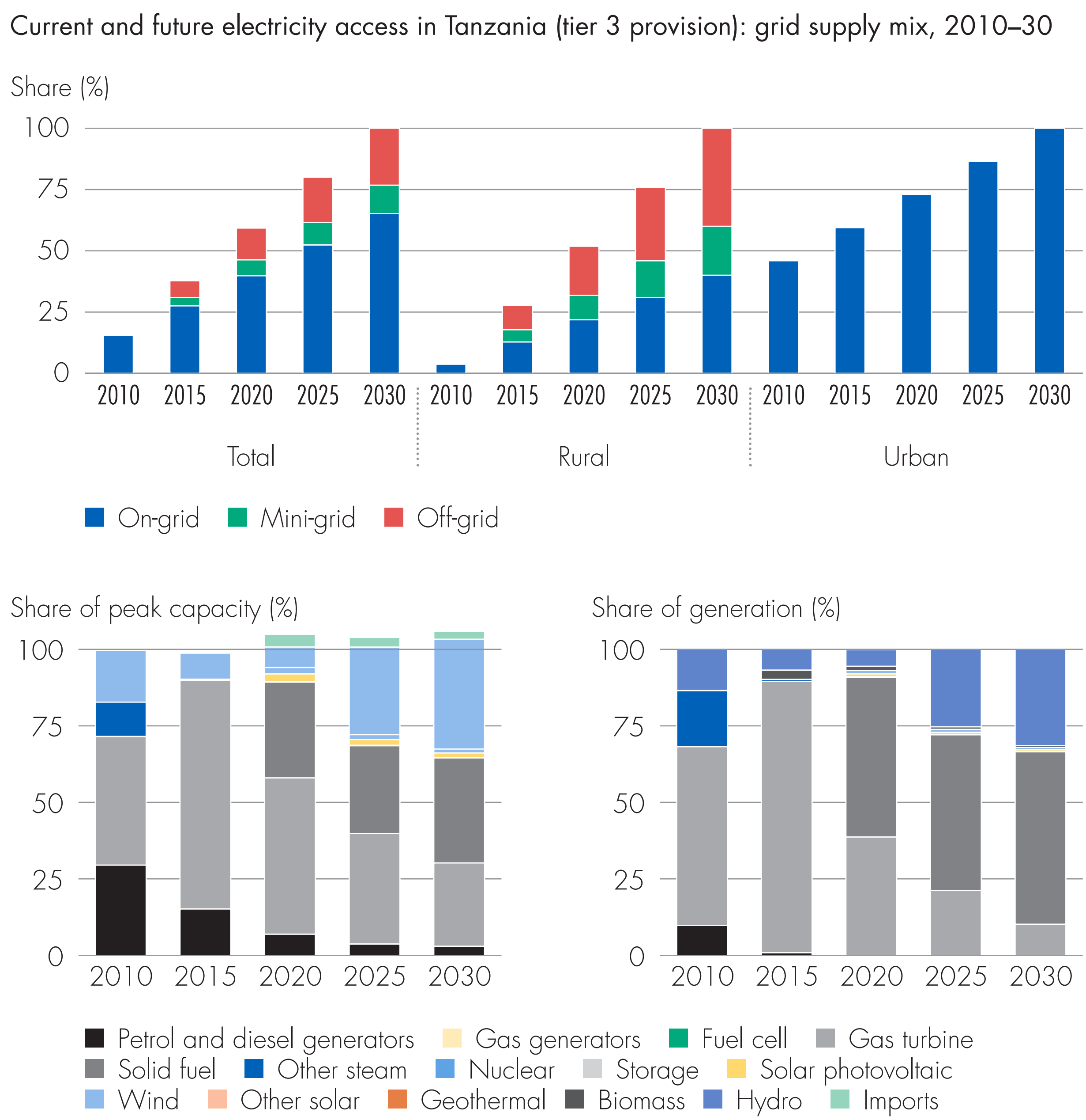
The SE4All Finance Committee (2014) estimated that the cost of universal access provision in Tanzania is $1.2 billion a year for 2010–30. The Committee's methodology differs from that of AIM. For example, newly connected urban households were assumed to demand, on average, 500 kWh a year within the first year of being connected, while newly connected rural households 250 kWh a year; consumption was then projected to reach 750kWh a year. This is roughly equivalent to the provision of tier 3 to tier 4 access for all newly connected households, estimated to require $0.5 to 1.2 billion a year using AIM.

For a group of selected high-impact developing countries, the aggregate annual investment needs range from $1 billion for tier 1 access to $40 billion for tier 5 access. For these high impact countries, the five scenarios described above are explored to move the unconnected households into access tiers. Figure 2.30 presents an upper bound of tier 5 access and a lower bound of tier 1 access (with the SE4All Finance Committee estimate for comparison). Three findings emerge.

First, the investment required varies dramatically for any single country—by more than thirty-five times. Therefore, given an investment budget, a country has options from which to select the tier or tiers of access provision. Second, Nigeria and Ethiopia, the largest access-deficit countries in Sub-Saharan Africa, have to spend $100 million–160 million annually to deliver even tier 1 access, and $4-$5 billion per year to deliver Tier 5 access. Third, SE4All's Finance Committee (2014) estimate is at the higher end of the AIM estimate, falling between the investment required for Tier 4 and Tier 5 access.

The Committee estimated that the cost of universal access provision for these select high impact countries is roughly $25 billion USD per year for the period 2010 through 2030. However, the underlying assumptions of the Committee analysis differ from that of this AIM assessment. For instance, the methodology employed by the Committee

Figure 2.28. **Assumptions in Tanzania's Access Investment Model**

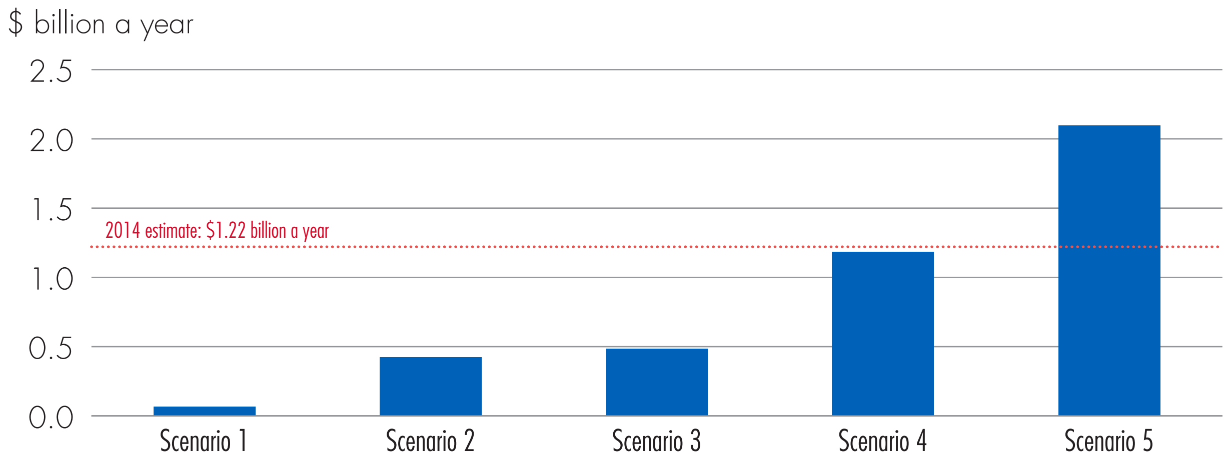


Source: Authors' estimates.

assumed a different breakdown of grid, mini-grid and off-grid supply technologies than that of AIM. Additionally, the level of consumption of newly connected households also differs, as demand grows from tier 3 to tier 4 in the Committee's assessment. The provision of tier 3 to tier 4 access for all newly connected households was estimated to require investment between $8 and $20 billion USD per year using AIM.

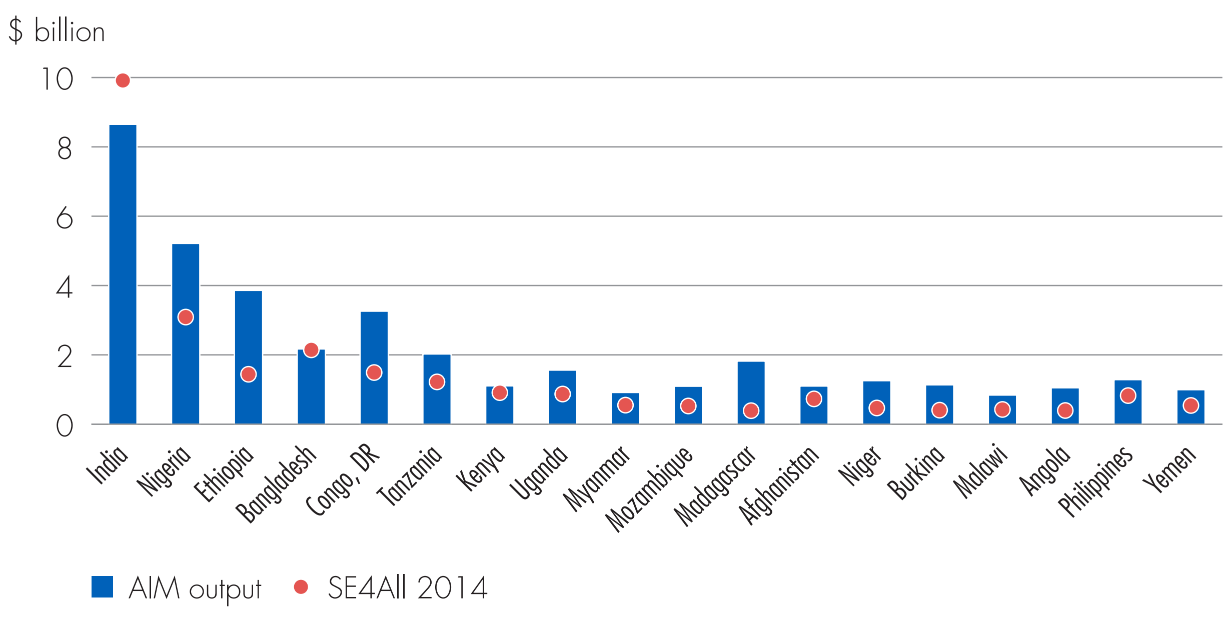
The global investment requirements could therefore range from $1.5 billion to $52 billion a year. This estimate is arrived at by scaling up the figures for the 18 countries that make up 79 percent of the global electricity access deficit. At the higher bound, this equates to at least double the investment observed in WEO 2014 in the New Policies Scenario. While this assessment confirmed that the absolute value of the range of investment

Figure 2.29. **Average annual cost of electricity access provision in Tanzania, five scenarios, 2010–30**



Source: Authors' estimates

Figure 2.30. **Range of annual investment required for various scenarios of universal access provision**



Source: Authors' estimates.

Table 2.3. **Annualized cost of electricity access provision per capita per supply type under five scenarios: Tanzania ($ per capita a year)**

Electricity supply	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Grid	n/a	n/a	14.54	31.53	54.53
Mini-grid	n/a	17.38	29.33	n/a	n/a
Off-grid	2.21	24.40	93.53	212.30	n/a

Source: Author's estimates.

Note: n/a is not applicable.

required for any single country is proportional to the number of people living without access, additional factors such as the area of the country and corresponding population density, the supply technologies under consideration, and the cost of transmission and distribution infrastructure have a tremendous impact on the investment needed to achieve universal electricity access.

Annex 1. Annual growth rate of access

The annual growth rate is calculated by using the absolute net increase of population with access as a numerator with the population at the end of the period as the denominator. The total is divided by the total years comprises in the period to annualize the growth. This way the growth performance of a country is normalized with respect to its population.

To summarize, the formula is:

$$\text{Annual growth rate of access} = \frac{\Delta A(y_t - y_{t-1}) - \Delta P(y_t - y_{t-1})}{P(y_t)} \times \frac{1}{(y_t - y_{t-1})} \times 100$$

$\Delta A(y_t - y_{t-1}) - \Delta P(y_t - y_{t-1})$ = Net increase in population with access

$\Delta A(y_t - y_{t-1})$ = Increase in population with access between the year t–1 and the year t

$\Delta P(y_t - y_{t-1})$ = Increase in total population between the year t–1 and the year t

$P(y_t)$ = Total population in the year t

To give a practical example:

	Population with access (million)		Total population (million)		$\Delta A(y_t - y_{t-1})$	$\Delta P(y_t - y_{t-1})$	Annual growth rate (%)
	2010	2012	2010	2012			
Bangladesh	82.1	92.2	148.7	154.7	10.1	6.0	1.3
Brazil	191.0	197.7	194.9	198.7	6.6	3.7	0.7
Ethiopia	19.1	24.4	82.9	91.7	5.3	8.8	–1.9
India	918.5	973.3	1,224.6	1,236.7	54.8	12.1	1.7
Indonesia	226.0	237.0	239.9	246.9	11.0	7.0	0.8
Mexico	112.3	119.8	113.4	120.8	7.5	7.4	0.0
Nigeria	76.0	93.9	158.4	168.8	17.8	10.4	2.2
Pakistan	158.7	167.7	173.6	179.2	9.0	5.6	1.0
Philippines	77.7	84.6	93.3	96.7	6.9	3.4	1.8

Annex 2. Assumptions and methodology of the Access Investment Model

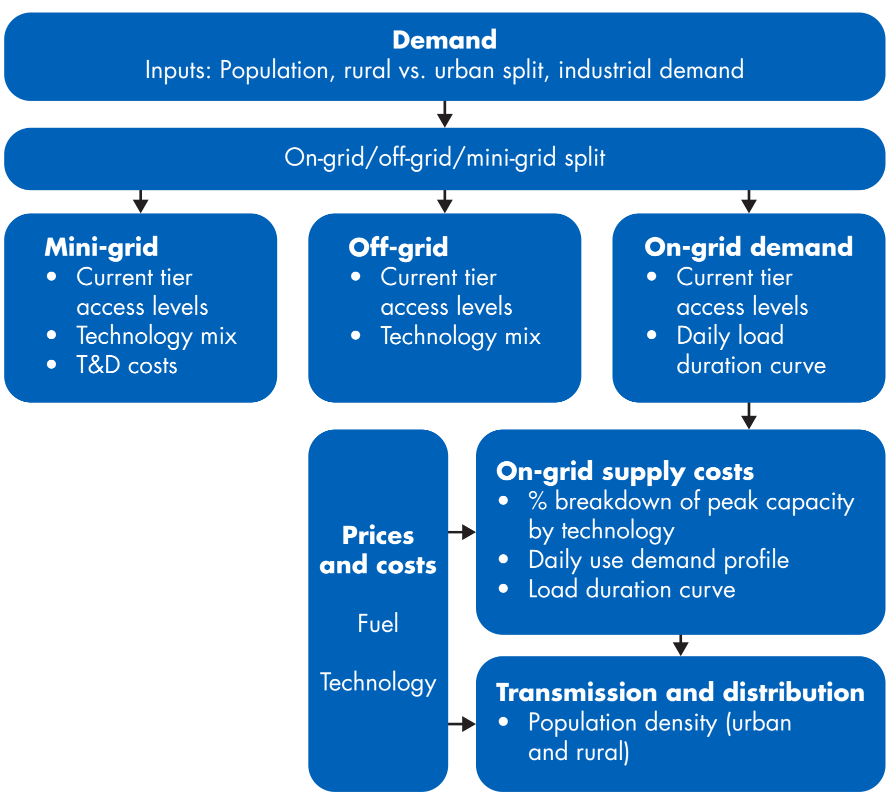
The Access Investment Model (AIM) calculates the investment, operating, and fuel costs to provide enough on-grid, mini-grid, or off-grid electricity for meeting a specified scenario for electricity access (figure A2.1). Costs are calculated for five-year intervals from 2010 to 2030, the study horizon.

Specifying the energy access scenario

AIM allows users to specify an electricity access scenario for a single country. Four elements must be defined:

- *Split between type of access for households:* For each year (2010, 2015, 2020, 2025, and 2030), the user specifies the fraction of the population (disaggregated by urban and rural categories) with access to on-grid, mini-grid, and off-grid supply sources.
- *Split between tiers for households with access:* For 2010 the user specifies the fraction of connected households with tier 1, 2, 3, 4, and 5 supply. The user must also specify the rate of progress from one tier to the next (as a fraction of the customers in any access tier).
- *Split between access tiers for newly connected households:* For each year (2015, 2020, 2025, and 2030), the user specifies the fraction of newly connected households provided with tier 1, 2, 3, 4, and 5 supply.
- *Industrial and commercial demand:* The user specifies industrial and commercial peak power demand in up to 10 subsectors. Demand growth can be specified by entering an annual growth rate or manual values for peak demand for each year (2010, 2015, 2020, 2025, and 2030).

Figure A2.1. **Overview of access investment model**



Source: Authors.

The tool draws on the United Nations World Urbanization Prospects[13] to generate population projections for rural and urban areas within the country. The fraction of the population with access to the grid, mini-grids, and off-grid supply technologies in 2010 is input into AIM. For the analysis presented here, it is also assumed that new access provision will be achieved via these technologies in the proportions presented in table A1.1. The evolution of household access from 2010 to 2030 is calculated as a simple linear progression. For example, if in 2010 access to off-grid supply is 2 percent of the population but by 2030 reaches 10 percent, then by 2020 off-grid access is estimated at 6 percent of the population. See table A1.2 for the split between type of access assumed for households in Tanzania in the case of Tier 3 provision.

For the purpose of the analysis presented above, it is assumed that solar is the dominant off-grid supply technology for households given Tier 1 and Tier 2 access. Off-grid supply is equally split between solar and diesel gensets for Tier 3 access, while the dominant off-grid supply technology for Tier 4 access is the diesel genset. AIM users can change these assumptions as appropriate and can consider additional off-grid system technologies.

The fraction of connected households with tier 1, 2, 3, 4, and 5 supply in 2010 is input into the AIM model for each country, and users can specify the rate of progress from one tier to the next as a percent of the customers in any single tier. For the simplified analysis presented here, it is assumed that demand remains constant from 2010 to 2030, and there is no shift from one tier to the next. Access tiers are defined in table A1.3.

Finally, the split between access tiers for newly connected households for each year (2015, 2020, 2025, and 2030) is assumed as follows for the scenarios explored in this Global Tracking Framework:

- Scenario 1: all new access connections are tier 1
- Scenario 2: all new access connections are tier 2
- Scenario 3: all new access connections are tier 3
- Scenario 4: all new access connections are tier 4
- Scenario 5: all new access connections are tier 5

Table A2.1. **Assumed split between type of access provision per tier level for newly connected households (%)**

Tier	Rural			Urban		
	Off-grid	Mini-grid	Grid	Off-grid	Mini-grid	Grid
Tier 1	100			100		
Tier 2	50	50		100		
Tier 3	25	50	25			100
Tier 4	20		80			100
Tier 5			100			100

Table A2.2. **Example of the split between type of access for households: the case of tier 3 provision in Tanzania case study (%)**

Type	Rural					Urban				
	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
Grid	3.7	9.5	15.3	21.1	26.9	45.9	59.5	73.0	86.5	100.0
Mini-grid	0.0	12.2	24.4	36.5	48.7	0.0	0.0	0.0	0.0	0.0
Off-grid	0.0	6.1	12.2	18.3	24.4	0.0	0.0	0.0	0.0	0.0

Table A2.3 **Definition of household access tiers in AIM**

Capacity Tier	Tier 0 No capacity	Tier 1 Very low capacity	Tier 2 Low capacity	Tier 3 Medium capacity	Tier 4 High capacity	Tier 5 High capacity
Minimum daily supply capacity		5 watts 20 watt-hours	70 watts 275 watt-hours	200 watts 1.0 kilowatt-hours	800 watts 3.4 kilowatt-hours	2,000 watts 8.2 kilowatt-hours
Supported appliances		Very low power appliances	Low power appliances	Medium power appliances	High power appliances	Very high power appliances
Typical supply technologies		Solar lantern	Rechargeable battery Solar home system	Medium solar home system Fossil fuel–based generator Mini-grid	Large solar home system Fossil fuel–based generator Mini-grid Central grid	Large fossil fuel–based generator Central grid

Industrial and commercial demand values assumed for each country of the analysis are based on the most recent power system development plans or publicly available sector strategies.

On-grid demand

Within AIM, on-grid demand is composed of household demand, and of industrial and commercial demand. Based on the input scenario for the level of on-grid access for urban and rural households through 2030 (above), the peak load (W) and average daily consumption (Wh) per household in each tier, along with an estimate of current and future peak power demanded by up to 10 subsectors of industry and commerce, AIM generates a projection of country-wide peak and energy grid demand over time.

AIM also allows users to specify a typical daily demand profile for each category of consumer. For the household sector, different access tiers can have a different daily profile (for example, households with lower-tier access levels may have lower base-load levels of consumption, mostly using the electricity for lighting after dark). Industrial and commercial users are likely to have higher consumption during normal working hours. The profile assumed for the Tanzania case study is in figure A1.2.

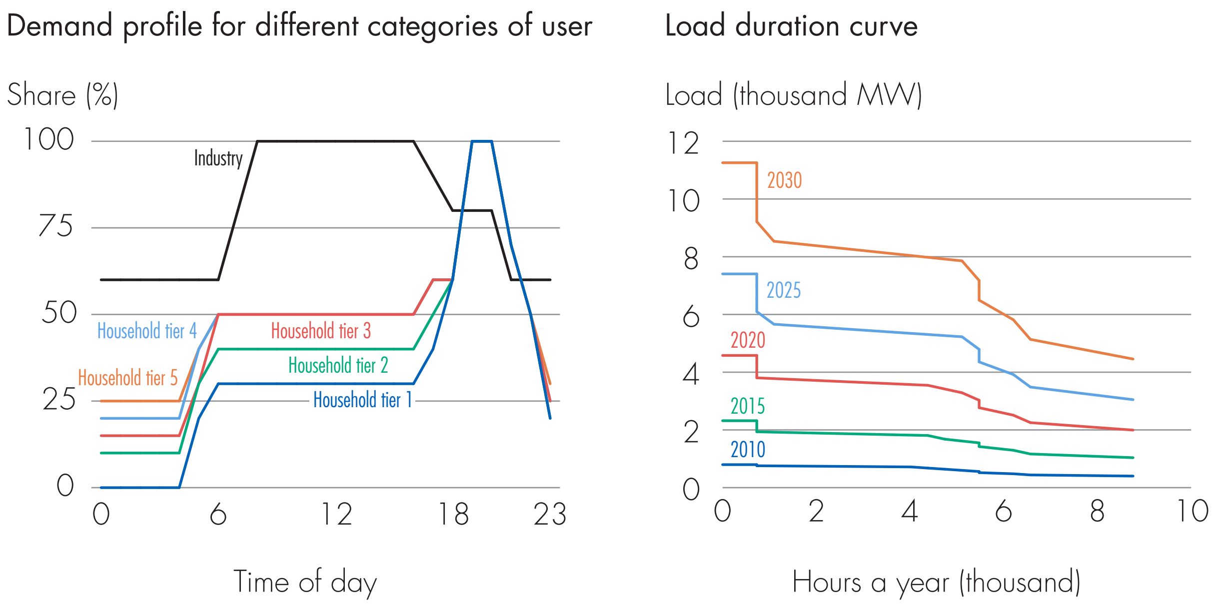
These profiles are aggregated to generate a countrywide load-duration curve, which provides an estimate of both the peak demand (MW) and the total amount of electricity (GWh) expected to be generated during the year, to 2030. The user can then specify a reserve margin that provides some additional capacity to increase reliability and security of supply. In some cases, there may be a shortfall between supply and demand, and the user can also specify if this is the case.

On-grid supply

The tool allows users to input the grid generation technologies to meet projected demand. More specifically, the user enters the share of installed capacity for each technology during each year of the study horizon (2010, 2015, 2020, 2025, and 2030). The values assumed for the analysis in chapter 5 are based on the most recent power system development plans or publicly available sector targets. Information on the generation technologies, along with the load duration curve, is used to determine optimal dispatch of installed power supply and subsequently the costs of on-grid power generation for each five-year period from 2010 to 2030.

The dispatch algorithm calculates how the load duration curve is to be filled using the specified generation technologies. Some generation types such as wind and solar have much lower firm capacity than others, so that meeting a particular level of power demand with these technologies would require a higher installed capacity (table A1.4). For each of these technologies, the user defines the average firm capacity at both base-load and

Figure A2.2. **Example of demand profile for different categories of user and of load duration curve, from Tanzania case study**



Source: Authors' estimates.

peak periods. Statistically, non-dispatchable plants often have a lower contribution to peak than to base load. Hydro plants with reservoirs, on the other hand, may function differently if system operators choose to dispatch them preferentially during peak hours.

The dispatch algorithm subtracts the firm capacity of non-dispatchable renewables (wind, solar, run-of-the-river hydro, etc.) from the load duration curve. Subtracting in this way gives a residual load duration curve that has to be met by dispatchable (mostly thermal) plants. The tool calculates a merit order dispatch such that technologies with the lowest marginal cost are assumed to be dispatched first, and the highest marginal cost plants are dispatched last, so that they operate only during peak hours. This roughly represents the lowest cost way of using a given fleet of power generation plants.[14] The procedure identifies how much electricity each technology type generates.

Capital and recurrent costs, including fuel and O&M costs, of various generation technologies are drawn from the World Bank/ESMAP 'Model for Electricity Technology Assessment' (META) with projections for oil prices for 2030 based on IEA *World Energy Outlook 2014* scenarios. The price of other fuels is assumed to follow the same trend as oil. The total installed capacity (MW) and total generation (GWh) for each type of plant is combined with data on capital and operating costs to calculate the total investment and running cost of electricity generation for each five-year period to 2030.

Transmission and distribution

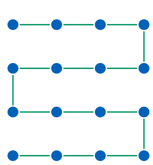
The methodology for calculating transmission and distribution (T&D) costs in the AIM model was designed to allow a bottom-up analysis of T&D needs, while simplifying the analysis as much as possible to enable multiple countries to be assessed based on basic country characteristics, including total land area and population density. The methodology also accounts for increasing consumption per household over time leading to higher T&D costs to carry the additional power.

A country's population is divided into two groups, rural and urban. Using publicly available demographic and land use information, the population density for each group is determined and input into AIM. Based on the population density and populations of urban and rural groups, the area populated by each group is also calculated. Households are assumed to be evenly spaced across this area. This enables AIM to modify the land area under consideration if there are unpopulated areas within the country.

Table A2.4. **Assumed firm capacity for renewable generation technologies in AIM (% of installed capacity)**

Renewable generation type	Max contribution to peak	Max contribution to base load
Solar PV (micro)	0	36
Solar PV (mini)	0	36
Solar PV (middle)	0	36
Solar PV (large)	0	36
Wind onshore (micro)	5	50
Wind onshore (mini)	5	50
Wind onshore (middle)	5	50
Wind onshore (large)	5	50
Wind offshore	5	68
PV–wind hybrid (micro)	5	41
PV–wind hybrid (mini)	0	54
Solar thermal with storage	50	50
Solar thermal without storage	0	36
Pico hydro (micro)	30	30
Pico hydro (mini)	30	30
Micro hydro	30	30
Mini hydro	45	45
Large hydro (reservoir)	70	34
Large hydro (run-of-the-river)	50	50

T&D lines are divided into six different voltages (0.24 kV, 11 kV, 33 kV, 66 kV, 110 kV and 230 kV). The lowest voltage 0.24V lines are assumed to go to every house. If we consider a particular (square) distribution area that has n line units along one side of the square, the total length of these low-voltage lines is approximately equal to $d(n^2 + 2n)$, where d is the average distance between houses (see below).



Number of lines along one edge $(n) = 3$

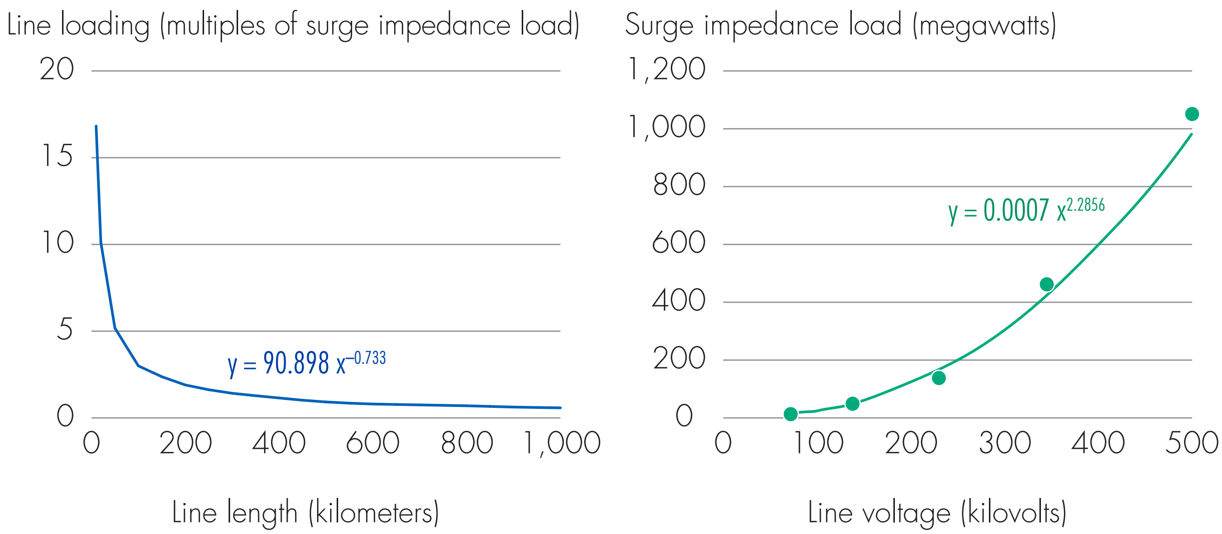
Total number of lines to connect all units $(n^2 + 2n) = 15$

The total number of houses that can be supplied by the low-voltage line is limited by the accumulated power demand of houses in that area. That is determined by the power requirement per household (as defined according to the multi-tier access demand scenario), and the number of households in the area. Once this power threshold is reached, either multiple lines must be installed to carry the power, or the next voltage level of transmission must be employed. To calculate the costs of the next level, the same process is applied, but this time, instead of each unit representing a household, it represents a whole distribution zone of the lower voltage level. This process is repeated for each of the voltage categories, each time scaling up the total area served until the whole area of the country is covered.

The maximum power-carrying capacity of a line is determined by its surge impedance load (SIL), a function of the distance over which the power is to be carried and the voltage level of the line. SIL is a measure of power-carrying capacity (measured in MW), but for short distances, power lines can carry many multiples of the SIL value (as measured by the St Clair curve).[15] These two relationships are shown in figure A1.3, and a parameterized relationship for each curve was derived for use in the model. These two relationships, combined with the fact that the power demand is a function of the area served (therefore increases with the square of the line length), provides a basis for calculating the maximum line length for each voltage category.

Once the line lengths for each voltage category have been calculated, they are multiplied by the cost per km for each

Figure A2.3. **Relationship between the maximum carrying capacity (line length), surge impedance load, and line voltage**



Source: Authors' estimates, adapted from Dunlop et al. (1979).

Note: The curve (on the left) was developed by St. Clair in the early 1950s based on empirical knowledge. In 1979, Dunlop et.al. published a paper demonstrating the physics and mathematics behind St. Clair's curve. Both were the subject of IEEE papers and are available online through either IEEExplore or the PES digital library.

type of line to obtain total T&D costs.[16] This is used to provide an estimate of the T&D cost per household. Substation costs are estimated as a percentage additional cost on top of the line costs. Variations in T&D costs between countries are accounted for by a "country cost premium," which can be calibrated against measured costs for countries where data exist, and used to extrapolate results to other similar countries.

This simple procedure allows T&D costs to be estimated based on a small number of inputs, namely the density of rural and urban populations, information on power requirements per household (drawing on the multi-tier access framework), and basic cost per km for different categories of T&D lines. The algorithm has advantages in terms of being able to apply a consistent methodology across many countries where data may be limited, but it should be kept in mind that important aspects of real-world T&D rollout are excluded. For example, there may be cases where rollout of a centralized grid is impractical, and other solutions such as mini-grids may be more appropriate. However, the relative advantages of centralized grids and mini-grids requires a more detailed geographic analysis of each country. Just as well, the assumption that populations are homogeneously spread out over a given area is a considerable simplification. In reality, populations tend to be more or less clustered into villages and towns, and these population centers themselves can be clustered in particular areas of the country. To some extent, this clustering can be accounted for by focusing on the effective land area of the country where the majority of people live to give a more indicative figure for population density.

Mini-grid generation

Cost calculations for mini-grid generation are also driven by the household access scenario for each five-year period through 2030. As for the on-grid calculations, the access scenario is specified by the breakdown of access into the five-tier access levels, subdivided by urban and rural populations. Technology options for mini-grid generation include solar, micro-hydro, and diesel generation. AIM allows users to specify per year (2010, 2015, 2020, 2025, 2030) the fraction of mini-grid capacity contributed by each of the technologies.

Based on the access scenario defined by the user, AIM calculates the total power (W) and energy (Wh) to be supplied by mini-grids. Using technology cost data from ESMAP's META model, capital and recurrent costs of

Table A2.5. **Assumed capital costs of off-grid supply options in AIM for Tanzania**

Tier	Capital cost per unit in 2010 ($)			Fixed operation and maintenance ($/year)		
	Solar photovoltaic	Pico-hydro	Diesel	Solar photovoltaic	Pico-hydro	Diesel
Tier 1	94	n/a	75	0.1	n/a	0.2
Tier 2	700	343	100	0.9	2.6	3.3
Tier 3	1,680	981	100	2.5	7.4	9.4
Tier 4	6,720	3,925	360	9.8	29.4	37.5
Tier 5	16,800	9,812	900	24.5	73.6	93.8

Table A2.6 **Average annual cost of electricity access provision for access scenarios for 2010–30 ($ billion/year)**

Country	SE4All 2014	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
India	9.915	0.305	1.090	1.605	4.500	8.955
Nigeria	3.090	0.155	1.075	0.920	2.575	5.370
Ethiopia	1.440	0.110	0.610	0.750	1.960	3.970
Bangladesh	2.145	0.095	0.570	0.505	1.160	2.265
Congo, Dem. Rep.	1.490	0.095	0.645	0.720	1.940	3.355
Tanzania	1.220	0.065	0.425	0.475	1.175	2.090
Kenya	0.910	0.045	0.255	0.305	0.650	1.150
Uganda	0.870	0.050	0.315	0.465	1.165	1.610
Myanmar	0.550	0.030	0.195	0.225	0.540	0.945
Mozambique	0.525	0.035	0.205	0.245	0.635	1.130
Madagascar	0.390	0.025	0.245	0.305	0.855	1.845
Afghanistan	0.730	0.030	0.170	0.200	0.560	1.130
Niger	0.468	0.020	0.220	0.335	0.770	1.275
Burkina	0.405	0.025	0.145	0.240	0.575	1.160
Malawi	0.425	0.020	0.135	0.195	0.470	0.860
Angola	0.395	0.020	0.230	0.270	0.660	1.070
Philippines	0.825	0.045	0.270	0.245	0.630	1.330
Yemen	0.540	0.015	0.170	0.200	0.535	1.010

generation are calculated. Additionally, the capital cost of low-voltage distribution to each household is assumed to be the same as the cost of distribution for homes connected to the centralized grid.

Off-grid generation

Off-grid generation cost calculations, too, are driven by the household access scenario for each five-year period through 2030. The access scenario is specified by the breakdown of access into the five-tier access levels, subdivided by urban and rural populations. Technology options for off-grid generation include solar PV, pico-hydro, and diesel and gasoline generators. AIM allows users to specify, per access tier, the fraction of households with off-grid electricity access that use the various supply options. Technology cost data are taken from ESMAP's META model, except for solar PV where updated figures have been substituted to reflect recent cost reductions in this technology. Table A1.5 depicts the capital costs assumed for the Tanzania analysis.

Each access tier is defined by peak load (W) and average daily consumption (Wh) per household. Given the number of households in each tier, the total capacity and energy requirements for the off-grid sector is calculated. Households are assumed to meet their own consumption needs independently of other households, and total power capacity need is simply the sum of all the individual household demands.

Given the technology mix used to meet this demand for each five-year period, and provided cost characteristics for each technology type, the total capital and recurrent costs for meeting off-grid demand are then calculated.

Summary of AIM assessment for high access-deficit countries

Table A1.6 depicts a summary of AIM simulation output obtained while assessing the investment required for the electricity access scenarios in 18 high-impact countries. These 18 countries make up 79 percent of the electricity access deficit, and altogether require annual investment ranging from $1 billion for tier 1 access to $40 billion for tier 5 access.

Notes

1. http://databank.worldbank.org/data/views/variableselection/selectvariables.aspx?source=sustainable-energy-for-all.
2. For details on the Global Electrification database, see World Bank (2013).
3. http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase.
4. CI derives from the concentration curve that plots the cumulative proportion of the population ranked by socioeconomic status, beginning with the least advantaged against the cumulative proportion of the variable. The range is between –1 and +1. CI is zero when the curve coincides with the line of equality, meaning that there is no inequality by socioeconomic status. CI is below zero when the curve lies above the diagonal; a negative CI indicates that electrification is favorable to the poor. If the concentration curve lies above the line, CI is greater than zero; a positive CI implies that electrification among the rich is higher than among the poor.
5. http://www.who.int/indoorair/health_impacts/he_database/en.
6. *Indoor Air Quality Guidelines: Household Fuel Combustion* (WHO 2014) (http://www.who.int/indoorair/publications/household-fuel-combustion/en/).
7. WHO updated the model estimates in 2014, and therefore the starting point estimates of 2010 reported in GTF 2013 are slightly different.
8. A CI above zero implies that access to non-solid fuels is higher among the wealthier. A CI below zero indicates that such access is favorable to the poor.
9. http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase.
10. The geographic analysis of the type of access that contributes to increased electrification rates in Nigeria and Ethiopia has been developed in collaboration with the KTH Royal Institute of Technology, division of Energy Systems Analysis (KTH-dESA).
11. As the efficiency of alternative cookstoves is higher than traditional ones—and cooking times are generally shorter—the move from traditional cookstoves results in far lower energy consumption.
12. An improved biomass cookstove typically requires replacement every 2–4 years, stoves using LPG every 5–15 years, and those using kerosene every 4–6 years.
13. http://esa.un.org/unpd/wup/default.aspx.
14. AIM uses a simplified dispatch algorithm, excluding some technical details from the calculations. For example, optimizing dispatch of hydro with storage requires more detailed analysis to account for seasonal and multiyear variations in rainfall and storage capacity. Other technical details such as maximum ramp rates of steam-cycle plants, and potential constraints in transmission capacity between different parts of the country, also affect real-world decisions about dispatch that are not reflected in the model.
15. It is currently assumed that the line loading as a fraction of maximum SIL loading from the St Clair curve is 50 per cent above the St Clair curve value.
16. T&D costs may be underestimated as a result of geographical factors being excluded. For example, countries with challenging terrain are likely to face considerably higher costs—where possible, these should be incorporated into the 'country cost premium' factor where it is possible to calibrate a country's situation to another similar country where good data exists.

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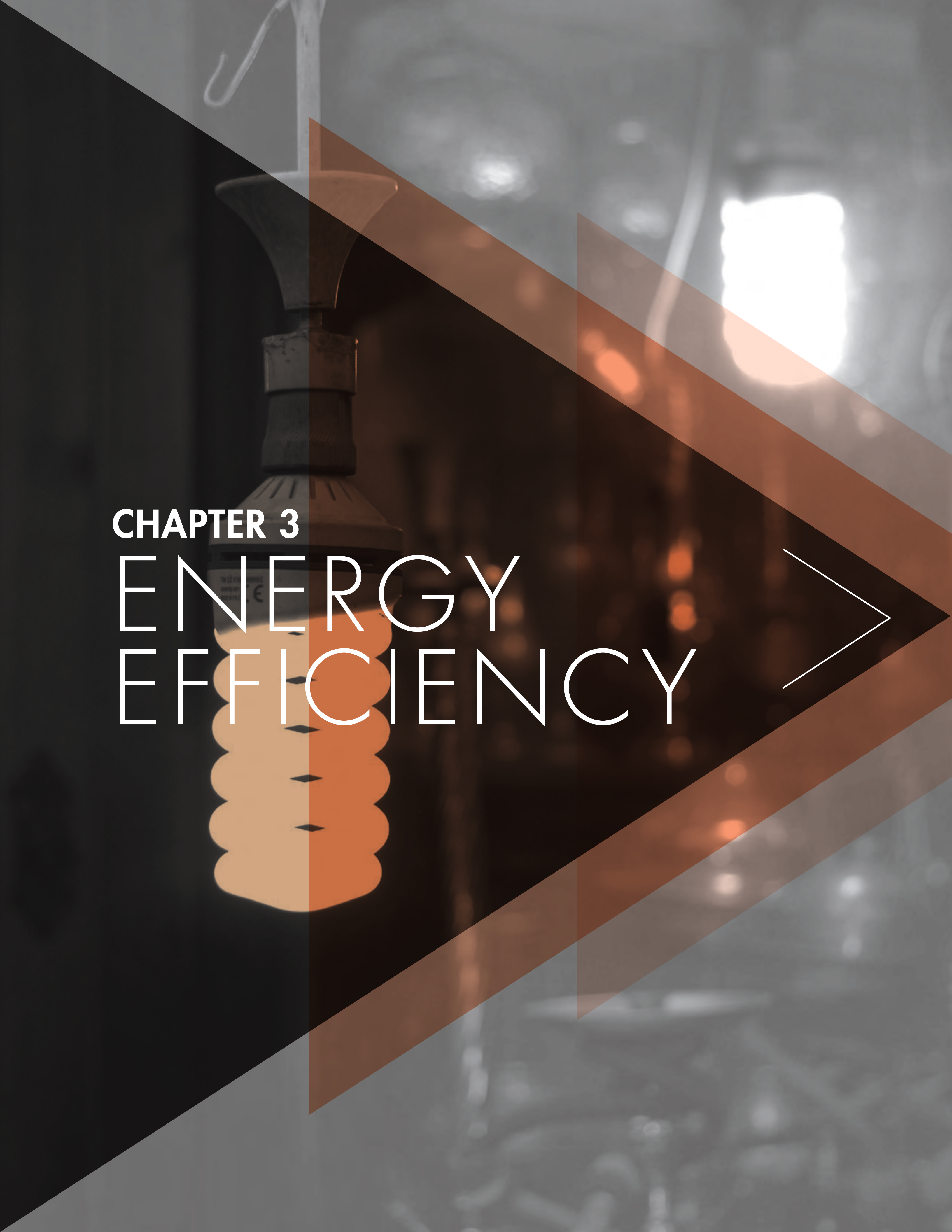
CHAPTER 3

ENERGY EFFICIENCY



Energy efficiency

Highlights

- After a slowdown at the end of the last decade, progress in improving energy intensity—the proxy indicator chosen in *Global Tracking Framework (GTF) 2013* (World Bank 2013)—has resumed, but still falls short of the rate needed to meet the Sustainable Energy for All (SE4All) goal of 2.6 percent a year.

- East Asia and North America—regions with large, energy-intensive countries that have made significant progress—have contributed the most to avoided energy demand.

- High-income countries have led the global acceleration in improving energy intensity since 2010, with emerging countries also contributing strongly.

- Continued dominance of coal in fossil power generation has held down progress in overall thermal efficiency, despite wide availability of improved technologies and the spread of natural gas.

- From 2010 to 2012, eight of the 20 largest energy-consuming countries, including several with low levels of primary energy intensity, experienced intensity declines exceeding 2.6 percent a year.

- In industry, falling energy intensity offset the upward effect of structural changes. Among the top 20 energy consumers, Indonesia, the Russian Federation, the Republic of Korea, the United States, and the United Kingdom had the most rapid reductions in energy intensity since 2000.

- In transport, the number of upper- and middle-income countries implementing fuel economy standards for cars is rising, now covering the world's largest markets, and a number of high-income countries have, or will soon have, standards for heavy-duty vehicles.

- Building energy codes are becoming more widespread, but Europe is leading the way on policies and financial programs to improve the building stock and to strengthen energy performance requirements for new buildings.

- Japan, the United States, and the European Union (EU) lead in regulating energy-using equipment, though many middle-income countries are adopting minimum energy performance standards (MEPS) for appliances as well. Reducing network standby power use is an emerging area of best practice.

- Expanding energy efficiency finance through performance contracting, new repayment methods, public and private funds, and novel business models is helping to scale up energy efficiency activities.

- Estimates of the size of the energy efficiency market vary depending on scope and method, but were at least on the order of $130 billion in 2012, potentially greater than $300 billion.

- Reaching the SE4All goal will require approximately quadrupling the average annual investment in energy efficiency from now until 2030, with investment needs in transport expected to be especially large.

This chapter begins with a summary of trends at a global level, in sectors, among different income groups, in regions, and in the countries that will most powerfully influence the pace and direction of global energy efficiency. The second section reviews important developments in efficiency policy and delivery mechanisms, spotlighting exemplars of good practice that have potential and that, if adopted more broadly, would aid in accelerating uptake of more efficient technologies and practices. The chapter concludes with a discussion of the scale of investments needed to reach the energy efficiency goal—a challenge that will necessitate raising energy efficiency investments to several times their current levels.

The first edition of the *GTF* examined the available methods and data for tracking energy efficiency. Owing to limitations in data availability and methodological challenges, it is not possible to represent energy efficiency as a single number at a national or global level. Therefore, primary energy intensity was selected as the "headline" indicator for tracking global progress toward the SE4All efficiency goal. Energy intensity is the ratio of total primary energy supply to the economy's value added, measured in purchasing power parity (PPP) for a fairer comparison across countries at different stages of economic development. It is not identical to energy efficiency—for which there is no single indicator—but intensity is typically used as a proxy for efficiency in macro analysis. See chapter 5 for details of the analytic methods used for this chapter and what would be needed to improve tracking of energy efficiency.

Global, regional, and sectoral trends in energy intensity

The starting point and developments to 2012

As reported in *GTF 2013* (World Bank 2013), the decline in the compound annual growth rate (CAGR) of primary energy intensity worldwide was about 1.3 percent in the base period (1990–2010). Based on the latest figures from the International Energy Agency (IEA)[1] and the United Nations (UN) Statistics Division,[2] the pace of improvement slowed from the first to the second decades of the base period, from 1.5 percent to 1.2 percent a year (figure 3.1).[3] However, the most recent data show that after slowing in the second decade of the base period, the pace of decline in energy intensity in the tracking period (2010–12) accelerated to over 1.7 percent a year.

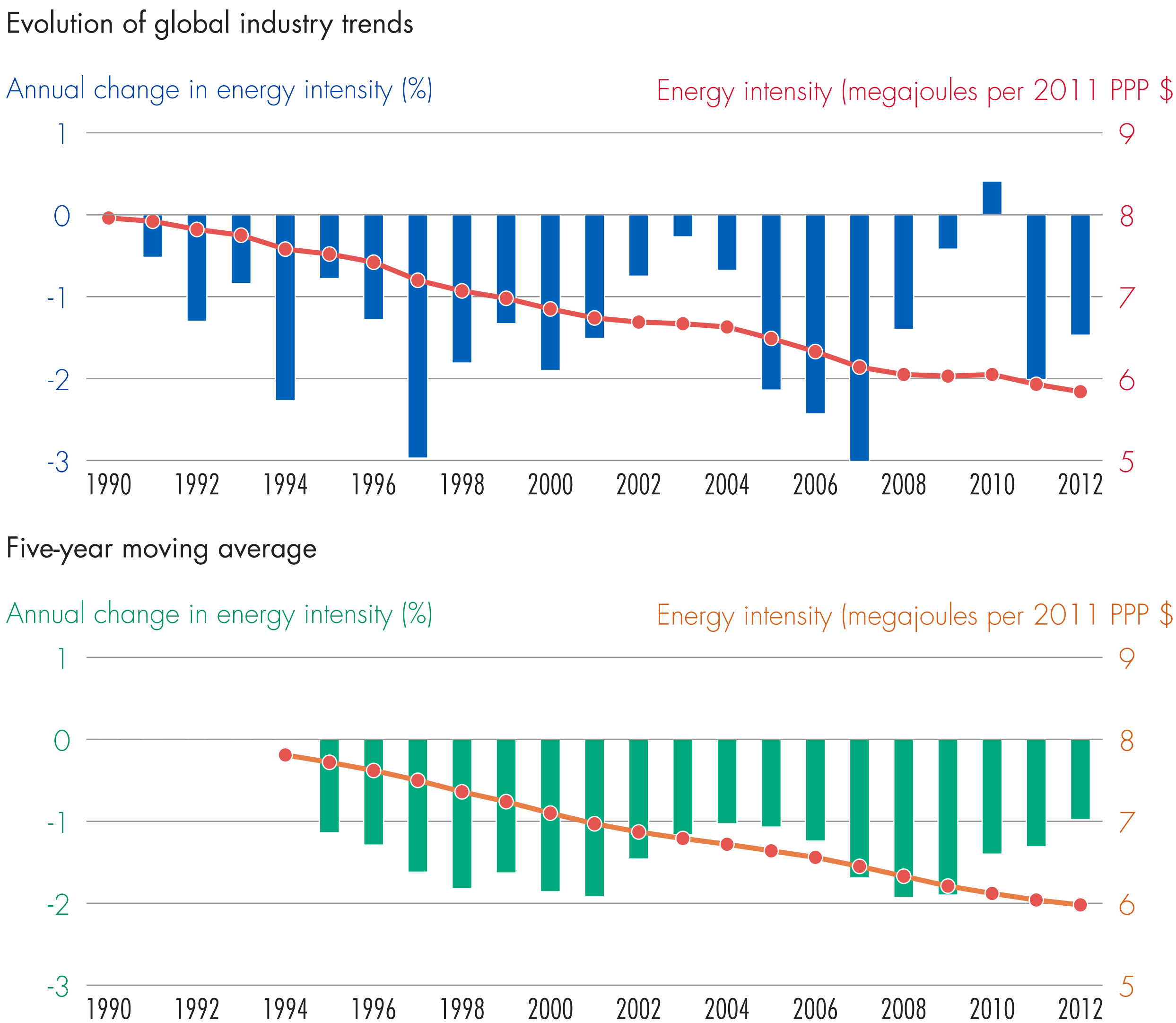
Figure 3.1. **Rate of change in global primary energy intensity across periods and annual growth in primary energy supply, GDP, and energy intensity in the tracking period**

Source: IEA and WDI databases.

This is the result of gross domestic product (GDP) growing nearly twice as fast as primary energy consumption. Thus after a period of slower progress due to the economic crisis at the end of the last decade, real progress in reducing energy intensity is being made, though still short of the 2.6 percent a year gain needed over 2010–30 to meet the SE4All objective of doubling the historical rate of decline in energy intensity.

Annual variations in primary energy intensity trends can be wide, so short-term variations should not be read as long-term trends (figure 3.2). But performance over the span of several years offers important information about the overall direction of progress. After decelerating and even reversing at the end of the last decade, the pace of decline in energy intensity has quickened. Still, the average 2.6 percent a year global objective has been approached in only two years since 1990. Not only has the world never experienced long-term decline in energy intensity at the intended rate, it also has rarely reached the objective in any single year, though individual countries have occasionally done so.

Figure 3.2. **Evolution of global energy intensity, annual change, and five-year moving average**



Source: IEA and WDI databases.

Note: PPP is purchasing power parity.

Variability from transient phenomena can be screened out by examining moving averages. Figure 3.2 displays a five-year moving average of annual changes in energy intensity: a medium-term variation around a strong central trend of declining intensity that nevertheless emphasizes that the targeted rate of decline has not been sustained.

The long-term decline in energy intensity means that the world now consumes less energy than if energy intensity had remained fixed. Global primary energy demand grew by over 1.9 percent a year in the base period, but continual improvements restrained energy intensity growth. Had energy intensity not changed, world energy consumption in 2012 would have been 25 percent higher (figure 3.3). The incremental change in energy intensity in the tracking period alone—without considering any of the intensity improvements—avoided primary energy consumption of 20 exajoules (EJ) in 2012, or more energy than Japan used that year. This was solid progress, but more is needed.

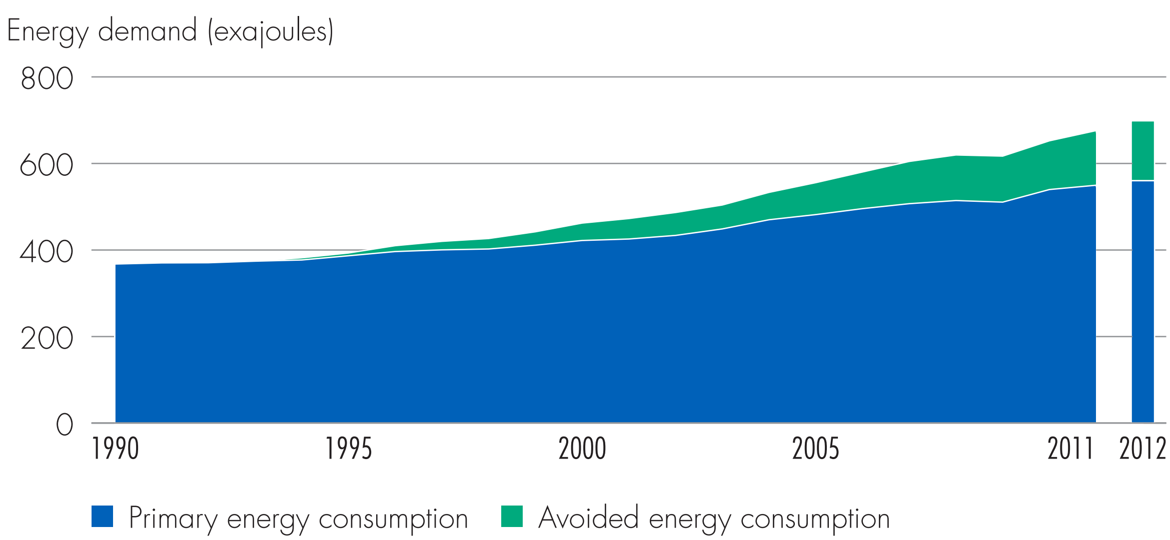
Sectoral shares of final energy consumption have been very stable even as total final energy consumption (TFEC) has grown by 41 percent since 1990 (figure 3.4). The share of households, for instance, has dropped merely from about 26 percent to near 24 percent, and services have risen by half a percentage point, remaining around 8 percent. Transport grew by two percentage points to a little over 28 percent. Although industry's share varied slightly over the period, it began and ended the period virtually unchanged. Agriculture declined by about half a percentage point.

Sectoral shares of global GDP have also shifted very little, even though shifting between sectors is often cited as a major driver of intensity change (figure 3.5). In 2012, services were 54 percent of GDP, virtually the same as in 1990. Industry accounted for 32 percent in both 1990 and 2012.

Similarly, the sectoral structure of the global economy remained stable even as the share in global GDP of industrializing non–Organisation for Economic Co-operation and Development (OECD) economies grew substantially, especially after 2000 (figure 3.6). In 2012, non-OECD countries accounted for 53 percent of world output, up from 39 percent in 1990. The universal decline in energy intensity helps explain the stability in sectoral shares of energy consumption.

All sectors witnessed falling energy intensity in the base and tracking periods (figure 3.7). The pattern for industry most closely matched the overall pattern of slower growth

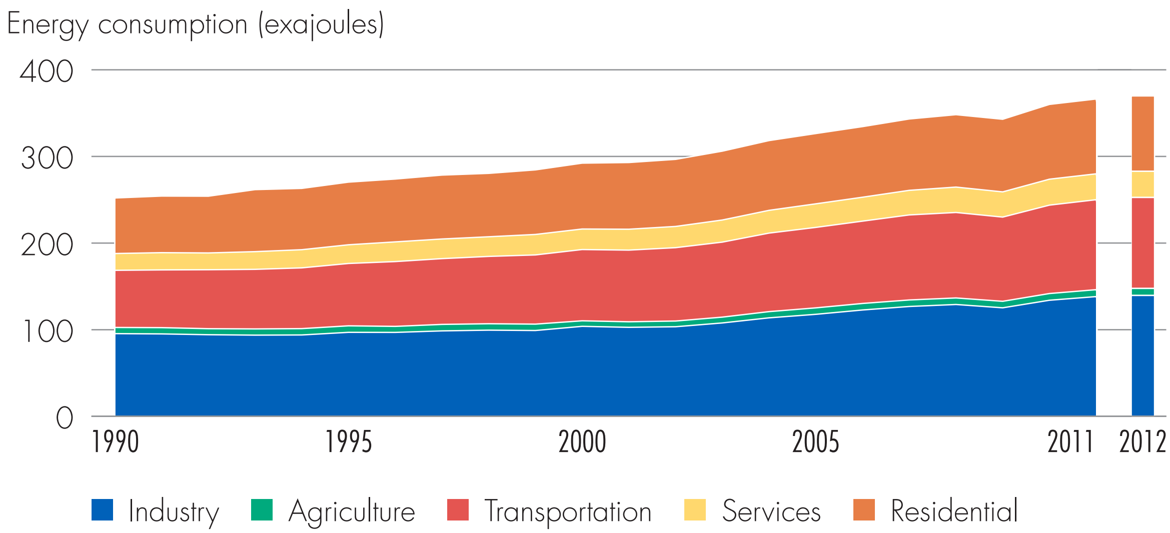
Figure 3.3. **Actual and avoided global primary energy consumption due to declining energy intensity**



Source: Energy intensity decomposition analysis based on IEA, WDI, and UN databases.

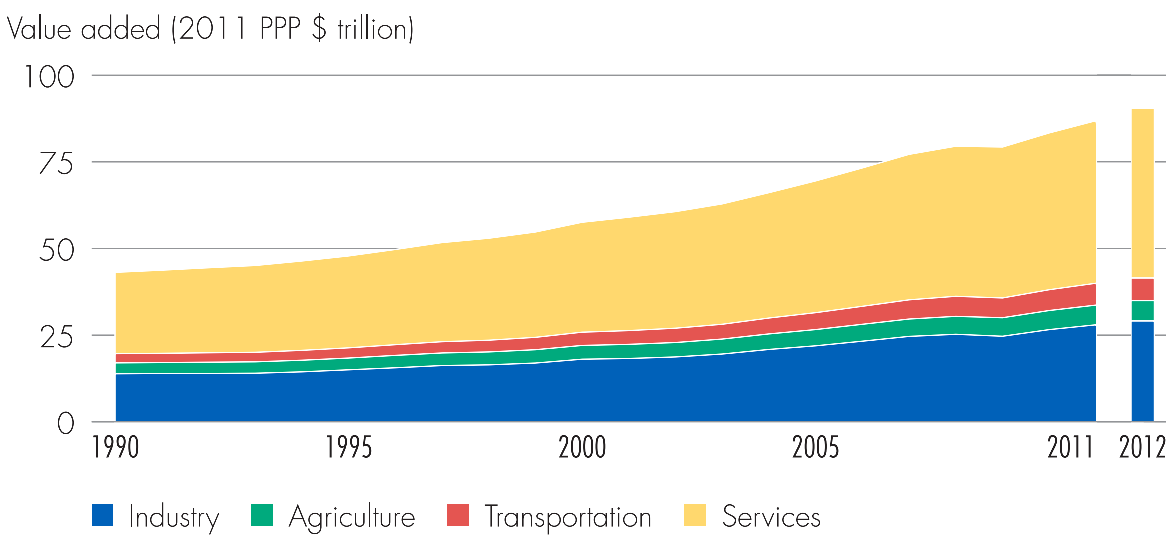
Note: Primary energy demand is represented by total primary energy supply. Avoided energy demand is estimated from the energy intensity component of decomposition analysis, with a base year of 1990; see chapter 5, annex 2.

Figure 3.4. **Global final energy consumption by sector and share of total**



Source: IEA databases.

Figure 3.5. **Global GDP by sector and shares of total**



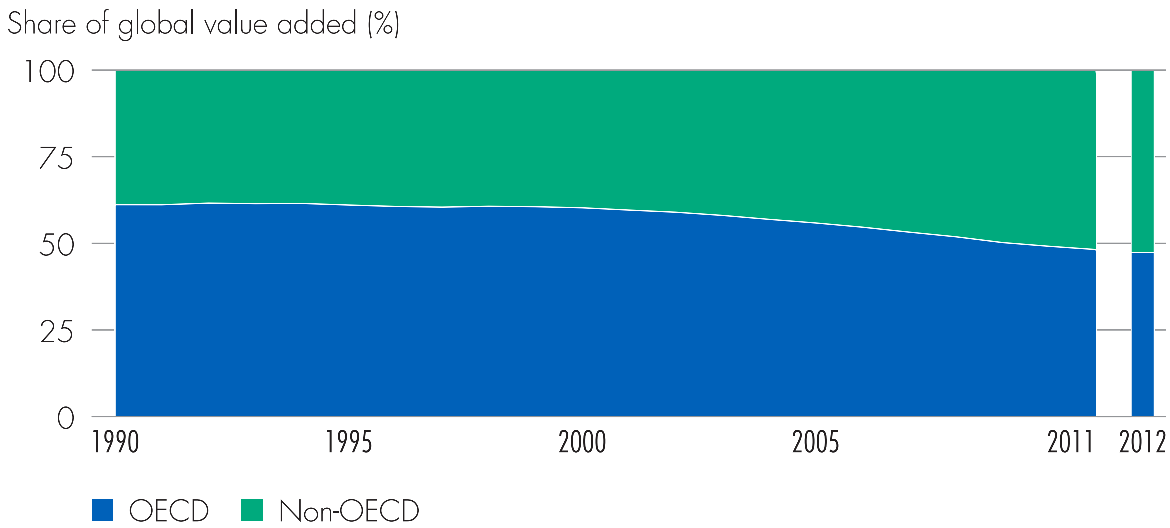
Source: WDI databases.

Note: PPP is purchasing power parity.

in the latter half of the base period, followed by faster intensity improvement in the tracking period. Intensity improvement in agriculture decelerated over time, while the services sector exhibited the opposite pattern. Residential energy intensity improved more slowly than that of the other sectors.

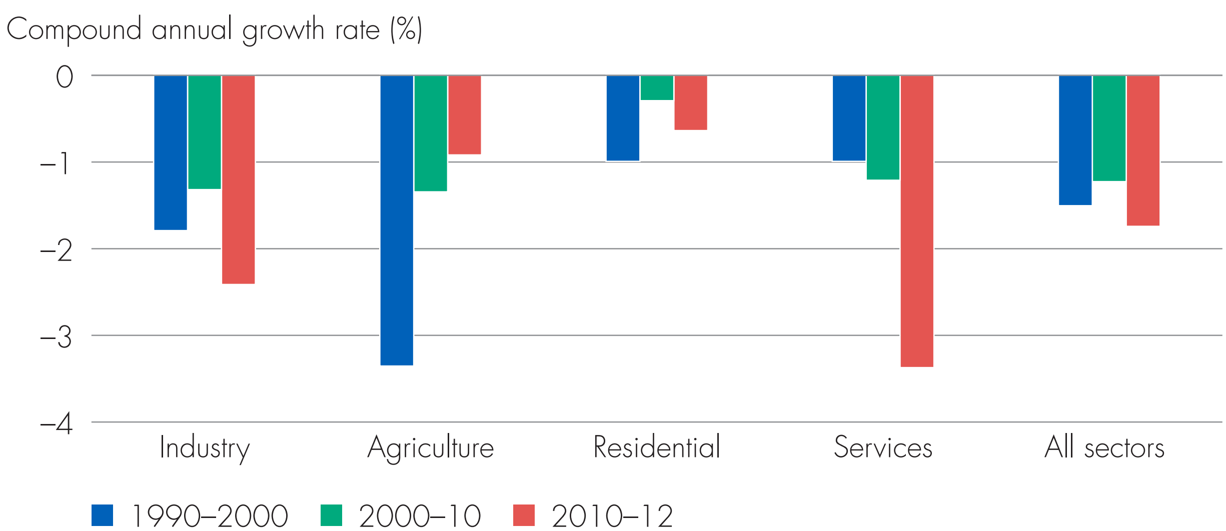
Transport presents special challenges, as its energy intensity is not well represented by the ratio of energy consumption to value added. In many countries, much motorized passenger transport is used by households, so a large fraction of fuel consumption is attributed to the residential sector in national energy balances rather than to

Figure 3.6. **Shares of global GDP by OECD affiliation**



Source: WDI databases.

Figure 3.7. **Rate of change in global final energy intensity by sector**



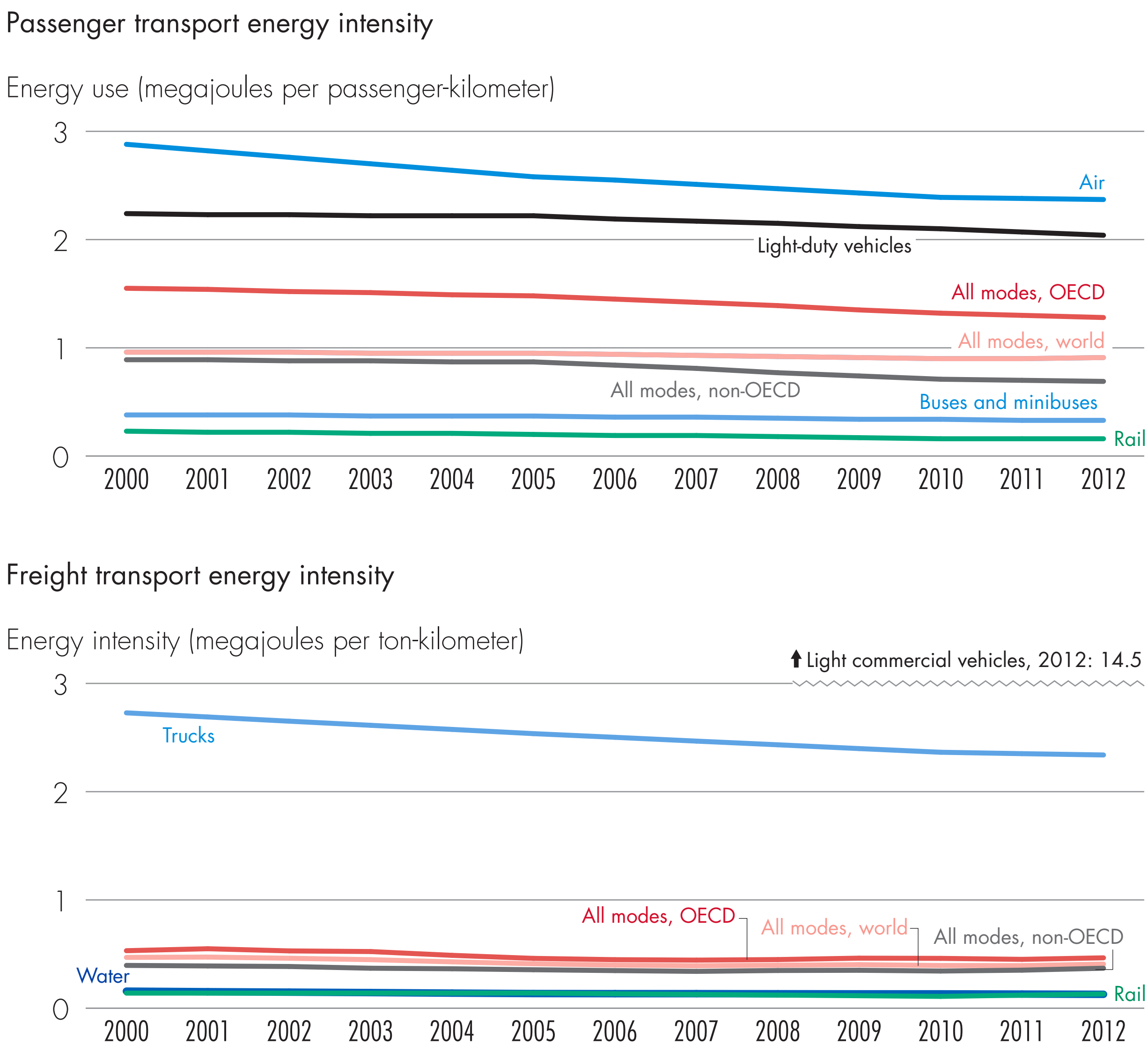
Source: IEA and WDI databases.

Note: Energy intensity in the residential sector is calculated as energy consumption per household. Transport is shown in figure 3.8.

transport. Moreover, passenger and freight transport have very different characteristics. To better capture actual activity, energy consumed per passenger-km (pkm) and per freight ton-km (tkm) is reported separately. Mode (road, rail, air, or water) is an important influence but cannot be disaggregated at global level.

The IEA-led Mobility Model shows that transport energy intensity for passengers and freight transport has fallen for most of a decade (figure 3.8). Road transport is much more energy intensive than any other mode apart from air (which carries a far smaller share of passengers and freight). Since OECD countries have a higher fraction of

Figure 3.8. Global average passenger and freight transport energy intensities



Source: IEA-led Mobility Model (http://www.iea.org/topics/transport/mobilitymodelling).

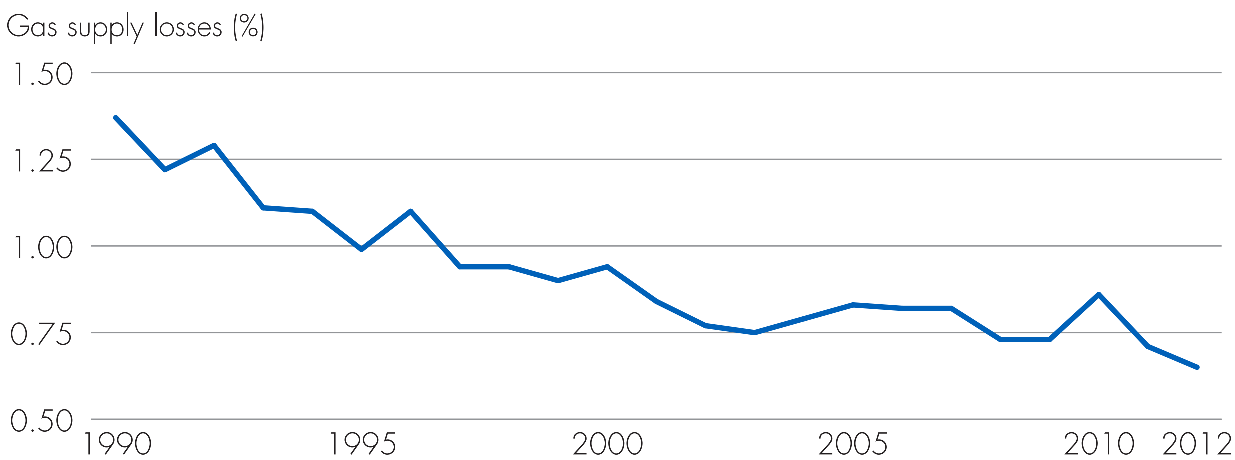
passengers and freight carried by motor vehicles, average energy intensity is higher than for non-OECD countries. The vast differences between trucks and rail or waterway shipping, and between small passenger vehicles and rail or buses, show clearly the potential savings from mode shifts.

Energy supply-side indicators

Provision of higher-quality energy to end users in the form of electricity and gas is an important contributor to development, but it has a cost in rising conversion, transmission, and distribution losses, even as technologies become more efficient and loss rates from energy extraction and delivery networks continue to shrink.[4] Figure 3.9 shows an important element in this, that is, that attention to reducing leaks and improving pipeline pressurization has led to a long-term decline in midstream gas sector losses.

Worldwide, an ever larger share of primary fossil energy is being converted to electricity, and fossil fuels will long dominate the generation mix. The efficiency of fossil power generation is thus a crucial determinant of global energy intensity. Technological progress has shifted the frontiers of efficiency for all fuels, but the average in practice does not always follow them (figure 3.10). In 1990–2012, the widespread introduction of combined-cycle natural gas turbines and concurrent global expansion of natural gas led to a rise in average efficiency associated with natural gas of more than three percentage points. But this gain was offset by a slight decline in the efficiency of coal-fired generation, due in part to rising self-use by power plants to meet tightening pollutant emissions standards and to the

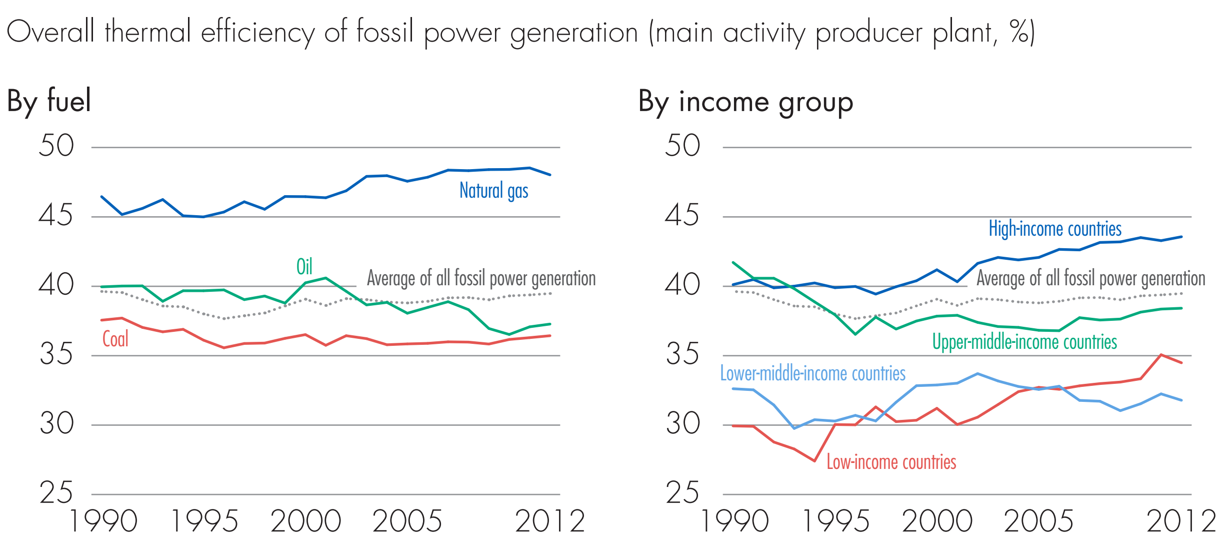
Figure 3.9. **Global losses in natural gas transmission and distribution**



Source: IEA databases.

Note: To compensate for inconsistencies in the underlying data, U.S. refinery losses are assumed constant at 2012 levels throughout the period.

Figure 3.10. **Thermal efficiency of fossil power generation by fuel and by income group**



Source: IEA databases.

Note: Data are for main activity electricity plants, excluding, for instance, on-site power generation at industrial facilities.

rapid construction of new coal-fired plants that do not use the latest technology. And as coal has dominated overall additions to generation capacity worldwide, average thermal efficiency of fossil power generation has stagnated.

Efficiencies of fossil power generation are generally greater in higher-income countries. In the lower middle-income group, efficiency has been declining for the past decade, as coal's share in the generation mix has risen. The wealthier countries are the largest power generators, so the global figure reflects trends in the top two groups—high-income and upper middle-income countries—resulting in the sluggish trend in thermal efficiency, again because of the rising share of the least-efficient fuel, coal.

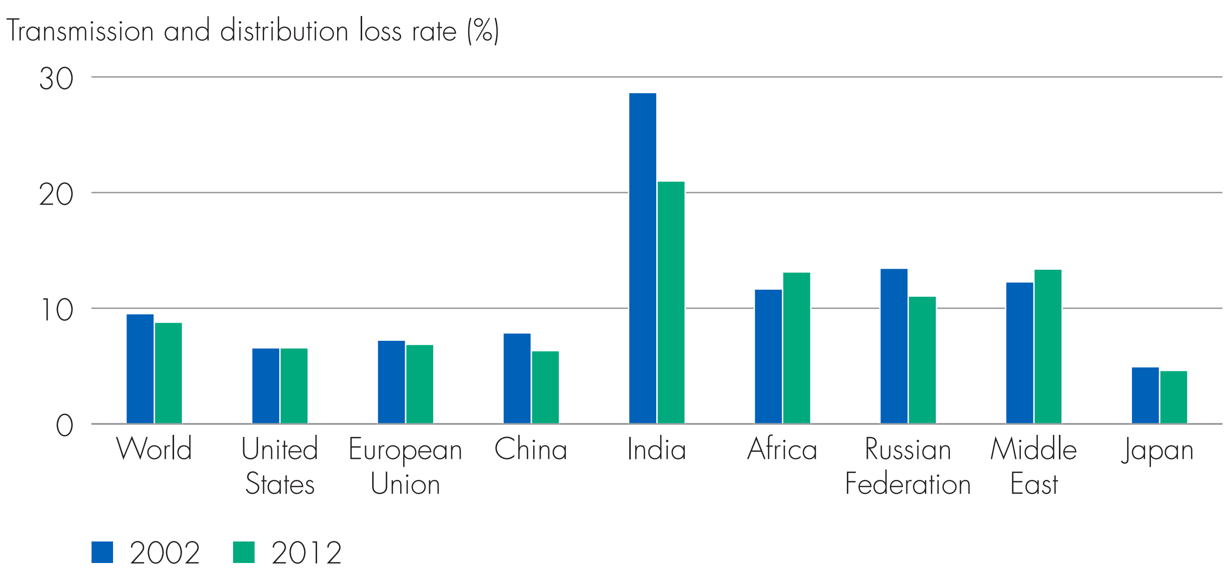
Energy demand can be reduced by increasing the efficiency of energy conversion, distribution, and use. In 2012, global transmission and distribution (T&D) losses of 1,880 terawatt-hours (TWh) were incurred, equivalent to 8.8 percent of worldwide generation that year. T&D losses are affected by the efficiency of the grid and its operation, climatic conditions, distances, density, and nontechnical matters such as theft (often referred to as *commercial losses*). T&D loss rates have gradually fallen worldwide over the past decade, though loss rates and trends vary greatly among countries and regions (figure 3.11). For instance, they average less than five percent in Japan but are more than 10 percent in Russia. In India and many other developing countries, nontechnical losses add heavily to overall T&D losses. Globally, the decline of 0.7 percentage points in T&D losses over 2002–12 saved about 160 TWh a year, equivalent to Poland's electricity generation in 2013.

Global trends by income level

Upper middle-income countries are on the verge of displacing high-income countries as the biggest energy consumers. The share of primary energy consumed by high-income countries is in long-term decline. At the start of the base period they accounted for 63 percent of TPES, but by 2012 only 50 percent (figure 3.12). In the two years after that, the share dropped further to 48 percent. This decline has come mainly through the growth of middle-income countries, especially upper middle-income countries, whose share of TPES grew by 2.2 percentage points over 2010–12, to near 34 percent.

Lower middle-income countries started in 1990 at a similar level of energy intensity as upper middle-income countries and made the most rapid progress through 2012 (figure 3.13). Despite solid progress, low-income

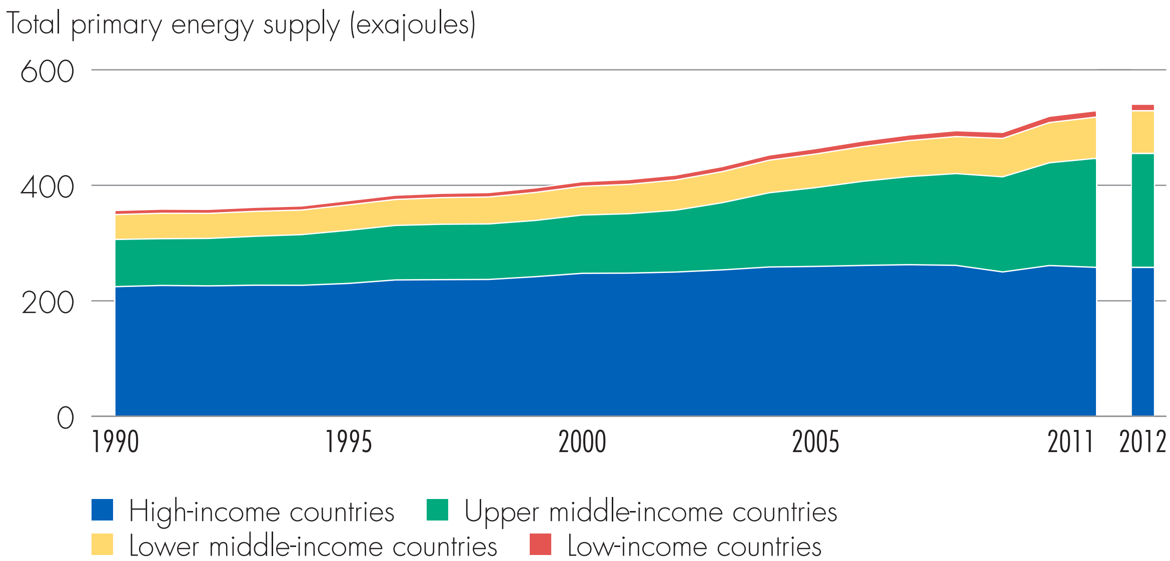
Figure 3.11. **T&D loss rates in the power sector, selected countries and regions**



Source: IEA data.

Note: Transmission and distribution loss rates are calculated as a share of domestic supply (net generation plus imports less exports).

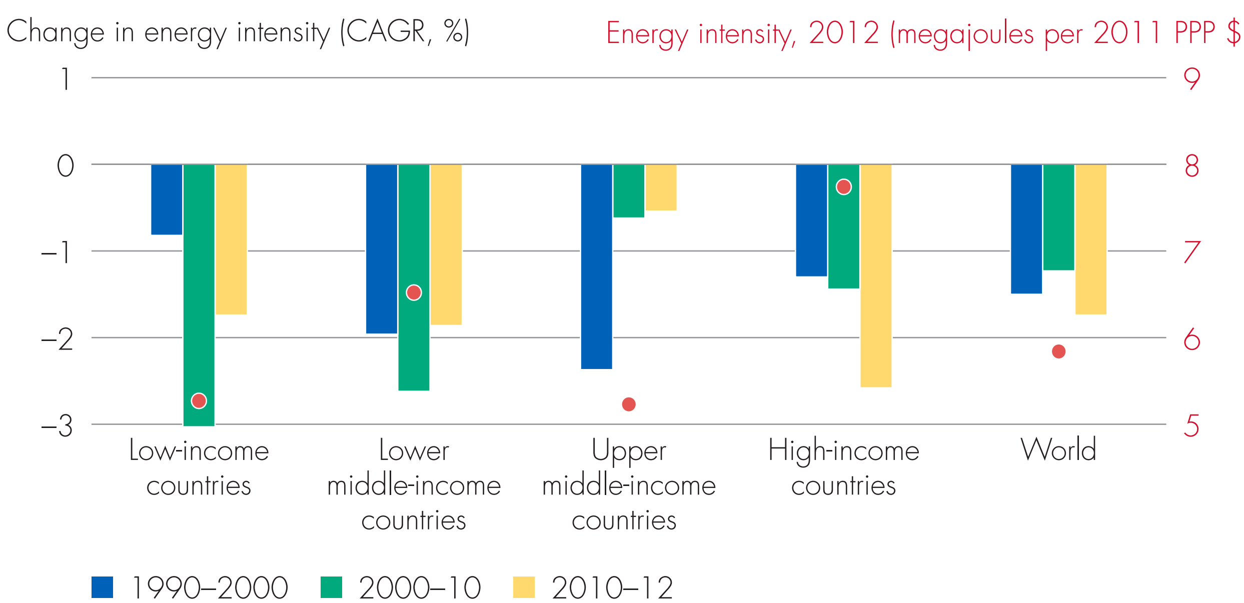
Figure 3.12. **Primary energy supply by income level, 1990–2012**



Source: IEA and WDI databases.

Note: For operational and analytical purposes, economies are divided among income groups according to 2013 gross national income (GNI) per capita, calculated using the World Bank *Atlas* method. The groups are: low income, $1,045 or less; lower middle income, $1,046–$4,125; upper middle income, $4,126–$12,745; and high income, $12,746 or more.

Figure 3.13. **Primary energy intensity by income group: Rates of change and energy intensity levels**



Source: IEA and WDI databases.

Note: CAGR is compound annual growth rate; PPP is purchasing power parity.

countries remain by far the most energy-intensive income group. Particularly after 2000, upper middle-income countries saw the slowest improvement in energy intensity, in part due to investment in energy-intensive infrastructure and production capacity. Upper middle-income countries aside, all income groups accelerated their rates of energy intensity improvement over 2000–10.

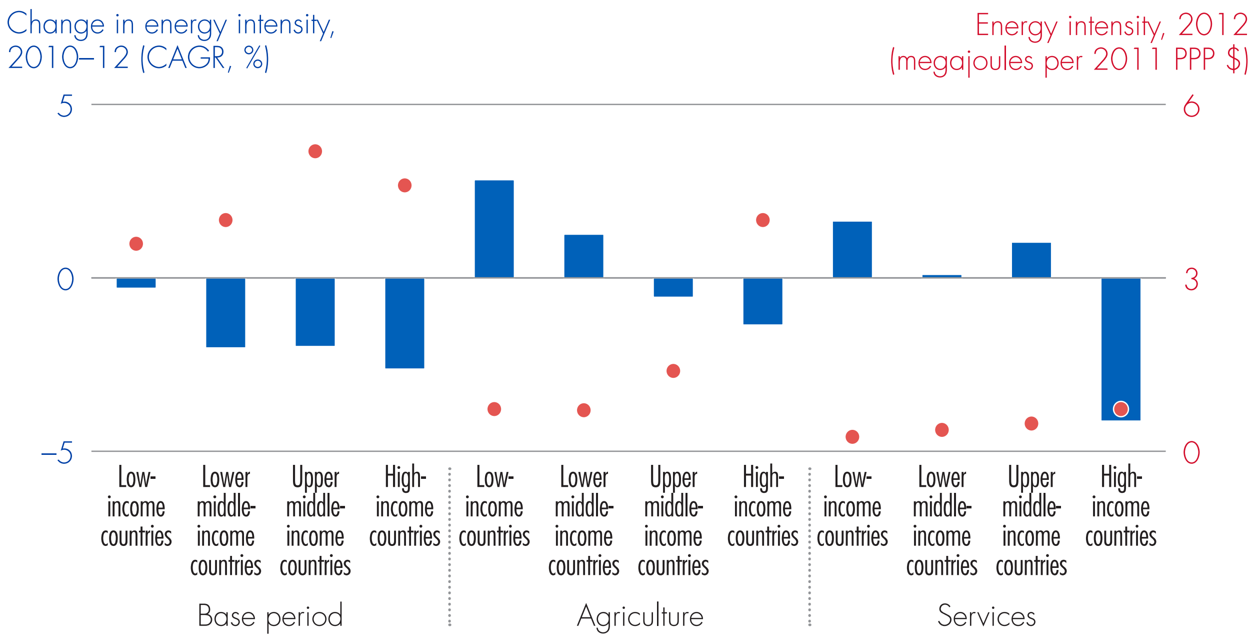
After 2010, global primary energy intensity was driven primarily by high-income countries, which saw their decline move from 1.5 percent a year in the baseline period to 2.6 percent a year in the tracking period, owing in large part to recovery from recession (see Lower middle-income countries started in 1990 at a similar level of energy intensity as upper middle-income countries and made the most rapid progress through 2012 (figure 3.13). Despite solid progress, low-income countries remain by far the most energy-intensive income group. Particularly after 2000, upper middle-income countries saw the slowest improvement in energy intensity, in part due to investment in energy-intensive infrastructure and production capacity. Upper middle-income countries aside, all income groups accelerated their rates of energy intensity improvement over 2000–10.). Middle- and low-income countries, by contrast, experienced no such shift after 2010, although in lower middle-income and low-income countries the pace of improvement remained rapid at near 2.0 percent. The striking exception is the upper middle-income group of countries, where the decline in CAGR for primary energy intensity remained stubbornly low at around 0.5 percent a year. Due in large part to rapid industrialization in these countries, energy intensity remains well above the global average.

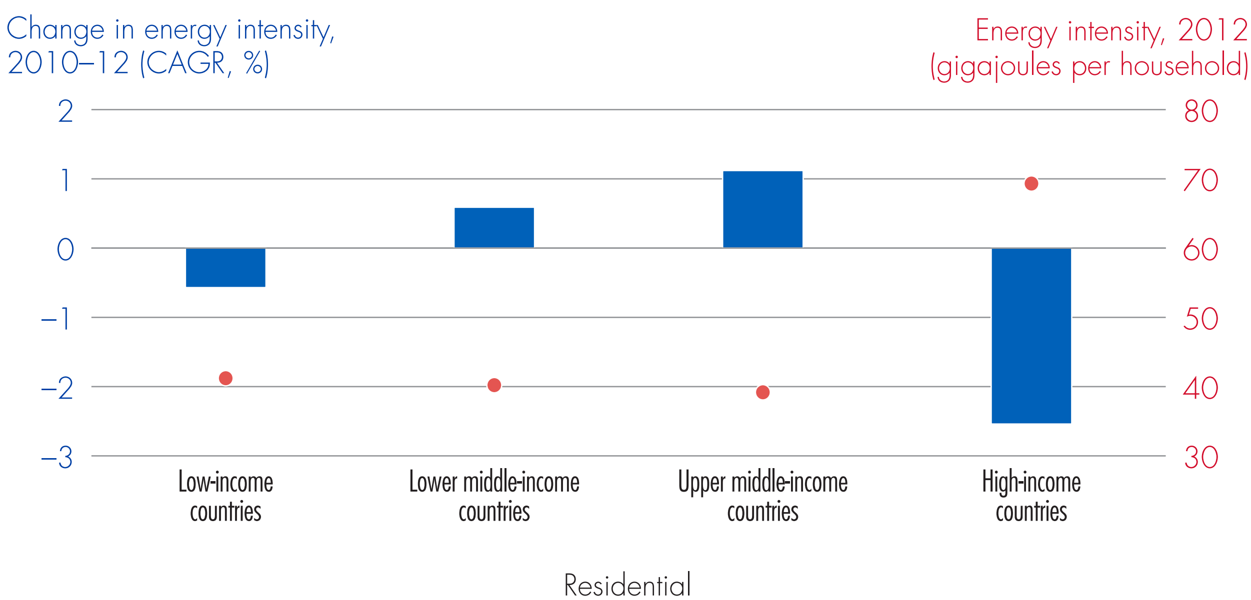
Sectoral energy intensities across income groups reveal disparate trends across different sectors, even as intensities in each sector are similar for each of the four income groups—except in agriculture and households, where high-income countries are notably more energy intensive (figure 3.14). High-income countries are the only group for which intensities in all productive sectors fell in the tracking period, though industrial energy intensity fell across the board.

Trends by region

By examining regional performance in the earlier and latter parts of 1990–2012 (the base period and the tracking period combined), one can see which regions contributed most to global trends (figure 3.15). For instance, the rate of decline in 2000–12 was slower than in the first decade of the base period—a phenomenon seen only in West Asia, North Africa, and East Asia. Elsewhere, energy intensity declined faster or at a similar rate to the first decade of the base period. Similarly, the resurgence in improvement in energy intensity in 2010–12 was mirrored by the trends in North America, the EU, Southeast Asia, West Asia (despite overall growth in energy intensity), and Latin America and the Caribbean. In terms of overall shares of energy consumption, in the tracking period, developing regions were ascendant. East and South Asia in particular continued to climb, while North America and Europe contracted (figure 3.16). Other regions with mainly developing countries continued to grow in share.

Figure 3.14. **Change in final energy intensity (2010–12) and energy intensity (2012) by sector**

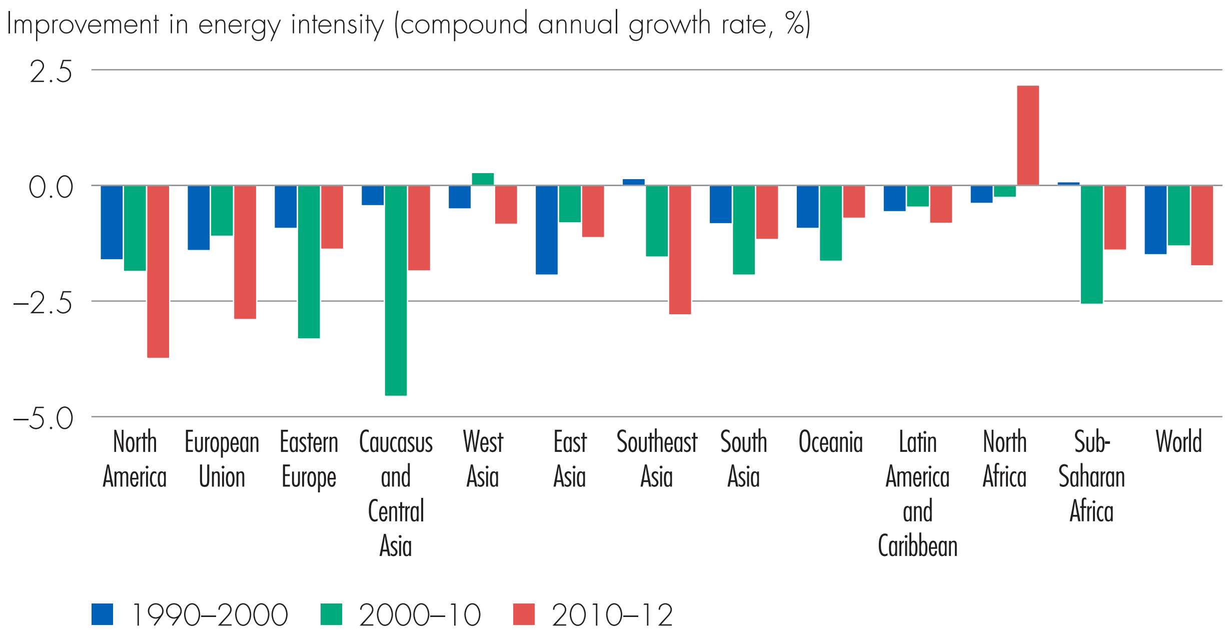




Source: IEA and WDI databases.

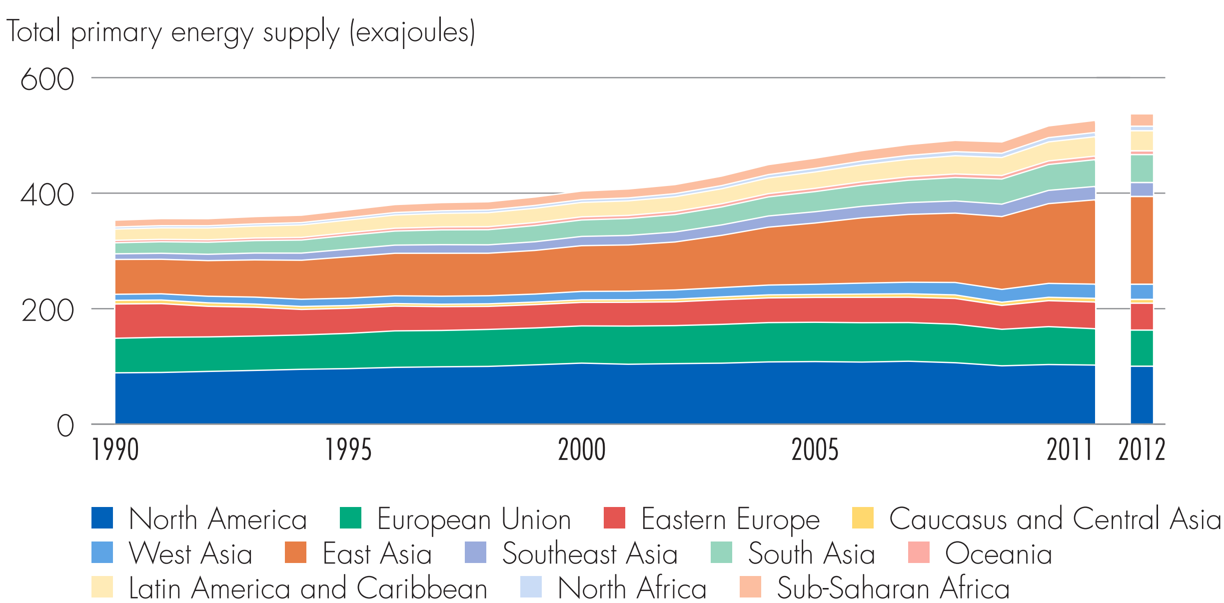
Note: CAGR is compound annual growth rate. Owing to data limitations, transport is not included.

Figure 3.15. **Average annual rate of improvement in primary energy intensity by region**



Source: IEA and WDI databases.

Figure 3.16. **Total primary energy supply by region, 1990–2012**



Source: IEA and WDI databases.

Attributing impact: Decomposition analysis of global intensity trends

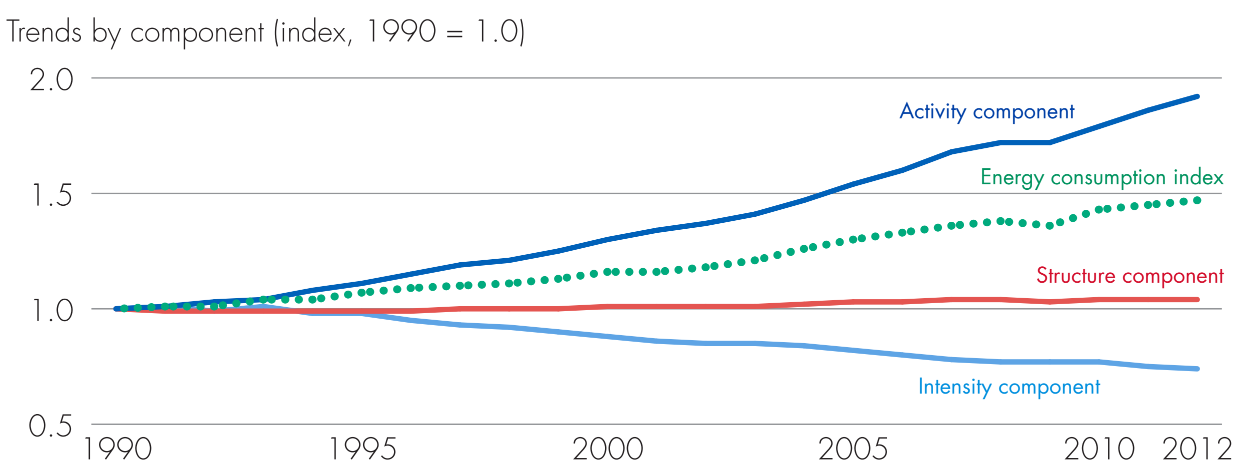
Results of an updated decomposition analysis confirm that changes in energy intensity are almost entirely responsible for the global decoupling of energy consumption from GDP growth; shifts in global economic structure contributed very little (figure 3.17). The energy intensity component fell by about one-fourth over 1990–2012. With the exception of the global economic slowdown in the last decade, the growth of economic activity has exerted a consistent upward pull on energy demand. At the same time, the economic structure index has remained almost flat, with a very slight increase since the late 1990s. Worldwide, there has been no shift from energy-intensive activities, like mining and manufacturing, toward less energy-intensive services activities; in fact, output from both has grown.

The energy intensity component has provided the main offset to rising economic output. Understanding the sources of the intensity trend, however, requires much more finely detailed analysis than is possible globally. The same is true for structural changes. A later section discusses how tracking can be improved where data are available. On the basis of the decomposition analysis, one can assign values of avoided energy consumption to sectors and regions.

East Asia contributed more than twice as much to avoided energy consumption in the base period as did North America (figure 3.18). In the tracking period, East Asia remained the largest contributor, even as North America's share fell. The EU contributed at a noticeable though declining level, while Eastern Europe and South Asia grew from virtually undetectable to small. Southeast Asia emerged in the tracking period as a growing contributor. The unsettled political situation in North Africa resulted in economic difficulties even as energy consumption continued rising, such that energy intensity rose and its performance subtracted from the global total (and so does not appear in the chart).

Upper middle-income countries—China the prime example—were by far the largest sources of avoided energy consumption (figure 3.19). High-income countries contributed one-third in the tracking period, demonstrating that large decoupling effects are not restricted to industrializing nations. Lower middle-income countries saw a growing but still small share in the tracking period,

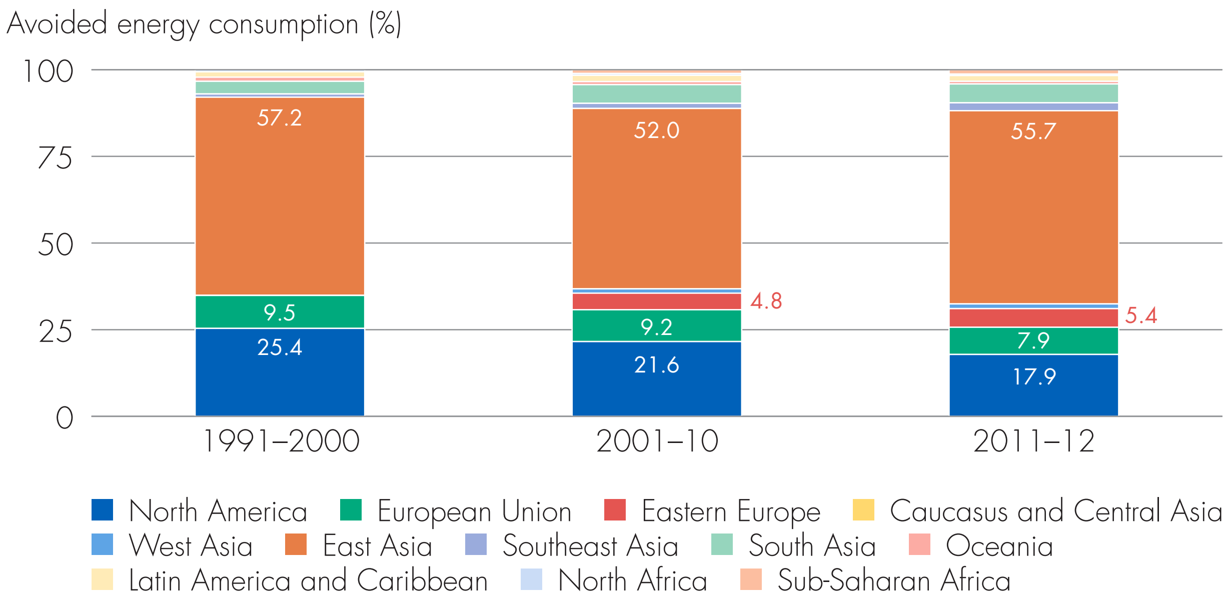
Figure 3.17. **Decomposition of trends in global final energy consumption: Contributions of activity, structure, and intensity components, 1990–2012**



Source: Energy intensity decomposition analysis based on IEA, WDI, and UN databases.

Note: See annex 1 for data and methods used for this and following figures. Includes industry, agriculture, transport, and services with activity measured as value added, and households with activity measured as household numbers.

Figure 3.18. **Avoided global final energy consumption by region and time period**



Source: Energy intensity decomposition analysis based on IEA, WDI, and UN databases.

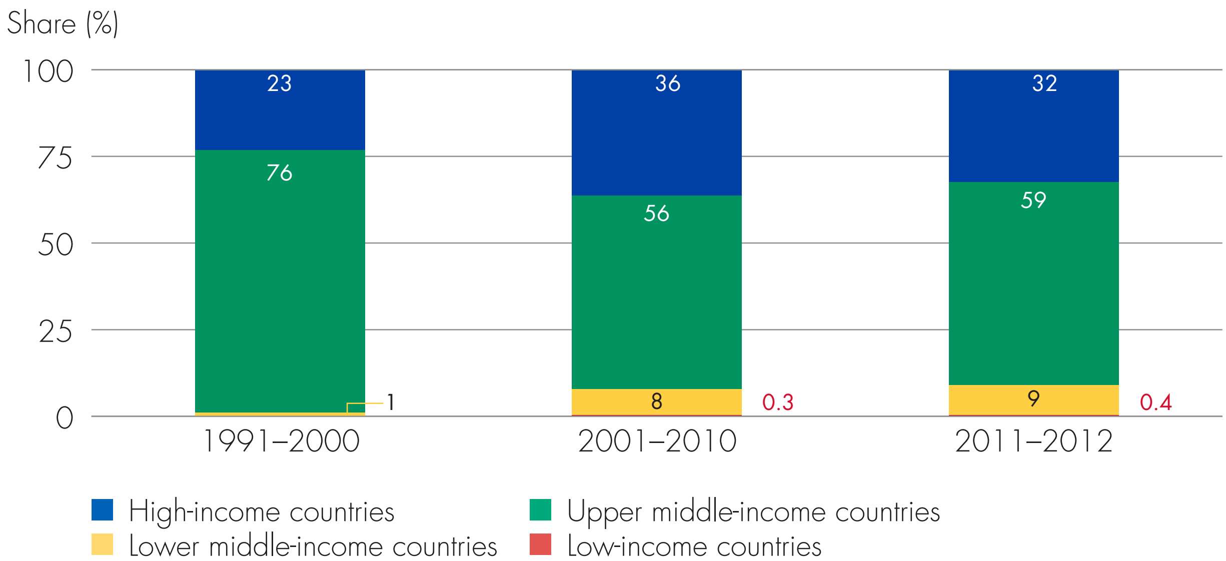
while low-income countries did not exert an appreciable influence.

Using the data set that includes transport, industry was the largest contributor to reduced energy intensity in 2000–12, closely followed by transport (figure 3.20). Worldwide, energy efficiency in industry has improved broadly, and many countries have adopted or strengthened fuel economy standards. The relatively small contributions from services and households imply there is a large store of potential future energy savings in buildings.

On the link between per capita energy consumption and energy intensity, high-income countries exhibit the most variation in per capita energy consumption, while low-income countries show the greatest intragroup difference in energy intensity (figure 3.21). Low-income countries tend to have the lowest per capita energy consumption, but also have the greatest country variation in energy intensity, ranging from Myanmar and Bangladesh at the low end to the resource-rich Democratic Republic of Congo and relatively energy-poor Ethiopia at the high end.

High-income countries, by contrast, exhibit the broadest range of per capita energy consumption by group, from energy-intensive North America and Saudi Arabia at the high end to Italy and the United Kingdom at the low end, while energy intensity is within a relatively narrow band, low compared with other income groups. Lower middle-income countries tend to cluster around both relatively low per capita energy consumption and low energy intensity, except for some former Soviet republics. Upper middle-income countries form a group with somewhat higher per capita energy consumption and energy intensity. The world averages for per capita energy consumption and energy intensity fall within this cluster of countries.

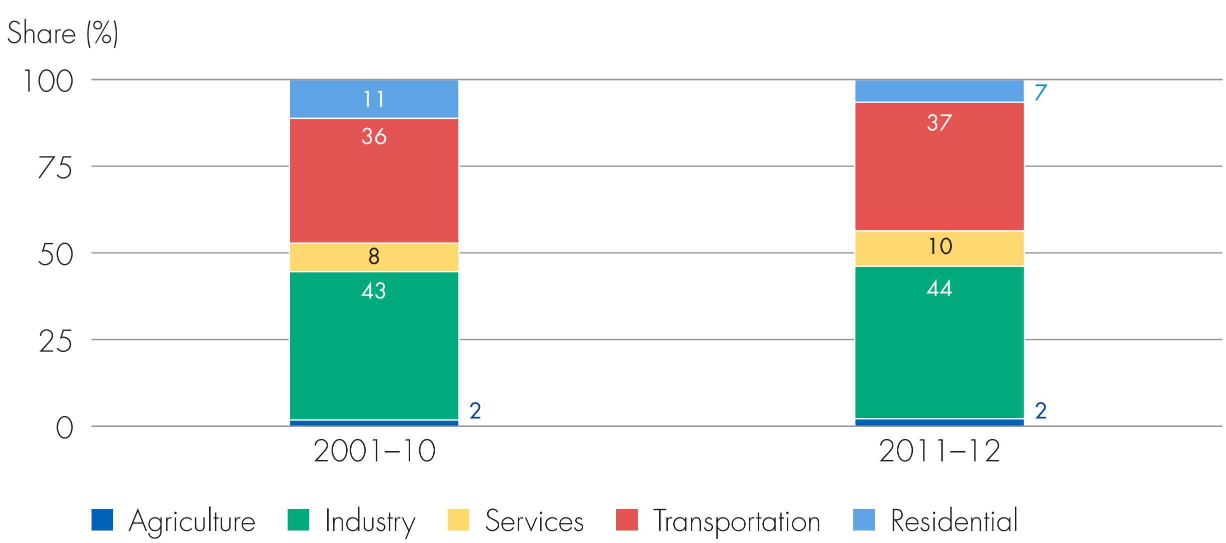
Figure 3.19. **Avoided global energy consumption by income group and time period**



Source: Energy intensity decomposition analysis based on IEA, WDI, and UN databases.

Note: Avoided energy consumption is calculated relative to a base year of 1990. Values for low-income countries are insignificant compared with other income groups.

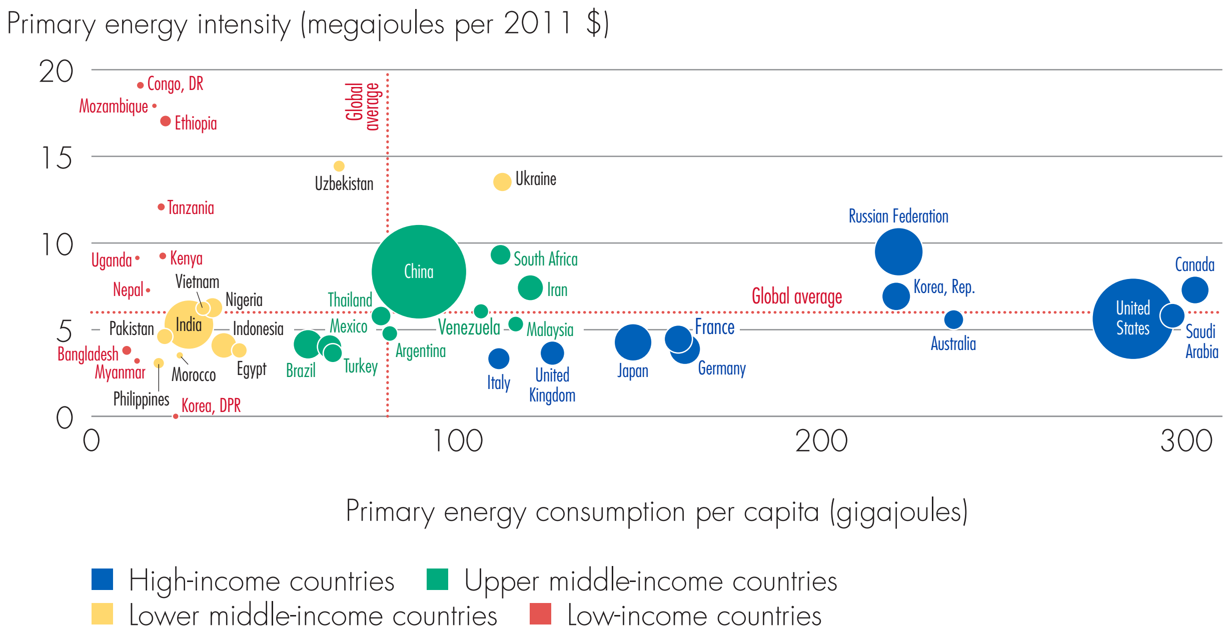
Figure 3.20. **Avoided global final energy consumption by sector, 2001–12**



Source: Energy intensity decomposition analysis based on IEA, WDI, and UN databases.

Note: As with figure 3.4, transport sector effects are based on global results of the IEA-led Mobility Model. These results cannot be disaggregated by country, region, and income group, and are only available for 2000 and later.

Figure 3.21. **Primary energy intensity versus primary energy consumption per capita, selected countries, 2012**



Source: IEA and WDI databases.

Note: Size of bubble reflects total primary energy supply by country.

Performance of key countries

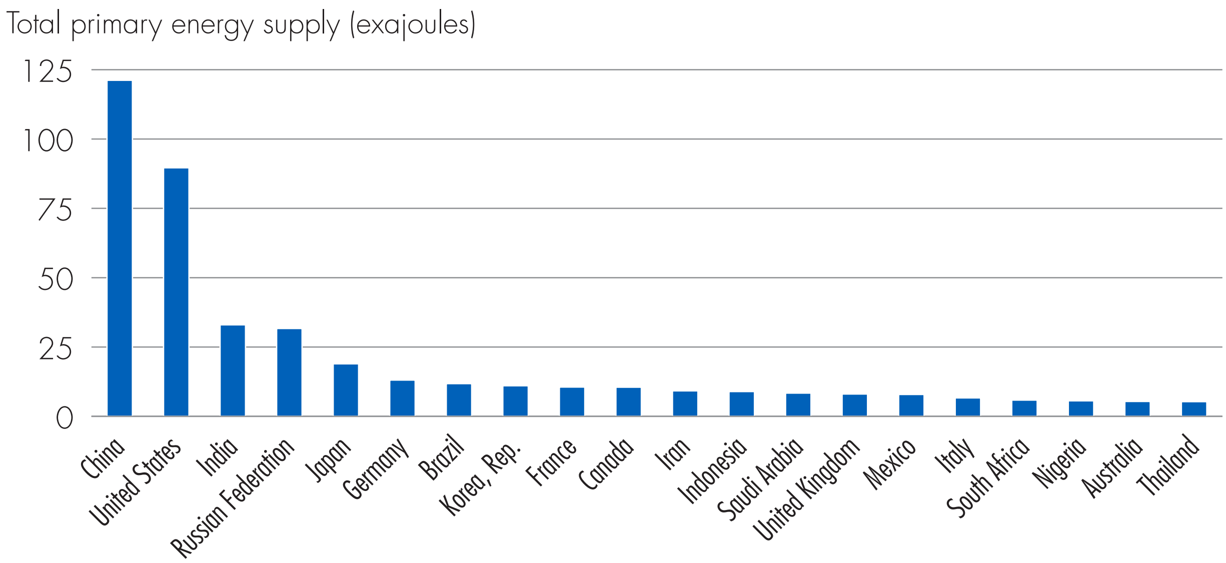
Achieving the global SE4All goal is most dependent on the performance of the world's largest energy-consuming countries. Twenty countries accounted for nearly 74 percent of global primary energy consumption in 2012 (figure 3.22). The top five alone accounted for over half. They range greatly in share—from just over 21 percent for China to just under 1 percent for Australia and Thailand—and each faces a different set of opportunities and obstacles, but each is important for raising the rate of improvement in energy intensity.

Of course, energy efficiency is also important to smaller consumers. It helps, for instance, maximize the development impact of new electricity supplies to communities and households, reduce energy bills and import dependence, raise economic competitiveness, and limit pollutant emissions. For global tracking, however, the larger countries warrant particular attention.

China led declines in intensity over 1990–2010, followed by the United Kingdom, India, and Nigeria, but a very different group of leaders emerged over 2010–12 (figure 3.23). In the latter period, eight of the top 20 energy consumers, including several with relatively low absolute levels of primary energy intensity, experienced intensity declines exceeding 2.6 percent a year—showing that decoupled growth is possible for mature economies. While high-income countries drove the global acceleration in reducing energy intensity after 2010, several large emerging countries—notably Indonesia, South Africa, and Saudi Arabia—also recorded high rates of improvement. Russia, the most energy-intensive of the group due in part to its large fossil fuel production, showed only a marginal decline in energy intensity. Intensity rose over the two-decade base period in four rapidly emerging economies: Brazil, Thailand, Iran, and Saudi Arabia. After 2010, however, only one of them, Brazil, saw continued rising intensity, and Saudi Arabia had a major reversal, with intensity dropping by around 3 percent a year.

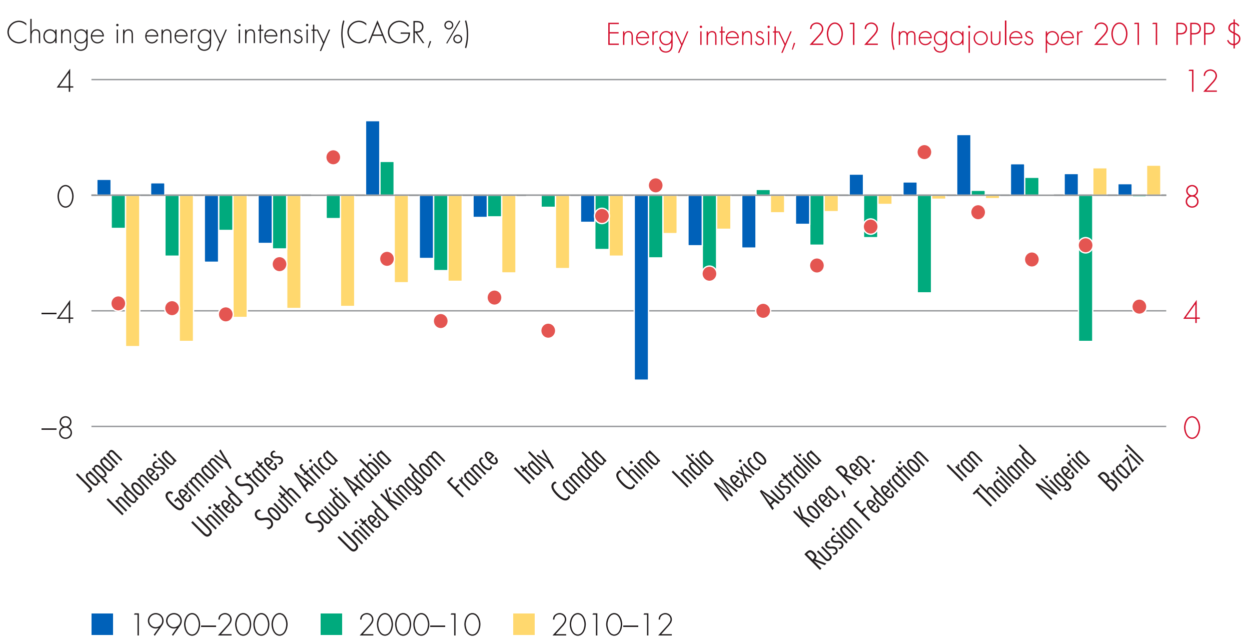
Analysis of these countries using the same approach as in figure 3.17 to figure 3.19 shows wide variation among them in the contribution of the structural and intensity components (figure 3.24).[5] China, now the largest annual energy consumer, saw the highest growth in its structural component (a shift toward more energy-intensive sectors)

Figure 3.22. **Top 20 primary energy consumers, 2012**



Source: IEA databases.

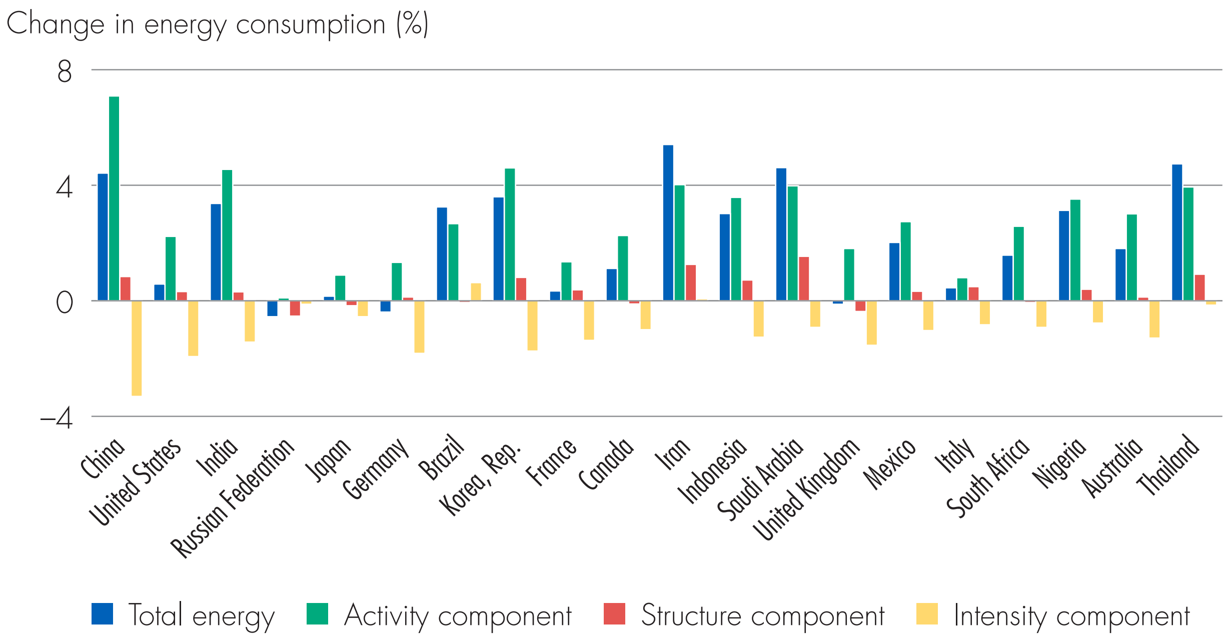
Figure 3.23. **Top 20 primary energy consumers: Primary energy intensity improvement across periods and energy intensity at PPP in 2012**



Source: IEA and WDI databases.

Note: Countries ordered by compound annual growth rate (CAGR) in 2010–12.

Figure 3.24. **Decomposition of trends in total final energy consumption, top 20 primary energy consumers, 2012**



Source: Energy intensity decomposition analysis based on IEA, WDI, and UN databases.

Note: Countries ordered by total final energy consumption in 2012. See annex 1 for data and methods used for this and following figures. Includes transport, with activity measured as value added.

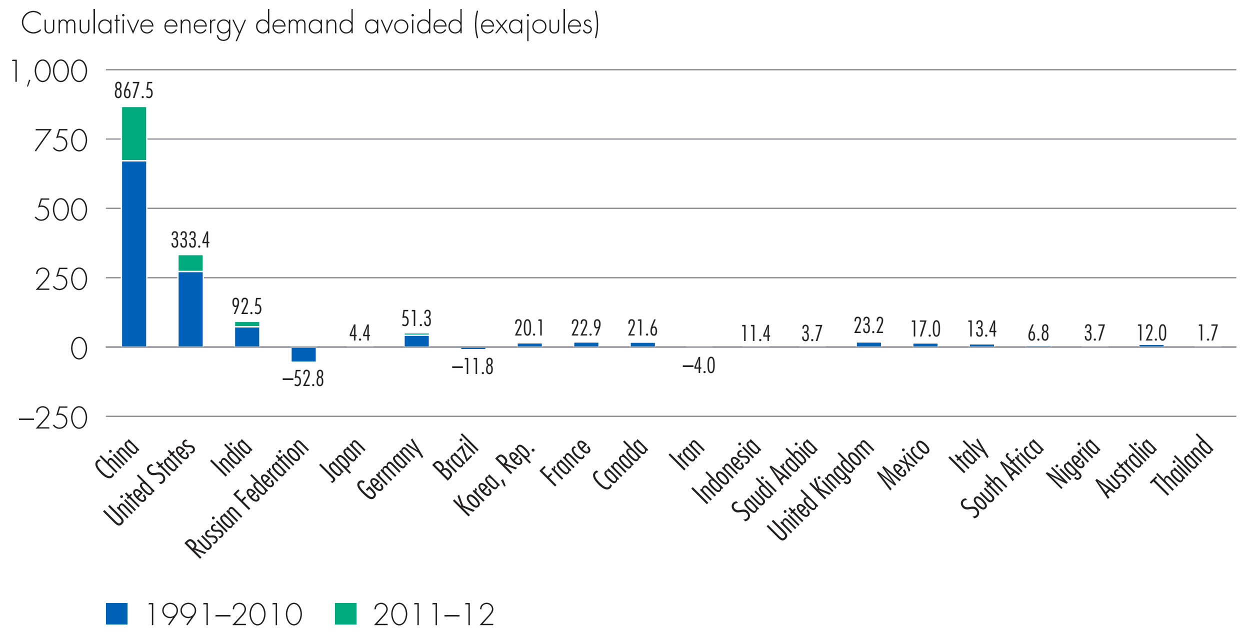
at an average of 1.2 percent a year. It also saw the fastest decline in its energy intensity component, at 3.5 percent a year, resulting in a large decoupling of energy consumption from activity.

Like China, the two next largest consumers—the United States and India—exhibited falling energy intensity components alongside shifts in structure that tended to pull energy consumption upward. Other countries with declines in intensity but rising structural components were (in energy-consuming order) Germany, the Republic of Korea, France, Indonesia, Saudi Arabia, Mexico, Italy, Nigeria, and Australia. Some countries exhibited declines in intensity and in structure: Russia, Japan, Canada, the United Kingdom, and South Africa. Only two countries—Brazil and Iran—exhibited a rise in the energy intensity component over the period. In Brazil, a mild downward trend in structure was a countervailing factor, whereas in Iran structural change pushed up energy consumption.

On avoided energy consumption based on the above decomposition analysis, many of the largest consumers play roles commensurate with their ranks as consumers (figure 3.25). China, the United States, and India (and to a lesser extent Germany) contributed to global energy savings on a large scale. Russia, given its relatively high energy intensity, actually increased its energy demand. The contribution from Japan was quite small relative to its rank as an energy consumer, as it had slow economic growth through most of the period and started with relatively low energy intensity.

Which countries outside the top 20 primary energy consumers saw big declines in energy intensity? Figure 3.26 illustrates the 20 fastest-moving countries for reduced primary energy intensity over 2010–12. Some are among the high-income group of countries, showing that rapid progress need not be confined to developing countries, but it is hard to generalize from this group, as diverse and often transient trends often drove energy intensity in these countries.

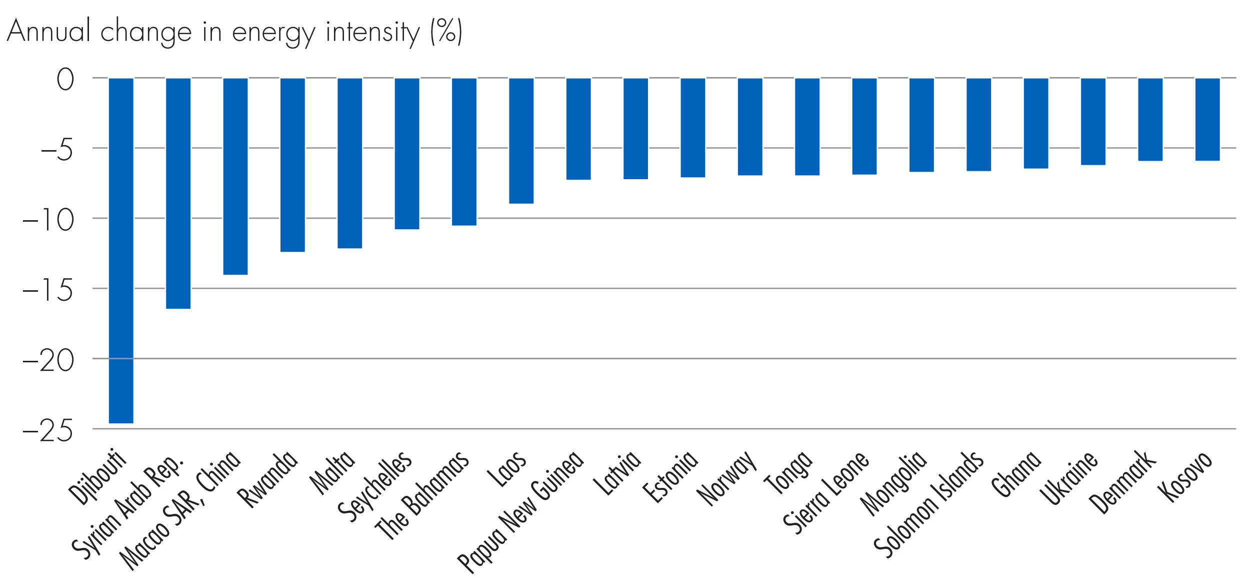
Figure 3.25. **Top 20 primary energy consumers: Avoided final energy consumption, cumulative 1991–2012**



Source: Energy intensity decomposition analysis based on IEA, WDI, and UN databases.

Note: These results cannot be directly compared to the sectoral results in figure 3.20, which are based on the same type of method but with different transport-sector data and a different base year. Ranks are by total final energy consumption in 2012.

Figure 3.26. **Annual change in primary energy intensity in the 20 fastest countries, 2010–12**



Source: IEA and WDI databases.

Note: SAR is Special Administrative Region.

Exemplars: policies and technologies

This section identifies end-use energy efficiency policy and technology developments since the *GTF* 2013 edition (World Bank 2013) in industry; transport; buildings; and appliances, lighting, and electronic equipment. (The chapter annex contains further detail on energy efficiency policy in the largest energy-consuming countries.) Although many of the cases come from the top 20 energy consumers, some are from other countries, whose recent accomplishments demonstrate approaches that could be fruitfully adopted elsewhere.

Industry

Industrial energy consumption has increased 36 percent since 2000, to reach 143 EJ in 2011. Rising material demand in non-OECD countries have largely fueled this increase. Non-OECD countries use 66 percent of industrial energy, up from 50 percent in 2000 (IEA 2014b).

Global industrial energy intensity is decreasing as energy efficiency improves, even as some countries have seen countervailing structural changes within the sector. China and India have had the highest annual reductions in energy intensity since 2000.

Policies to improve energy efficiency in industry include energy management programs; MEPS for industrial equipment and systems; energy services for small and medium enterprises such as audits, benchmarking, and information on proven practices; and complementary policies such as removing energy subsidies and offering financial incentives (to buy efficient vehicles, for instance).

Several countries, including China and India, have launched new programs since the *GTF* 2013 edition (World Bank 2013). Even in 2013 China, for example, mandated supervised implementation of energy management programs in companies covered by the Top-10,000 (energy conservation) Program (IEA 2014b). This program, introduced in 2011 and building on the Top-1,000 Program launched in 2006, covers over 15,000 enterprises (mainly industrial) that consume more than 10,000 tons of coal equivalent per year,[6] as well as around 160 large transport enterprises, public buildings, hotels, and enterprises that use more than 5,000 tons of coal equivalent a year (IEA 2014a).

In 2012, India launched a market-based Perform, Achieve & Trade mechanism (box 3.1). Otherwise, innovations in energy-savings technologies in energy-intensive industries have been slow since the *GTF* 2013 edition (World Bank 2013), although there have been a few notable advances. For example, in the pulp and paper industry, the Confederation of European Paper Industries (CEPI) announced in 2013 promising laboratory-scale results of deep eutectic solvents (DES), which allow production of pulp at low temperatures and atmospheric pressure (IEA 2014b). Applying DES-based pulp making throughout the pulp and paper sector has the potential to reduce its carbon dioxide (CO_2) emissions by 20 percent from current levels by 2050 (CEPI).

Transport

Between 2000 and 2011, energy consumption for transport increased 25 percent to 102 EJ. Road transport accounts for the largest share (76 EJ, 75 percent), with passenger light-duty vehicles (PLDVs) consuming just over 40 percent of total transport energy demand. Road freight accounts for nearly 30 percent of energy demand, shipping and air 10 percent, and buses and trains 7 percent.

Important policy developments in recent years include the increasing number of governments—whether OECD members or not—adopting fuel economy standards that set corporate average efficiency targets, which now cover around 70 percent of global passenger vehicles on the market (figure 3.27). Fuel economy standards are in place for PLDVs in Canada, China, the EU, Japan, the Republic of Korea, Mexico, and the United States. And they are under development in Brazil.

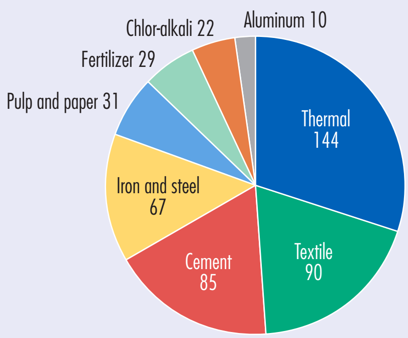
The next step is to address freight haulage. China, Japan, and the United States have set fuel economy standards for heavy-duty vehicles, and the EU plans to implement such standards this year. Canada, the Republic of Korea, and Mexico are developing proposals for heavy-duty vehicle fuel economy standards.

Sales of electric vehicles are advancing in several markets thanks to new or continued rebates, tax credits, purchase subsidies, or exemptions from vehicle registration taxes and licensing fees. Sales of electric vehicles grew 50 percent from 2012 to 2013, reaching 170,000 units. The global electric vehicle stock reached 350,000 vehicles at the end of 2013. In the United States, around 100,000 electric vehicles were sold in 2013, the largest increase of any country and a number that almost matches global electric vehicle sales in 2010. In the Netherlands, Norway, and the United States, electric vehicles account for over 1 percent of vehicle sales (IEA 2014b).

Box 3.1. **Perform Achieve & Trade mechanism in India**

Perform, Achieve & Trade is a market mechanism to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through tradable energy savings certificates. The mechanism was formally launched in April 2012 and targets 478 industrial units from eight energy-intensive industries—thermal power, aluminum, cement, fertilizer, iron and steel, pulp and paper, textiles and chlor-alkali. These 478 industrial units account for 25 percent of Indian GDP and about 45 percent of the country's primary energy consumption, or 165 million tons of oil equivalent (Mtoe) annually.

Number of industrial enterprises by subsector



Under the mechanism, each of the 478 industrial units has been assigned individual energy consumption reduction targets which the individual units have to achieve during the first target period of April 1, 2012 to March 31, 2015. At the aggregate level, the mechanism envisages saving 6.6 Mtoe of energy per year by the end of the first period.

The mechanism incentivizes industrial units that more than meet their energy saving targets by providing a facility to convert the excess energy savings achieved (above the target) into energy saving certificates (ESCerts), with each ESCert equivalent to 1 Mtoe savings over the target. The mechanism provides for trading of these EScerts on power exchanges, where the industrial units who fail to achieve the targets are obligated to purchase EScerts to meet their targets. Price discovery for the EScerts at the power exchanges is envisaged to be an outcome of double-sided, closed-end auctions.

While the framework for measurement and verification of the savings achieved has been put in place, that for accreditation, registration, issuance, and redemption of EScerts through a web-based application, on the lines of what is being done in the case of renewable energy certificates, is being set up. The trading of EScerts is expected to start in 2015.

Source: Bureau of Energy Efficiency, India; Indian Energy Exchange Ltd., New Delhi, India.

Sales of non-plug-in hybrid electric vehicles were stable at 1.3 million in 2013 and reached 1.6 percent of the global market share; 52 percent of such vehicle sales were in Japan. Initial subsidies for hybrid-electric vehicles were discontinued at the end of September 2012, although a tax reduction is still in place (IEA 2014b). The United States, accounting for 39 percent of hybrid-electric vehicle sales, does not have subsidies for hybrid electric vehicles at the federal level, but hybrids do qualify within vehicle acquisition laws that promote alternative-fuel vehicles in government fleets. Some states have financial and nonfinancial incentives (such as priority lane access; IEA 2014b).

Electric bike sales are also growing worldwide, with China holding the largest fleet (over 150 million battery-electric two-wheelers on the road, equivalent to more than half the global two-wheeler stock; IEA 2014b).

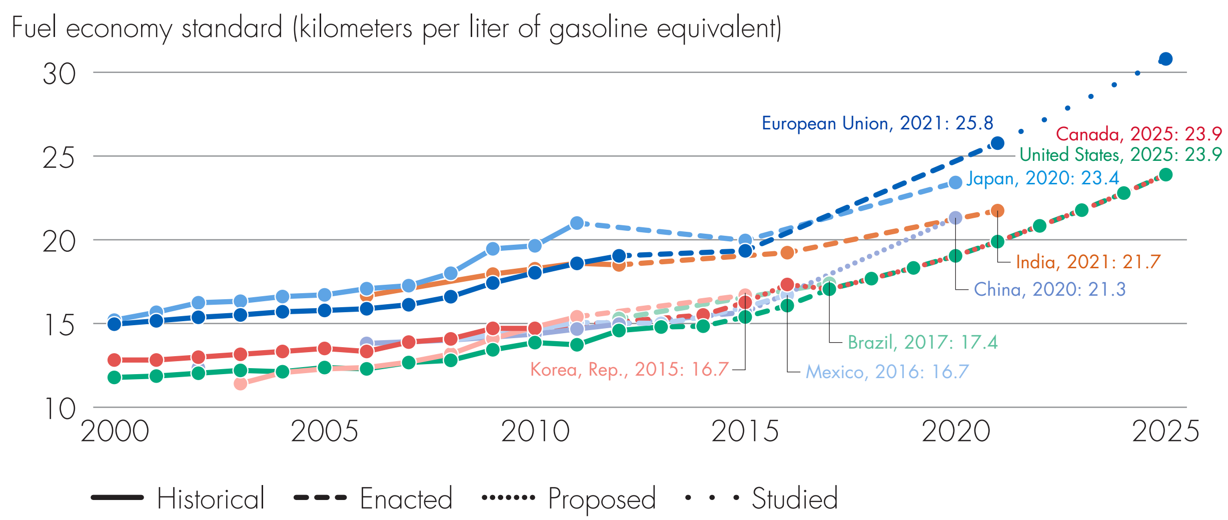
Since the *GTF* 2013 edition (World Bank 2013), electric-vehicle charging infrastructure has expanded, with 12,500 slow (up 27 percent) and 1,300 fast (up 67 percent) chargers installed in 2013 around the world (IEA 2014b).

Urban transport is another important area for energy efficiency improvements. Bus rapid transit systems can be effective in shifting passenger travel to more sustainable modes: 200 cities and 48 countries had such systems by 2013 (EMBARQ 2014).

Buildings

Buildings are the largest energy-consuming sector and account for 31 percent of the global total. Building final energy consumption increased 19 percent over 2000–11 to 119 EJ and is expected to continue increasing as a result

Figure 3.27. **Enacted passenger light-duty vehicle fuel economy standards**



Source: ICCT 2014; IEA 2014a.

Note: The solid lines in the chart describe the historical national annual average efficiency performance as measured by number of km traveled per liter of gasoline equivalent. The higher the number, the greater the average efficiency of new vehicles sold. Dotted lines represent announced standards.

of population and income growth in some regions. Space conditioning (heating and cooling) is the largest end use in the buildings sector. Per unit of floor area, heating is becoming more efficient, but growth in floor area per capita in residential buildings across all regions is driving up overall demand.

Policies to improve energy efficiency in the sector include mandatory building energy codes; MEPS for new buildings, those undergoing renovation, and building components; energy audits, incentives, and technical training; and energy labels and certificates.

Europe is leading the way on policies and financial programs to improve the building stock and to strengthen energy performance requirements for new buildings. For example, the European Commission adopted the Energy Performance of Buildings Directive (EPBD 2002/91/EC) in 2002 and its 2010 revision (2010/31/EC) that require member states to establish and apply MEPS to new buildings and buildings undergoing renovation. The 2010 revision requires all new public buildings to be at least "nearly zero energy" by the end of 2020, and all new buildings should reach this target by the end of 2020. The EPBD requires all member states to set building energy code requirements based on the integrated performance of the whole building and all energy end uses (BPIE 2011).

To complement these policies, many EU countries are providing fiscal incentives for energy efficiency improvements in the sector. KfW Group, Germany's public investment bank, committed €16 billion to energy efficiency investments in the country, including through the Energy Efficient Construction and Refurbishment program. In 2013, KfW invested €4.1 billion in residential retrofits (slightly less than the €4.3 billion invested in 2012). Financing is provided through concessional loans and grants for energy-efficient construction and refurbishment activities in the German residential sector (that is, efficiency achieved beyond the requirements of the German Energy Savings Ordinance). For energy efficiency refurbishments, KfW offers partial debt relief. It also offers promotional loans that it refinances via the capital market with an interest rate subsidy from the Federal Ministry of Building, Transport and Urban Development, for single measures such as windows, heating systems, and insulation (Dorendorf 2013). Since 2006, KfW has provided more than €50 billion in loans and grants to 3 million homes to promote energy-related modernization and energy-efficient new buildings (IEA 2014a).

In Ireland, the Better Energy Homes programs provide financial support to households for energy efficiency investments. These programs led to average annual investments of €230 million in related construction over the five years 2009–13 (IEA 2014a).

Italy offered a 55 percent tax deduction for energy efficiency investments in the residential sector (starting in 2014, the tax deduction has been increased to 65 percent for some measures). Over 2007–13, more than 1.8 million applications were approved, and around €23 billion of investments were leveraged by households, at a cost of about €13 billion in undiscounted forgone tax revenue. In 2012 alone, more than €2.8 billion was invested in 265,500 energy efficiency measures, which included 2.3 million square meters of window replacements and 1.2 million square meters of rehabilitated solid surfaces (IEA 2014a).

Investments in building insulation in the Netherlands have been growing at 10 percent a year, reaching a value of €680 million in 2012 (IEA 2014a).

Outside Europe, energy efficiency policies in the sector have advanced in a few countries. Canada released its Model National Energy Code for Buildings in 2011, which aims for a 25 percent energy efficiency improvement against the current code for commercial and multistory residential buildings and is expected to save Can$70 million for occupants. The code is now in force in four provinces, with six other provinces and territories adopting the code this year (IEA 2014a).

Japan has continued to expand its Top Runner program: it added building insulation materials as target products; strengthened energy auditing, certification, and labeling of buildings; implemented more stringent energy performance requirements for new buildings; and scaled up efforts to improve efficiency of the building stock (IEA 2014a).

On the technology front, significant advances have been made in dynamic glazing that improve passive heating benefits, reduce lighting loads (up to 60 percent), reduce cooling loads (up to 20 percent) and lower peak electricity demand (up to 25 percent) (IEA 2014b).

Appliances, lighting, and electronic equipment

Growth in demand for appliances, lighting, and electronic equipment helped push the average growth of electricity consumption in the buildings sector to 3.4 percent a year over 2000–11.

To improve energy efficiency in the appliances, lighting, and electronic equipment sectors, governments are adopting (and regularly updating the stringency of) MEPS and comparative and endorsement labels. They are also putting in place and updating product test standards and measurement protocols, while providing incentives for the uptake of more efficient technologies.

The United States and the EU are ahead in regulating energy-using products, with 67 and 70 products regulated with MEPS or labels (or both) in mid-2013 (CLASP 2014)]. The EU leads with the number of MEPS (62), and China leads with energy labels (42). The EU has the most ambitious MEPS and energy labels in the world (CLASP 2014b).

In 2013, China introduced new or strengthened MEPs for products including flat-screen TVs, cooktop hoods, lighting systems, fluorescent bulbs, transformers, and water heaters. And it introduced labels for networking equipment (CLASP 2014). Japan expanded its Top Runner program in 2013.

In lighting, compact fluorescent lamps (CFLs) and light-emitting diodes (LED) use one-fifth to one-third of the energy of incandescent lamps. Global initiatives like the United Nations Environment Program (UNEP) Global Environment Facility (GEF) en.lighten Global Efficient Lighting Partnership Program are helping deploy efficient lights in developing countries and to phase out inefficient lights (IEA 2014b). LEDs, in particular, are expected to increase market share in the years to come. In 2012, global sales were $24 billion, and they are expected to reach $57 billion by 2018. In the United States, LEDs saved 75 petajoules of primary energy in 2012 of an annual savings potential of 4,086 petajoules (IEA 2014b). In Japan, LED sales reached $5.2 billion in 2013 and accounted for over 30 percent of all Japanese bulbs sold that year.

The Thailand LED market has grown rapidly in recent years, with sales reaching almost $15 million in 2011 and growing to $38 million in 2013. By 2011, LED lighting had achieved an 8 percent share of the total Thai lighting market, and it has increased to 12 percent today.

India's market for LEDs is poised to expand as the country rolls out a market-based LED program in Puducherry that, if replicated nationally, could lead to the sale of 34 million LED lamps in 2014 and 10 times more by 2016/17. This could reduce electricity demand by over 50 TWh annually (equivalent to avoiding installing 19 gigawatts of generating capacity) and reduce consumer bills by over €3.1 billion (IEA 2014a).

Focus on standby power for networks

Within this sector, increased attention is being paid to the growing number of Internet-connected devices and associated electricity demand. Global demand from such "network-enabled" devices in homes and offices reached 616 TWh a year in 2013 (surpassing the current electricity consumption of Canada). It is projected to grow to 1,140 TWh a year (more than the current electricity consumption of Russia) by 2025 (IEA 2014c).

Much (up to 80 percent) of the electricity used in Internet devices is just to maintain network connectivity. Devices that are part of a network continuously respond to signals from other devices on the network that are checking whether they are still part of the system. This amounts to an almost continuous flow of messages. If the device does not respond promptly, it is considered not part of the network and can be excluded. The continuous flow of messages can keep "waking up" a device so that it cannot power down to low-power mode. But when a device does power down it can lose connectivity because it does not respond to messages.

Most of this energy consumption is unnecessary. Electricity demand from network-connected devices could be slashed by 65 percent by using best available technologies. Best-in-class products use just 0.5 milliwatt (mW) to provide continuous network connectivity, while some today use 25 watts or more (IEA 2014c). As many of these products have a short life cycle, matters could be improved quickly. If best available technologies had been adopted globally in 2013, then 400 TWh could have been saved, and consumer bills could have been cut by $80 billion, assuming an average electricity price of $0.20 per kilowatt-hour (kWh) (IEA 2014c).

There are no technical barriers to integrating energy efficiency and power management solutions in mobile devices with other network-enabled devices. Unfortunately they are not routinely implemented, primarily because of a lack of market demand.

Policy options to tackle energy demand from network standby consumption include MEPS, voluntary agreements with industry, and consumer awareness. Efforts should also come from software developers, hardware producers, service providers, and consumers, as well as standards bodies for test procedures, new energy efficiency metrics (that link power demand to work performed or data transmitted), and the like.

Energy efficiency finance

Expanded finance—through innovative contract terms, repayment methods, funding approaches, and business models—is helping scale up energy efficiency activities.[7] In 2012, the size of the energy efficiency market was estimated at more than $310 billion, of which third-party finance was around $120 billion.[8]

The private sector is the key source of finance. But the public sector is not just a catalyst for private investment: it is also important on its own account through activities like efficient lighting in public buildings and more efficient industrial processes in state enterprises. Public-finance institutions are active in sectors where market failures have limited private sector investment and often have a mandate to provide long-term finance independent of market cycles and in line with longer-term policy objectives. They can frequently leverage capital at below-market rates for targeted investments and develop tools for them. The energy efficiency investments for four public financial institutions in Europe in recent years are summarized in table 3.1.

The EU has several initiatives to scale up this type of finance. For example, the European Structural and Investment Funds provided around €5.6 billion for energy efficiency, cogeneration, and energy management over its 2006–13 funding period. Under the new funding period, 2014–20, the amount is expected to at least double. The European Energy Efficiency Fund acts as a risk-sharing facility that works with financial institutions to provide finance to local authorities and to energy service companies, with a focus on promoting Energy Performance Certificates; in 2013, the fund committed €101 million to seven institutions in France, Germany, Italy, and Romania.

China's energy efficiency service and investment demand is largely driven by the government's comprehensive policies. During the 11th Five-Year Plan, 2006–10, energy efficiency investment surpassed $100 billion, an amount expected to climb to $200–270 billion to achieve its 16 percent energy intensity reduction mandate of the 12th Five-Year Plan, 2011–15.

Multilateral development banks promote energy efficiency investments, often using loans, grants, and guarantees. They frequently provide support through local commercial banks and other financial intermediaries. The European Bank for Reconstruction and Development increased energy efficiency finance from $2.3 billion in 2012 to almost

Table 3.1. **Domestic energy efficiency investment and share of total investment by selected public finance institutions, Europe**

	2010		2011		2012		2013
	€ million	%	€ million	%	€ million	%	€ million
CDC	40	0.3	38	0.2	53	0.3	—
KfW	10,315	16.0	9,701	19.0	13,697	27.1	16,000
UKGIB	n/a	n/a	n/a	n/a	181	—	—
European Investment Bank	2,200	3.1	1,300	2.1	1,100	2.1	2,100

Source: Cochran et al. 2014; IEA analysis.

Note: — is not available; n/a is not applicable. Figures are self-reported and indicative only, due to data limitations and differences in definition. Figures for France's CDC (Caisse des Dépôts et Consignations) exclude ExterImmo and CDC Climat's 2013 investments in industry. The United Kingdom Green Investment Bank (UKGIB) began investing in 2012; figure is for non-residential projects.

$2.7 billion in 2013, although the equivalent figure for the Asian Development Bank declined from $973 million to $854 million in the same period.

Commercial banks supply most finance. Citigroup, for example, directed $1.4 billion to energy efficiency investments over 2007–13. Other sources and channels, however, are becoming mainstream, including green investment banks, capital markets for debt, energy performance contracting, and on-bill financing, often by energy service companies. In China, the market for energy performance contracting, created when three pilot energy service companies were set up in the mid-1990s, is probably the largest in the world. Annual investments reached over $12 billion in 2013 (EMCA 2013), and over 4,800 energy service companies have been registered.

Scale of the efficiency challenge

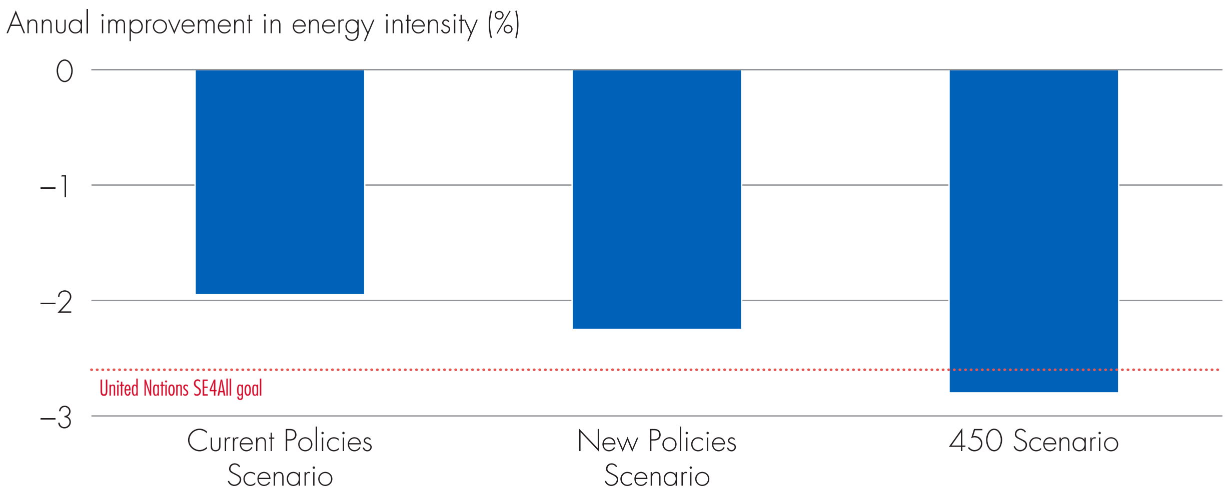
Achieving the goal of the UN's Sustainable Energy for All Initiative of doubling the improvement in global energy intensity from 1.3 percent over 20 years toward 2.6 percent over 2010–30 will be far from easy, as seen when comparing three scenarios in the World Energy Outlook (WEO) 2014 (IEA 2014f):

- *The New Policies Scenario* is the *WEO*'s central scenario. It incorporates policies and measures in energy markets adopted by mid-2014, with policy proposals, even though the implementing measures had yet to be developed. These proposals include targets and programs to support renewable energy, energy efficiency, and alternative fuels and vehicles, as well as commitments to reduce CO_2 emissions, to reform energy subsidies, and to expand (or phase out) nuclear power.

- *The Current Policies Scenario* considers only those policies and implementing measures formally adopted by mid-2014. The scenario is designed to offer a baseline picture of how global energy markets may evolve without new policy interventions. Neither of these scenarios envisages reaching the energy reduction goals of the SE4All initiative (figure 3.28).

- *The 450 Scenario* is the only scenario that achieves the SE4All objective, with energy intensity declining annually by 2.8 percent. In this scenario, policies bring about a trajectory of energy-sector greenhouse-gas emissions consistent with the goal to limit the rise in the long-term average global temperature to 2°C. As concerted global policy action before 2020 is now unlikely, near-term policy assumptions for the period to 2020 draw on measures outlined in the *WEO* Special Report *Redrawing the Energy-Climate Map* (IEA 2013). Emissions reductions to 2020 come from four measures that, together, have no net economic cost: targeted energy efficiency improvements in industry, buildings, and transport; limits on the use and construction of inefficient coal-fired power plants; curbs on methane emissions in upstream oil and gas

Figure 3.28. **Annual energy intensity improvement, three WEO 2014 scenarios, 2010–30**



Source: IEA 2014f.

production; and partial phase-out of fossil fuels subsidies to end users. After 2020, it is assumed that a CO_2 price is adopted in OECD countries and other major economies. By 2035, all fossil fuel subsidies are removed in all regions except the Middle East, and CO_2 pricing is extended to the transport sector. Further extension and strengthening of MEPS in transport and buildings also form part of the scenario.

The outlook for efficiency improvements

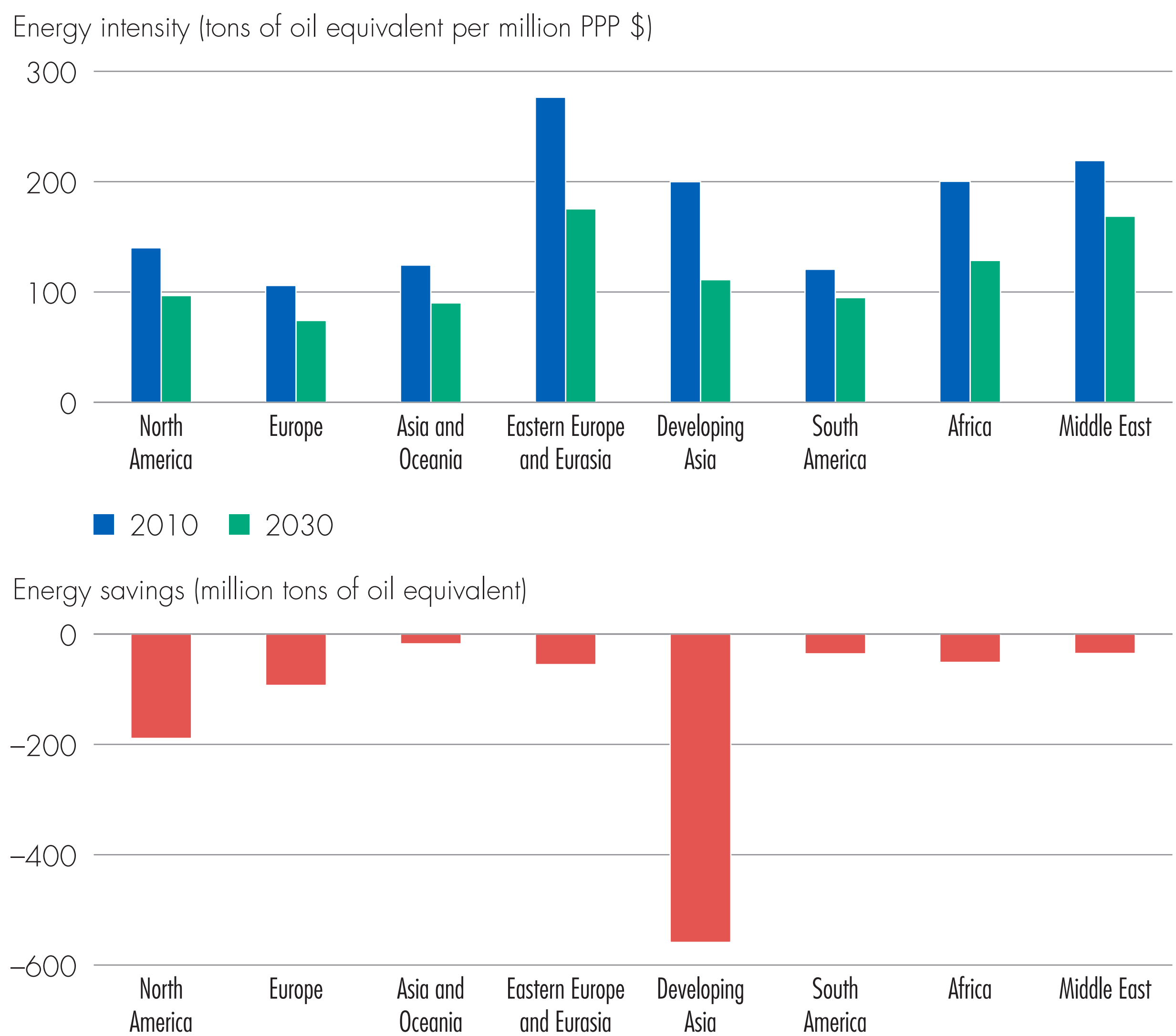
In the New Policies Scenario, energy intensity declines by 2.2 percent annually, still better than the trend seen in 1990–2010, but current policy commitments and those under discussion but not yet implemented have to be strengthened to achieve the SE4All objective. In this scenario energy demand is projected to increase from 540 EJ in 2010 to 700 EJ in 2030, or almost 30 percent (about 45 EJ, or 6 percent, lower than in the Current Policies Scenario).

Energy efficiency accounts for almost two-thirds of the difference in energy demand between the New and Current Policies Scenarios with the vast majority of savings from end uses, which are evenly spread among buildings, transport, and industry. In transport, several countries are discussing strengthening fuel economy standards to increase energy security by reducing oil imports, and to improve air pollution. In buildings, savings arise mainly from two areas: space and water heating due to improved building insulation, retrofits, and higher uptake of more efficient boilers; and appliances stemming from policies to introduce or tighten efficiency standards. In industry, most of the efficiency-related savings arise in non-energy-intensive industries incentivized by policies such as encouraging adoption of energy management systems and energy audits, incentives, and enhanced use of energy service companies.

In the New Policies Scenario, global energy intensity decreases by about a third over 2010–30 with regional savings ranging from 20 percent in Latin America and the Caribbean (partly as the regional system is heavily reliant on hydropower, which is attributed 100 percent efficiency) to almost 45 percent in developing Asia (figure 3.29). Given different climatic and economic conditions among regions, as well as energy efficiencies, energy intensities vary and are set to converge only slowly.

Energy efficiency policies, alongside structural changes in the economy and fuel switching (particularly in power generation) in developing Asia account for more than half the reduction in global primary energy demand in the New Policies Scenario compared with the Current Policies Scenario. This reflects the sheer size of the energy market in this region (more than 40 percent of global energy demand in 2030), the large size of the remaining energy

Figure 3.29. **Results of the New Policies Scenario**



Source: IEA 2014f. Definitions of world regions in *WEO* scenarios differ somewhat from SE4All regions.

Note: PPP is purchasing power parity.

efficiency potential, and the emphasis on exploiting the benefits of energy efficiency.

In developing Asia, China is by far the largest energy consumer. Its 16 percent goal for reducing energy intensity over 2011–15 is supported by policies to mitigate energy demand growth in industry, including the Top 10,000 energy-consuming enterprises program, Ten Key Projects, and industrial energy performance standards. Current restructuring of the economy is also expected to lead to pronounced savings in energy consumption per unit of GDP.

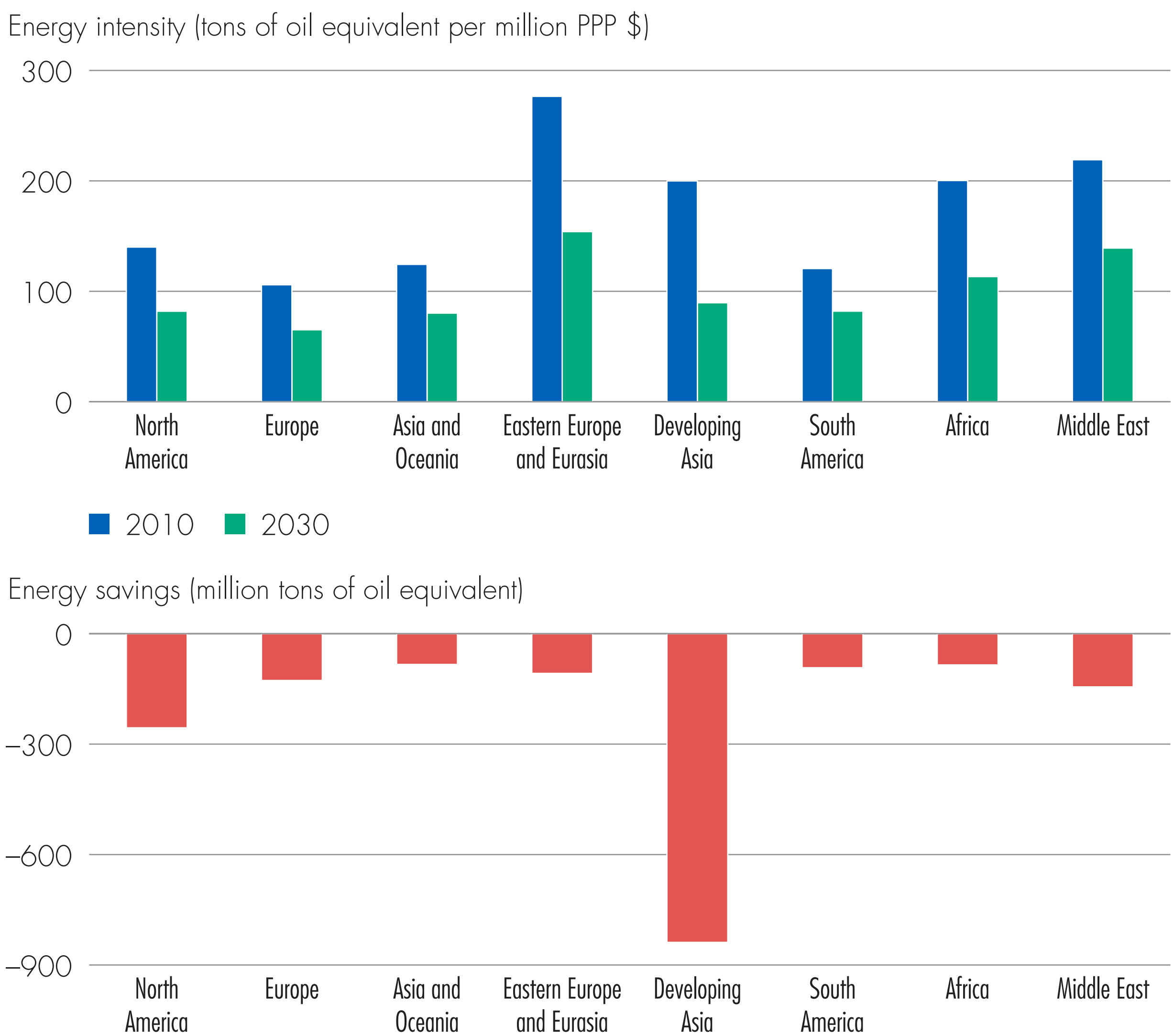
In India, the central policy for energy efficiency is the Perform, Achieve & Trade mechanism, which targets a 5 percent reduction in energy consumption by 2015 compared with 2010. The system is likely to be enlarged in the New Policies Scenario.

North America sees the second-largest savings in the New Policies Scenario, driven by fuel economy standards expected to be extended and tightened. Next are savings in buildings, based on efficiency standards for appliances announced in the U.S. President's Climate Action Plan.

Europe has a long history of energy efficiency policies—including emissions standards in transport, the EcoDesign and Energy Labelling Directive, and the Energy Performance of Buildings Directive—which makes this region one of the least energy intensive. The EU aims to reduce energy consumption by 20 percent in 2020 and 27 percent in 2030 against its reference projection. To achieve this, the Energy Efficiency Directive will be vital in further decreasing energy intensity through, among others, obligation programs or other targeted policy measures and mandatory energy audits for large enterprises.

In Eastern Europe and Eurasia, Russia has passed a law on energy conservation and energy efficiency, which aims to increase energy efficiency in industry by, for instance, phasing out outdated industrial processes. Consequently, energy demand in 2030 in the New Policies Scenario is about 2.3 EJ below the Current Policies Scenario. In Asia/Oceania, a renewed focus on energy efficiency standards

Figure 3.30. **Results of the 450 Scenario**



Source: IEA 2014f.

Note: PPP is purchasing power parity.

for buildings and appliances (including Japan's Top-Runner program) leads to further savings.

Impeded by low energy prices, energy efficiency uptake in the Middle East has been slow as subsidized prices render energy efficiency projects economically nonviable, though in recent years this has begun to change in some countries. Saudi Arabia became the first country in the region to announce fuel economy labeling and standards for imported vehicles, in 2014. Mandatory building codes and the introduction or strengthening of standards for air conditioners are becoming more common. In most African countries, except for a few countries in North Africa and Southern Africa, the focus has been on providing access to basic energy services to boost economic growth. This means that energy efficiency has received less attention even though it could speed up access to energy and render this effort more economical.

In the 450 Scenario, which limits the long-term temperature increase to 2°C, energy intensity improves by 2.8 percent annually. Its central assumption is that in the long term, policies such as international sectoral agreements in industry, energy efficiency standards in buildings, and fuel economy targets in transport allow the market to realize the full potential of economically viable energy efficiency measures. Up to 2020, the scenario has four key measures for energy efficiency that can be quickly adopted and that have already been developed in numerous countries:

- More efficient heating and cooling systems in residential and commercial buildings through MEPS for new equipment and technology switching, such as through greater use of heat recovery and better use of automation and control systems.
- More efficient appliances and lighting in residential and commercial buildings.
- Use of more efficient electric motor systems in industrial applications, such as pumping, compressing air, and other types of mechanical handling and processing.
- Fuel economy standards and labeling for new PLDVs and freight trucks in road transport.

In the 450 Scenario, oil demand peaks around 2020 at roughly 93 million barrels per day (mb/d) and declines due to increasingly strict fuel standards toward 86 mb/d in 2030. Similarly, coal demand peaks before 2020 at around 5,800 million tons of coal equivalent (Mtce), before dropping to 4,200 Mtce in 2030. This largely stems from a decreasing share of coal in the power mix, abetted by energy efficiency policies in industry. Global demand for natural gas—unlike the other two fossil fuels—increases to 2030, reaching 4,100 billion cubic meters in 2030.

The 450 Scenario also incorporates staggered introduction of CO_2 prices in all OECD countries and in major non-OECD countries. Further, fossil fuel subsidies are phased out within the next 10 years in net-importing countries and by 2035 in net-exporting countries (except for the Middle East where some remain). To limit the rebound effect where efficiency savings lead to lower international energy prices and encourage higher demand, end-user prices are assumed to stay on the same level as in the New Policies Scenario, for example, through an increase in fuel taxes.

Regionally, developing Asia is responsible for almost half the energy savings in the 450 Scenario against the New Policies Scenario. Still, energy intensity drops steeply in all regions (figure 3.30). The fall in energy intensity over 2010–30 is particularly strong in Developing Asia, Eastern Europe and Eurasia, and Africa, indicating the large untapped potential there (Table 3.2. Key energy efficiency indicators, selected regions).

Table 3.2. **Key energy efficiency indicators, selected regions**

	World		North America		Europe		Asia and Oceania		Eastern Europe and Eurasia	
	2010	2030	2010	2030	2010	2030	2010	2030	2010	2030
Energy intensity (megajoules/dollar, PPP)	6.8	3.9	5.9	3.4	4.4	2.7	5.2	3.4	11.6	6.4
Energy demand per capita (GJ/capita)	78.4	74.5	239.4	190.0	137.2	111.6	182.6	165.5	138.7	147.2
Residential energy intensity (2010 = 100)	100	76	100	72	100	76	100	77	100	70
Service energy intensity (2010 = 100)	100	63	100	64	100	73	100	65	100	57
Fuel consumption new PLDVs test-cycle (l/100 km)	7.0	4.0	7.4	4.1	5.8	3.2	6.6	3.7	7.3	4.5
Fuel consumption new heavy trucks on-road (l/100 km)	42	27	50	29	31	19	32	19	43	28
Energy intensity of industries (terajoules/$1,000 VA industry)	4.2	2.7	3.5	2.4	2.7	1.9	3.1	2.2	5.9	4.3
Fossil fuel power plant efficiency (%)	43	51	42	51	51	59	43	50	61	71

	Developing Asia		South America		Africa		Middle East	
	2010	2030	2010	2030	2010	2030	2010	2030
Energy intensity (megajoules/dollar, PPP)	8.4	3.8	5.0	3.4	8.4	4.7	9.2	5.8
Energy demand per capita (GJ/capita)	47.5	57.7	54.3	60.1	28.3	25.9	130.3	125.8
Residential energy intensity (2010 = 100)	100	77	100	82	100	77	100	86
Service energy intensity (2010 = 100)	100	47	100	81	100	70	100	67
Fuel consumption new PLDVs test-cycle (l/100 km)	7.1	3.8	7.4	4.2	7.4	4.7	10.1	6.5
Fuel consumption new heavy trucks on-road (l/100 km)	40	28	42	28	48	31	40	27
Energy intensity of industries (terajoules/$1,000 VA industry)	5.7	2.9	4.3	3.1	2.9	2.0	3.2	2.4
Fossil fuel power plant efficiency (%)	37	47	39	47	37	44	33	42

Source: IEA 2014f.

Investment needed to reach the energy efficiency objective

Current efficiency investment

To achieve the energy efficiency gains, huge investments are required. But there is no standard definition of such investments across governments, academia, and financial institutions. For the WEO calculations, energy efficiency investment is defined as the additional expenditure made by households, firms, and governments to improve the performance of their energy-using equipment above the average efficiency level of that equipment in 2012. In the case of a refrigerator, the baseline in 2012 can be assumed to be an A++ refrigerator (with annual electricity consumption of 230 kWh) costing $800. A family replacing this refrigerator in 2020 buys an A+++ refrigerator (annual electricity consumption: 150 kWh) costing $950, so the investment related to improving energy efficiency is $150.

The extensive technology detail in the World Energy Model enabled an analysis of investment, stock turnover, and the economic return required across subsectors in industry, modes in transport, and end users in buildings. This analysis allows one to estimate current levels of investment and projected future investment needs. Efficiency levels and their associated investment costs vary by region and technology, of course.

But energy efficiency investment is notoriously difficult to track because it is carried out by a multitude of agents, households, and firms, often without external financing. It often constitutes only a portion of broader investment, and analysis is further complicated by definitional and data quality issues on energy consumption in end uses. Based on the definition outlined above, the World Energy Investment Outlook 2014 (IEA 2014g) estimated annual investment at around $130 billion in 2012, which should be seen against the roughly $900 billion invested in the oil and gas industry and the approximately $650 billion in the power sector.

Other estimates of the global energy efficiency market come from the IEA's Energy Efficiency Market Report (IEA 2014a), which puts it at $316–350 billion, arriving at that central range through several methods (box 3.2). These estimates are much higher than in the World Energy Investment Outlook 2014 (IEA 2014g) due to differences in methods, including market definition. To provide consistency within this report, the approach taken for the World Energy Investment Outlook is adopted to estimate current market size and future investment needs. It bears emphasis that conclusions about the scale of growth needed to meet the efficiency goal are not affected by the choice of method.

Box 3.2. **Estimating investment in energy efficiency**

The two chief approaches to estimating the size of investment in energy efficiency are counting energy efficiency adoption with bottom-up data; and estimating investment flows with top-down proxy indicators.

The bottom-up approach counts physical units and estimates the energy efficiency component of the cost of that unit relative to a baseline or standard efficiency unit. The top-down approach uses readily available data, such as energy intensity trends, to infer changes in efficiency and the required investment to achieve those changes. Bottom-up methods can be more precise but are costly, and top-down methods are less analysis- and data-intensive and broader in scope. With similar parameters, both methods should produce similar magnitudes of estimates.

The *Global Energy Assessment* (IISA 2012) estimates the global energy efficiency market using bottom-up data and uses the energy component of stock and equipment. The analysis sums the energy-related component of the stock volume into an estimate of the energy efficiency market of $124–713 billion, with a central estimate of $297 billion. The authors note this estimate is conservative and misses investments with important energy efficiency outcomes such as transport infrastructure, building-envelope improvements, and information and communications technology investments (Wilson and Grubler 2012).

Top-down methods use more available and aggregated data as a proxy for energy efficiency to infer a probable magnitude of market size. The IEA's *Energy Efficiency Market Report* (2014a) used a series of top-down methods to build a range of investment magnitudes.

(continued)

Box 3.2. **Estimating investment in energy efficiency** *(continued)*

The first method is the simplest and is an "eye-test" for the likely magnitude. Global gross capital formation measures the total capital investment in all energy-using stock. Investment in appliances, vehicles, and construction (all other physical capital investment) was around $6.8 trillion. Results of research efforts estimating total capital investment in the energy efficiency component range from 5 to 15 percent of the total capital cost (for example, Ehrhardt-Martinez and Laitner 2008). Using a 5 percent estimate for global capital formation returns an investment estimate of $340 billion.

The next methods use annual change in energy intensity as a proxy for energy efficiency, capturing structural and efficiency changes. Decomposition analysis highlights that efficiency in IEA countries has had a greater role in reducing energy demand than structural change. Structural change can have a substantial impact on energy intensity, but is usually felt over a longer period.

Between 2011 and 2012 energy intensity changes led to 11.5 EJ of avoided energy consumption, which can be monetized using a global average price of energy of $13.96 per gigajoule, or $160.5 billion (IEA 2014a). Assuming that investments were made using a two-year payback to achieve these savings, the estimated investment was $321 billion.

Changes in energy intensity can also be run through a model designed to estimate investment needs to achieve energy intensity improvements. The Long-term Industrial Energy Forecast (LIEF) model was developed by Argonne National Laboratory in the United States to evaluate sector-specific responses to increasing cost curves for energy efficiency against a backdrop of changing energy prices (Ross et al. 1993). The assumption is that, as a sector or the economy moves closer to best energy efficiency practice or technologies, the cost of efficiency investment per unit of energy saved increases. The rate of increase depends on energy prices, elasticity of the efficiency supply curve, and the discount rate. It also depends on how innovations and research and development policies might shift the best technology or best practice frontier.

The LIEF model estimates that an 11.5 EJ saving from energy intensity improvements would require a $313 billion investment. This estimate can be further proofed using sensitivity analysis in a Monte Carlo simulation. In a 1,000-iteration randomization of the input parameters, the average investment is $356 billion.

Finally, the IEA estimated the investment in energy efficiency based on leveraged private finance from public financing dedicated to energy efficiency. The IEA built a databank of multi- and bilateral public financing dedicated to energy efficiency and estimated the amount of private finance leveraged by region and sector. It estimated the total investment capital mobilized in 2011 for energy efficiency at $147–300 billion.

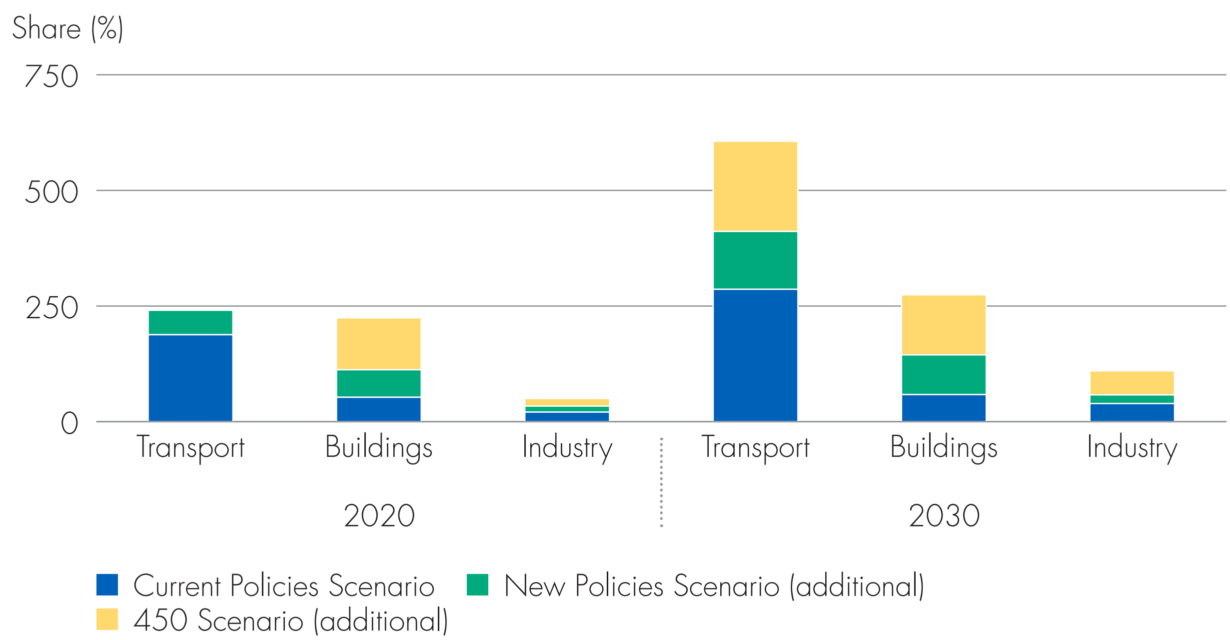
The differences between these estimates highlight the importance of the conceptual framework, the lack of uniform definitions, and the deficiencies of available data. That said, most estimates of energy efficiency investments are very large, in excess of $100 billion annually, underlining the large need for more investment to achieve the 450 Scenario.

Future efficiency investment

To achieve the savings from energy efficiency laid out in the Current Policies Scenario, cumulative additional investment of $4.8 trillion is needed over 2014–30 (averaging $280 billion a year). In other words, investment in energy efficiency is seen increasing more than fourfold to 2030 in the central scenario, but needs to increase a further 60 percent by 2030 to stay within a 2°C trajectory (figure 3.31).

Investment in transport is $3.5 trillion, largely to improve fuel economy. Residential, public, and commercial buildings account for another $0.9 trillion, taking the form of

Figure 3.31. **Annual energy efficiency investment, by sector, three scenarios**



Source: IEA 2014f.

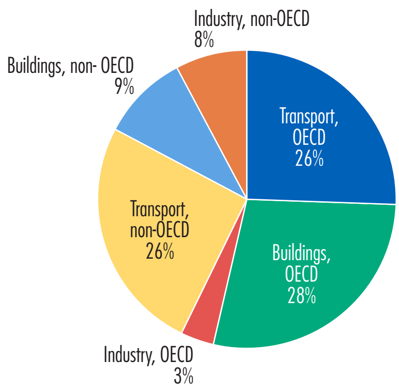
investment in retrofits, insulation, boiler efficiency, and appliances. Industry accounts for $0.4 trillion, most of it to improve efficiency of process heating and steam systems, and much of the rest to improve electric motor systems. Cumulative investment increases by $2.3 trillion in the New Policies Scenario (49 percent) and by another $3.1 trillion (64 percent) in the 450 Scenario compared with the Current Policies Scenario.

Annual investment in the Current Policies Scenario rises gradually from the current estimate of $130 billion in 2012 to $260 billion in 2020 and $380 billion in 2030. Annual investment in energy efficiency increases sharply in the 450 Scenario to $520 billion in 2020 and almost $1 trillion in 2030. Through 2020, the 450 Scenario assumes that only the four key efficiency measures (outlined above) will be implemented on a wider scale than in the New Policies Scenario. As most of the measures are directed at saving energy in buildings (more efficient heating and cooling, appliances, and lighting), investment in buildings doubles in the 450 Scenario against the New Policies Scenario. While spending on more efficient electric motor systems in industry increases investment by around 50 percent, transport investment is almost unchanged from that in the New Policies Scenario. This stability is due to higher investment in electric vehicles and plug-in hybrid electric vehicles, which are not included in efficiency investment in the 450 Scenario, and because today more than three-quarters of car sales are covered by fuel economy standards, leaving little room for additional efficiency improvements over the period.

In the 450 Scenario, transport accounts for slightly more than half of all energy efficiency investment over 2014–30 due to the sheer volume of new, more efficient cars and trucks sold and the high unit investment costs compared with other end-use sectors (figure 3.32). The share of industrial energy efficiency investment is relatively low at 11 percent, as more of the efficiency potential is already implemented, unit investment costs are less expensive, and most of the efficiency improvement occurs during stock turnover, which is quite slow.

From a regional perspective, Europe, developing Asia, and North America dominate energy efficiency investment, accounting for almost 80 percent (figure 3.33). This partly reflects the size of their current energy consumption, but is also a consequence of their current and planned energy efficiency policies. North America, Europe, and China are, for example, the world's largest car markets and have all adopted stringent fuel economy or emission standards for cars and, in some cases, light commercial vehicles

Figure 3.32. **Share of annual average energy efficiency investment in the 450 Scenario, by sector and region, 2014–30**



Source: IEA 2014f.

Note: OECD is Organisation for Economic Co-operation and Development. Average annual investment (2014–30) is $560 billion.

and trucks. Several other regions account for far less investment than their share in final energy consumption, including Africa and the Middle East, due to their lower capital stock than in OECD countries, and different climatic conditions (requiring less space heating). Other factors are the lack of stringent efficiency policies, absence of a functional local banking sector (in some countries), and persistence of fossil fuel subsidies.

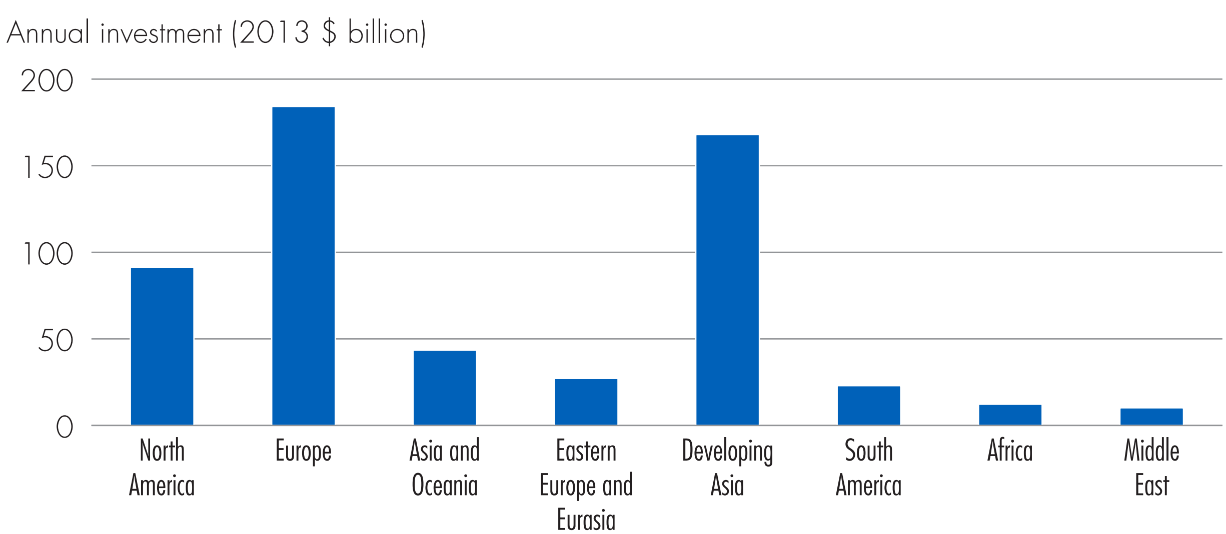
The additional investments in energy efficiency in the 450 Scenario are more than offset by fuel-expenditure savings, and these savings can sharply curtail fuel import bills. Developing Asia, for example, saves more than $300 billion in 2030 in this scenario compared with the New Policies Scenario, mainly on oil imports, helped by improved energy efficiency. Similarly, as Europe has to import less oil and natural gas, it saves more than $150 billion in fuel bills.

Energy-related CO_2 emissions in the 450 Scenario peak before 2020 and decline to 25.4 gigatons in 2030. CO_2 emissions in 2030 in the 450 Scenario are about 11 gigatons less than in the New Policies Scenario, with about half of this attributable to energy efficiency.

The role of subsidies in efficiency uptake

Subsidies for fossil fuels and other forms of energy that lower prices to end users mask the real cost of energy and undermine the financial attractiveness of investments by businesses and by households in more energy-efficient equipment and appliances. Assessing the payback period (time needed to recover an initial expenditure) for a project aimed at improving energy efficiency or spending

Figure 3.33. **Annual average energy efficiency investment in the 450 Scenario by region, 2014–30**



Source: IEA 2014f.

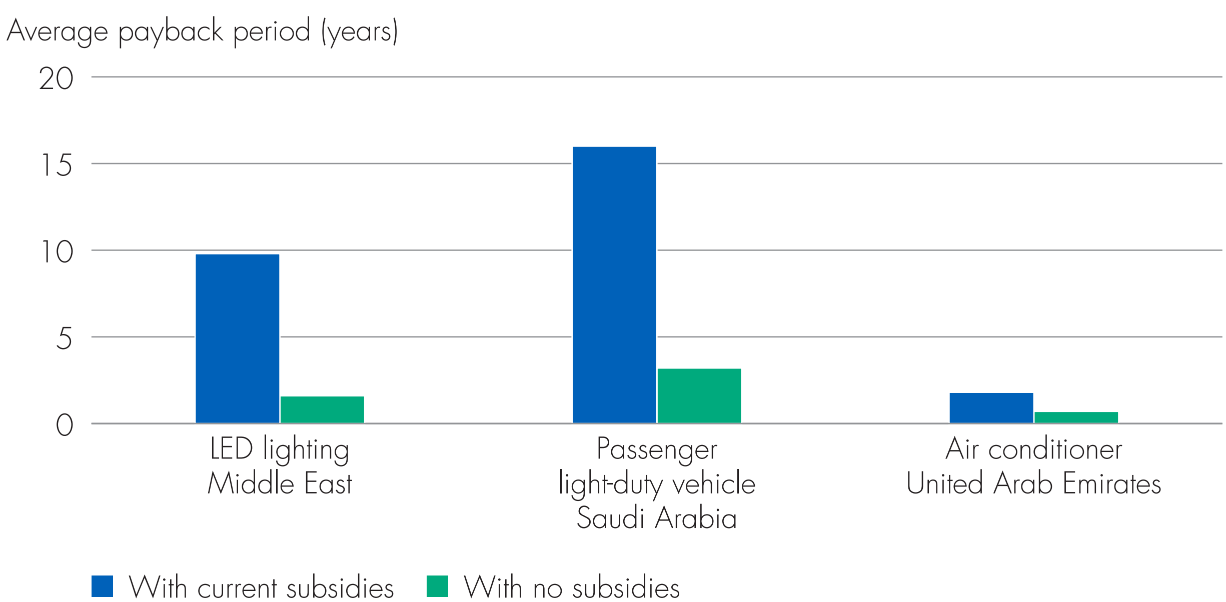
on more efficient equipment is a simple, common method to gauge the financial viability of the expenditure. Energy subsidies lengthen the effective payback periods for investments in energy efficiency by reducing the savings on energy bills. The higher the rate of fuel or electricity subsidy, the longer the payback period, and the less likely consumers will be to commit to the initial spending. To motivate consumers, payback periods often need to be very short, especially where relatively modest amounts of spending are involved and financing is by individuals, who may struggle to afford more costly, efficient equipment and appliances.

The Middle East provides a striking example of the effect of subsidies on energy efficiency (figure 3.34). Energy subsidies in most countries have slowed the uptake of modern, energy-efficient technologies in most end-use sectors. In transport, the average passenger car uses 60 percent more fuel per kilometer than in the OECD (partly because it is larger). In Saudi Arabia, gasoline prices at the pump were around $0.15 per liter in 2013, compared with $0.97 in the United States and $2.10 in Europe on average. It would take around 16 years for a Saudi motorist to recover the cost of upgrading from a vehicle with average fuel economy to one that uses half as much fuel per kilometer—a payback period that most motorists would consider highly unattractive. Removing gasoline subsidies would cut the payback period to just three years.

A similar case applies to lighting, which accounts for more than 15 percent of electricity demand in the building sector in the Middle East. Given the large subsidies to electricity, the payback period for installing LEDs is almost 10 years across the region, against about 1.5 years if electricity tariffs were to cover the full cost of supply.

Subsidies to fossil fuels can also distort consumer awareness of the potential gains from energy efficiency. In some cases, even with subsidized prices, the payback periods on more efficient equipment are shorter than typically required to shift purchasing habits, but are not having the expected effect. For example in the United Arab Emirates, some air conditioners on the market use half as much electricity as the current average, and their additional upfront expense could be recovered in under two years, but have yet to become market leaders. If electricity subsidies were removed, the payback period would drop to just eight months. In both cases, these particularly short payback periods are linked to the very high utilization rates of air conditioners.

Figure 3.34. **Payback period for energy-consuming equipment in selected Middle East countries**



Source: IEA 2014f.

As with other countries in the region, heavily subsidized electricity prices in Saudi Arabia, which are around 10 percent of the EU average, represent the main barrier to adoption of more energy-efficient technologies. For air conditioning, responsible for 70 percent of the country's total residential electricity consumption, the reduction in electricity demand by efficiency increased to current best-practice levels would free about 120,000 barrels per day of oil and almost 5 billion cubic meters of natural gas used to generate electricity. At international prices, this amounts to a saving of almost $7 billion per year. In addition, removing subsidies would encourage investment in building insulation, which could yield large additional savings over the longer term.

Annex 1. Policies and targets by country and sector

Developed economies

Countries	Australia	Canada	EU member states	Japan	Republic of Korea	New Zealand	United States
Cross-sectoral							
Energy efficiency strategy or target	Clean Energy Future Plan National Strategy on Energy Efficiency (NSEE).	Provincial and territorial governments target a 20% increase in energy efficiency by 2020.	National Energy Efficiency Action Plans. Member states presented national indicative targets in April 2013.	Energy Conservation Frontrunner Plan. Target to improve energy efficiency by 30% in 2030. Plan is updated continuously.	The National Energy Master Plan and Energy Use Rationalization Master Plan.	New Zealand Energy Strategy (NZES) 2011–21.	Target: Cut in half the energy wasted in homes and businesses over the next 20 years. Energy efficiency action plans at state level.
Buildings							
Building energy codes	Mandatory for new and existing residential and commercial buildings. Codes updated in 2010.	Voluntary national Energy Code for new and existing residential and commercial buildings, published in 2011 for adoption by subnational regulators. New national building codes in 2015.	Mandatory for new and existing buildings when renovation is undertaken.	Voluntary guidelines for residential and building codes for new non-residential buildings larger than 300 m².	Mandatory for residential buildings and commercial buildings 500–300 m². Codes updated in 2010.	Mandatory for new residential and commercial buildings.	Mandatory for new residential and commercial buildings and major renovations, with some exceptions. Authorize and appropriate adequate funding and technical assistance to states and local governments for energy code compliance and enforcement.
Energy labeling	Seven appliances covered by the mandatory Energy Rating Labelling Scheme. Mandatory disclosure of commercial building energy efficiency.	Mandatory EnergyGuide label for seven major household appliances and light bulbs. Voluntary EnergyGuide label for five household appliances. International Energy Star symbol promoted in Canada.	Energy performance certificates mandatory for all new buildings. Labelling in place for household appliances and office equipment.	Voluntary building labeling program and Energy Star for office equipment.	Mandatory labeling of 35 products under the Energy Efficiency Standards & Labeling Program and 44 target products under the voluntary High-efficiency Appliances Certification Program.	Mandatory Energy Performance Labelling (MEPL) for 7 products.	Mandatory EnergyGuide label for most household appliances. Voluntary energy star labeling for over 65 categories of appliances, equipment, and buildings.
Appliance, equipment and lighting MEPS	20 products covered.	50 products covered.	17 product groups covered by EcoDesign Directive.	Top Runner: 29 products covered.	35 products covered.	21 products covered.	50 products covered.

Countries	Australia	Canada	EU member states	Japan	Republic of Korea	New Zealand	United States
Transport							
Fuel efficiency standards	LDV: Implementation planned from 2015. HDV: None.	LDV: published October 2010 for model years 2011–16. HDV: emission standards for new HDVs and engines.	LDV: 130 g/CO_2 per km by 2015. 95 g/CO_2 from 2020 onwards • HDV: under consideration. • Switzerland is also implementing these standards.	LDV: 16.8 km/l (45.1 mpg). HDV: starting MY 2015.	LDV: 17 km/l and 140 g/CO_2 per km until 2015. HDV: starting after 2015.	Use of European standards.	LDV: 54.5 mpg by 2025 (4.32 l/100 km; HDV: Regulation for 2 sets of standards.
Fuel efficiency labeling	LDV: Yes. HDV: None.	LDV: EnerGuide Label. HDV: None.	LDV: Yes. HDV: None.	LDV: Yes. HDV: Yes.	LDV: Yes. HDV: None.	LDV: Yes. HDV: None.	LDV: Yes. HDV: None.
Fiscal incentives for new efficient vehicles	None.	Several provinces and territories offer incentives or rebates for the purchase of fuel-efficient vehicles, including electric vehicles.	Most countries align vehicle taxes with CO_2 emissions.	Registration taxes according to CO_2 emissions and fuel economy.	None.	None.	Tax at federal level; 39 states offer tax incentives, rebates, or voucher programs for advanced vehicles (electric vehicles, PHEVs, hybrid electric vehicles, and/or fuel cell vehicles).
Industry							
Energy management programs	Energy Efficiency Opportunities (EEO) Program mandatory for corporations using more than 0.5 petajoules per year. Voluntary participation of medium energy users commenced 2012; extended to new developments & major expansion projects 2013; terminated 2014.	EcoEnergy Efficiency for Industry program, which supports the early implementation of the new ISO 50001 Energy Management Systems standards.	Voluntary agreements in place in Belgium (Flanders), Denmark, Finland, Ireland, Netherlands, Sweden.	Energy managers required for large industries.	Voluntary Energy Saving through Partnership program. Mandatory Energy Audits for Large Power Consumers (> 2 ktoe per year).	Energy management diagnostic tools, training for energy managers, and other support.	Voluntary energy management certification program, implementation of ISO 50001. Technical support programs in place, especially for SMEs.
MEPS for electric motors	IE2 for three phase industrial electric motors.	Must meet or exceed the efficiencies outlined in either table 2 or table 3 of CAN/CSA C390–10.	MEPS for three phase induction motors < 7.5kW by 2015; all IE3 (IE2+Variable Speed Drive) in 2017.	Three phase induction MEPS included in Top Runner program.	IE2 (high efficiency) three phase electric motors.	Mandatory MEPS for IE2 and voluntary for IE3.	IE3 (premium efficiency) MEPS for three-phase induction motors.

Developing economies

Countries	Russia	China	India	Brazil	South Africa	Mexico
Cross-sectoral						
Energy efficiency strategy or target	• 2009 Federal Law No. 261-FZ on energy saving and improving energy efficiency; reduce energy intensity by 40% by 2020. • Gradual real increases in residential gas and electricity tariffs (1% per year), and gas prices for industry (1.5% per year) (WEO 2014; IEA 2014f).	12th Five Year Plan (2011–15): Target to reduce energy intensity by 16% by 2015 as compared to 2010.	12th Five-Year plan (2012–17): Multisectoral targets for the Plan period: Industrial sector: 13.18 Mtoe (potential); Appliances and equipment: avoided peak capacity of 2308 MW; Transport sector: 4.3 Mtoe; Buildings: 75% of new buildings (load > 100 kW or Demand > 120 kVA) are Energy Conservation Building Code (ECBC) Compliant by 2017, 25% of existing building reduce energy consumption, 5.07 billion units of electricity saved.	2011 National Energy Efficiency Plan: Reduce projected power consumption by 10% by 2030.	Energy Efficiency Strategy of the Republic of South Africa: Sets a national target of energy efficiency improvement of 12% by 2015.	2008 Law on Sustainable Energy Use; Goal: reduce electricity demand by 12% by 2020 and 18% by 2030.
Buildings						
Building energy codes	Mandatory building codes (but not yet fully implemented).	• Mandatory codes for all new large residential buildings in big cities. • Civil Construction Energy Conservation Design Standards.	Energy Conservation Building Code (2007), with voluntary guidelines for commercial buildings.	Voluntary guidelines in place.	National Building Regulation with voluntary guidelines for new buildings.	National Thermal Insulation and Lighting Standards for commercial buildings.
Energy labeling	Information on energy efficiency classes for appliances required since January 2011.	Labeling mandatory for new, large, commercial, and governmental buildings in big cities.	Voluntary Star Ratings for office buildings.	Labeling program for household goods and equipment in public buildings.	Voluntary Green Star South Africa label.	Green Building Labeling System.

Countries	Russia	China	India	Brazil	South Africa	Mexico
Appliance, equipment, and lighting MEPS	• Voluntary labeling program for electrical appliances • Restriction on sale of incandescent light bulbs (IEA, WEO 2014).	• 46 products covered by labeling programs. • New and strengthened MEPS for products such as flat screen TVs, cooktop/ cooker hoods, lighting systems, fluorescent bulbs, transformers, and water heaters; labels for networking equipment.	• Mandatory S&L for room air conditioners, refrigerators (frost free), tubular fluorescent lamps, and distribution transformers; voluntary for 14 other products, including direct cool refrigerators. • All central government ministries/ departments and their attached and subordinate office to procure air conditioners, refrigerators, ceiling fans, and water heaters of prescribed energy efficiency (star rating on the energy label).	13 products covered by voluntary labels.	Standards under development for lighting; planned for air conditioners, solar water heaters, heat pumps, and shower heads.	Standards for freezers, refrigerators, washing machines, and fluorescent lamps; 186 products covered by mandatory labels.
Transport						
Fuel efficiency standards	None.	PLDV: 6.9l/100 km by 2015, 5.0 l/100 km by 2020; trucks: proposed MY 2015. HDV: Standards in Place.	LDV: Norms finalized, improvement of 10% by 2021. HDV: None.	• Ethanol blending mandates in road transport between 18% and 25%; and biodiesel blending mandate of 5%. • Fuel economy standards under development for PLDV.	None.	LDV: Average new car fleet average fuel economy of 14.9 km/l (35 mpg) in 2016. HDV: Under development.
Fuel efficiency labeling	None.	LDV: Yes. HDV: None.	None.	None.	None.	None.

Countries	Russia	China	India	Brazil	South Africa	Mexico
Fiscal incentives for new efficient vehicles	None.	• Acquisition tax based on efficiency. • Subsidies for hybrid and electric vehicles and consolidation of vehicle charging standards. • Ethanol blending mandates 10% in selected provinces. • Cap on PLDV sales in some cities to reduce air pollution and traffic jams. • Enhanced infrastructure for electric vehicles in selected cities.	Registration taxes by vehicle and engine size, sales incentives for advanced vehicles.	None.	None.	None.
Industry						
Energy management programs	• Competitive wholesale electricity market price. • Federal law on energy conservation and energy efficiency, including mandatory energy audits and energy management systems in energy-intensive industries. • Complete phase-out of open hearth furnaces in iron and steel industry.	• Top 10,000 Program setting energy savings targets by 2015 for the largest 10,000 industrial consumers. • Partial implementation of Energy Performance Standards. • Mandatory adoption of coke dry quenching and top pressure turbines in new iron and steel plants/support non-blast furnace iron making. • Small plants closures and phasing out of outdated production capacity, including the comprehensive control of small coal fired boilers.	Cycle 1 of Perform, Achieve & Trade (April 2012–March 2015) launched. To target 478 industrial units from eight energy-intensive industries. Target saving of 6.6 Mtoe per year by the end of cycle.	None.	Voluntary "Energy Efficiency and Energy Demand Management Flagship Programme" involving 24 major industrial energy users and associations.	None.
MEPS for electric motors	None.	High-efficiency (IE2) MEPs for three-phase induction motors in place.	None.	High-efficiency (IE2) MEPs for three-phase induction motors in place.	None.	Premium efficiency (IE3) for output power ratings of 0.75–150 kW.

Notes

1. http://data.iea.org.
2. http://unstats.un.org/unsd/energy.
3. Time series statistics for national energy and economic accounts are subject to constant retroactive modifications as data are updated to reflect newer and more accurate information. Thus, some of the figures and numbers in this edition of the *GTF* may not precisely match corresponding ones in the 2013 edition. For instance, in the case of energy intensity in the 1990–2010 base period, the overall effect of using the latest data series is a revision of the global CAGR, from 1.30 percent in the *GTF* 2013 edition (World Bank 2013) analysis to 1.36 percent now, a difference of less than 5 percent. This arises mainly from more accurate and more complete GDP data compared to two years ago.
4. Worldwide, roughly one-third of total primary energy supply is attributable to energy production, conversion, refining, transmission, and distribution. The remaining two-thirds are attributable to final energy consumption in end uses.
5. Owing to data limitations, it is currently not possible to apply the approach used in figure 3.21 to this group of countries.
6. One ton of coal equivalent equals 29.31 gigajoules.
7. This section draws heavily on IEA 2014a.
8. See the last section of this chapter on estimating the size of the market for such investments.

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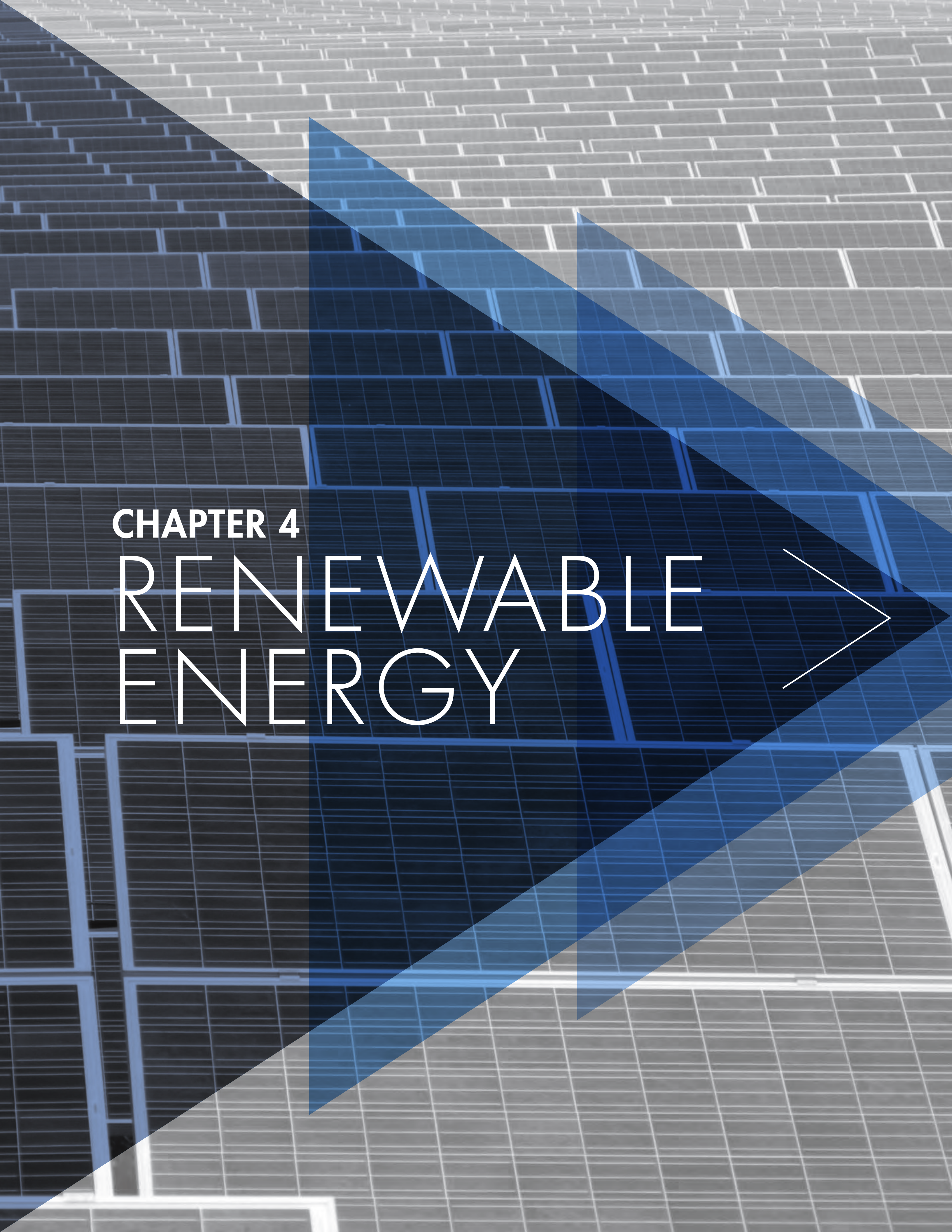


CHAPTER 4
RENEWABLE ENERGY

Renewable energy

Highlights

- The global share of renewable energy (RE) in total final energy consumption (TFEC) increased from 17.8 percent to 18.1 percent over the two-year tracking period 2010–12. This represents an absolute increase in RE consumption of 2.9 exajoules (EJ), equivalent to the annual energy consumption of Thailand or Pakistan.

- The average annual RE share increase over the tracking period was three times as high as that in the previous 20 years. But it is still only one-fifth of the level to meet the Sustainable Energy for All (SE4All) objective of doubling the RE share of global TFEC over 2010–30.

- Global RE consumption grew at a compound annual growth rate (CAGR) of 2.4 percent over the tracking period (4 percent excluding traditional use of solid biofuels). TFEC grew at a CAGR of 1.5 percent.

- In electricity, RE generation capacity grew at a CAGR of nine percent in 2010–12, up from five percent the previous decade, and more than double the growth rate of fossil fuel capacity over the same period. The share of RE consumption in the electricity sector increased by 1.3 percent over the period, while changes in the heating and transport sectors were almost negligible at around 0.3 percent and 0.1 percent, respectively.

- Half of the top 20 energy consuming economies increased their renewables share in TFEC. These were all high-income countries, with the largest share increases registered in the European Union (EU; Germany, Italy, Spain, and the United Kingdom) and Australia. In large middle-income countries such as China and Nigeria, a reduction in the share of solid biofuels for traditional biofuels weighed down the total RE share, but the share of modern renewables increased. Brazil, with the highest share of modern renewables among the large economies, saw that share slip significantly due to a contraction in the consumption of liquid biofuels.

- Global investment in RE increased from $227 billion in 2010 to $278 billion in 2011 but fell to $258 billion in 2012. The decline of investment in the tracking period reflected in part a rapid drop in the cost of solar photovoltaic (PV) modules and in part a sharp investment fall in Organisation for Economic Co-operation and Development (OECD) countries in Europe, attributed to uncertainty over long-term policy. Although investment in RE remained stable in 2013 at about $252 billion, emerging data for 2014 suggest a rebound to about $270 billion in that year.

- The number of countries introducing new policies to support investments in RE continued to increase rapidly over 2010–12, particularly competitive biddings and policies to support distributed generation, such as net metering. In addition, 35 more countries introduced RE targets, lifting the total number to 144 during the tracking period.

- In the New Policies Scenario and the 450 Scenario in the *World Energy Outlook (WEO) 2014*, the share of RE in TFEC reaches, respectively, 24.0 percent and 29.4 percent by 2030, indicating that achieving the SE4All objective of doubling the share of RE in TFEC to 36 percent over 2010–30 is extremely challenging and requires a fundamental change in the way energy is produced and used. Other assessments and modeling exercises forecast a higher share of RE in 2030, but this more positive expectation requires existing challenges to be tackled more strongly, including heavily reducing fossil-fuel activities, supporting technology innovation, introducing new finance and business models, and implementing transformational policies.

- Attaining the RE objective is tightly intertwined with the other two SE4All objectives. For instance, increased access to modern sources of energy could reduce the consumption of solid biofuels and thus the overall renewables contribution or allow biomass to be used more efficiently, which would lower overall energy demand and make the RE objective more attainable.

- A recent analysis by the International Renewable Energy Agency (IRENA) of the existing options and actions to double RE's share in TFEC over 2010–30 (IRENA 2014a) estimates a needed 2.5–fold increase in annual RE investment, assuming that progress is also made in energy access and energy efficiency.

Introduction

This chapter reports on progress over the two-year tracking period 2010–12 toward achieving the SE4All objective of doubling the share of RE in the global energy mix. The rate of this progress is far below that required to meet the objective.

The inaugural edition of the SE4All *Global Tracking Framework (GTF)* in 2013 (World Bank and IEA, 2014) proposed a methodology for establishing a baseline against which to measure global progress in RE and provided an indicator framework for tracking that progress (both are detailed in chapter 5).

The next section looks at the main RE tracking indicators —final consumption of energy and electricity from renewable sources at global, regional, and country levels. The following section focuses on tracking complementary indicators, including investment flows, policy instruments, technology costs, and RE in distributed and rural markets. The fourth section examines the scale of the SE4All challenge through a review of future scenarios and an evaluation of existing barriers. The last section estimates the investment required to attain the SE4All RE objective.

Tracking the renewable energy share

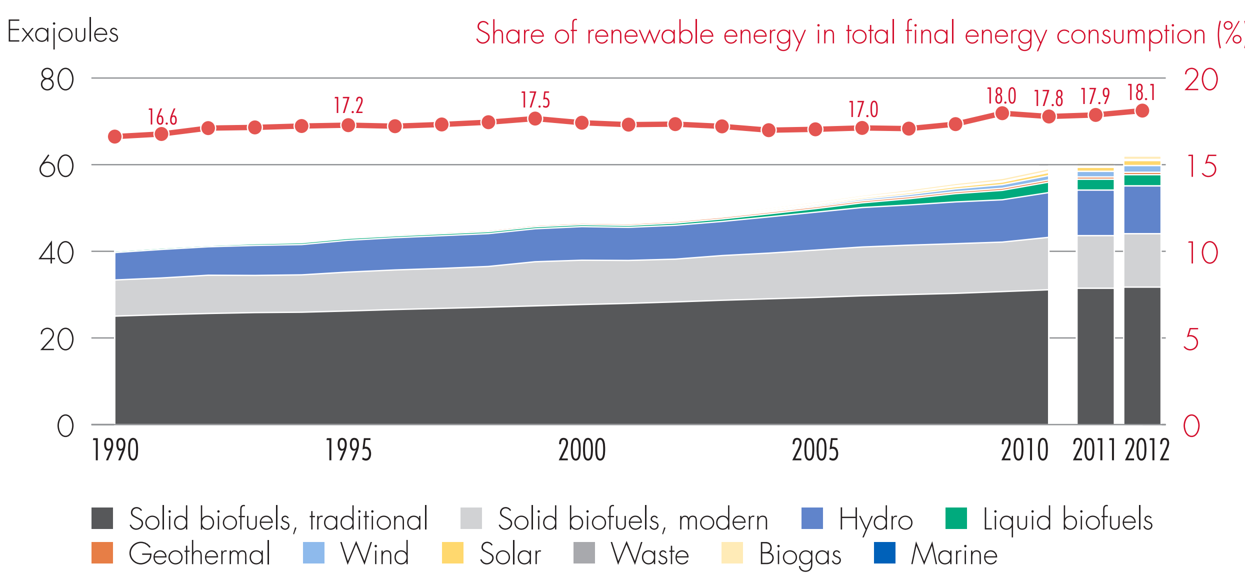
Share of renewable energy in total final energy consumption

The share of RE in TFEC increased from 17.8 percent to 18.1 percent globally in the tracking period (figure 4.1). This represents an absolute increase in RE consumption of 2.9 EJ, equivalent to the entire annual energy consumption of Thailand or Pakistan.[1]

In 2012, solid biofuels used in traditional activities such as cooking and heating accounted for 9.3 percent of TFEC, solid biofuels for modern uses and hydropower accounted for 3.6 percent and 3.2 percent respectively, and all other renewable resources for 2.0 percent of TFEC. The share in TFEC derived from fossil fuels remained unchanged at 79.4 percent, while the share derived from nuclear power declined from 2.5 percent (in 2010) to 2.2 percent (figure 4.2).

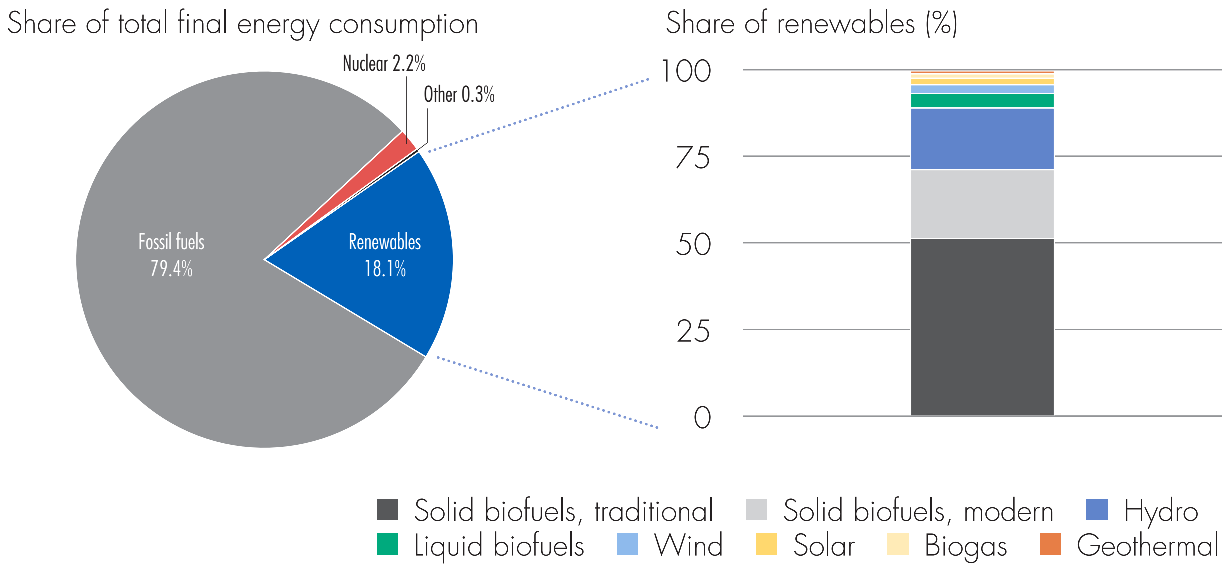
The 0.35 percentage point increase in the share of renewables over the two-year tracking period (from 17.78 percent in 2010 to 18.13 percent in 2012, or 0.17 percentage points a year) is well below the annual average of 0.89 percent to meet the SE4All 2030 objective—only one-fifth as large, in fact (figure 4.3).

Figure 4.1. **RE final energy consumption by source and RE share of total final energy consumption, 1990–2012**



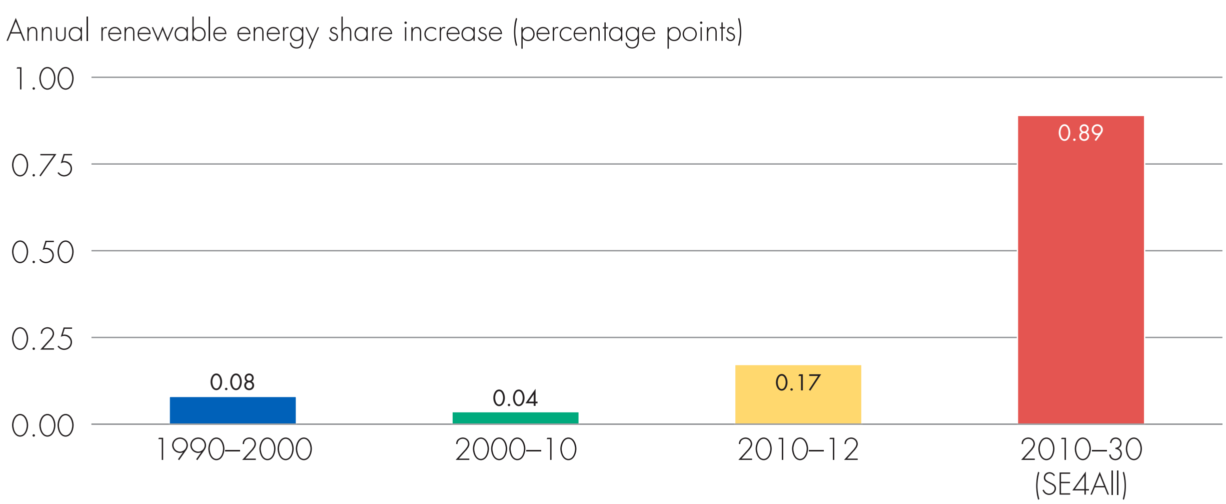
Source: IEA and UN data.

Figure 4.2. **Total final energy consumption by source, 2012**



Source: IEA and UN data.

Figure 4.3. **Average annual increase of renewable energy share, actual and required**



Source: IEA and UN data.

Different RE technologies contributed in varying degrees toward the 0.35 percentage point increase. Hydropower, solid biofuels used in traditional activities, wind, and solar showed the highest contributions (figure 4.4).

Growth rates of renewable energy in total final energy consumption

The RE share increase resulted from both an acceleration of the growth rate of RE consumption and a deceleration of the growth rate of TFEC. RE grew at a CAGR of 2.4 percent (up from 2.3 percent in 2000–10) against TFEC's 1.5 percent (down from 2.1 percent). Consumption of modern RE resources (renewable resources excluding solid biofuels used for traditional purposes such as cooking and heating)[2] grew even faster, averaging four percent (figure 4.5).

The renewables CAGR was higher than the TFEC rate only in high-income countries (HICs); in low- and middle-income countries (LICs and LMICs) RE consumption grew more slowly than TFEC (see figure A1.1 in annex 1). There is still an important gap between the growth rates of RE consumption and TFEC in upper middle-income countries (UMICs), given their energy demand growth.

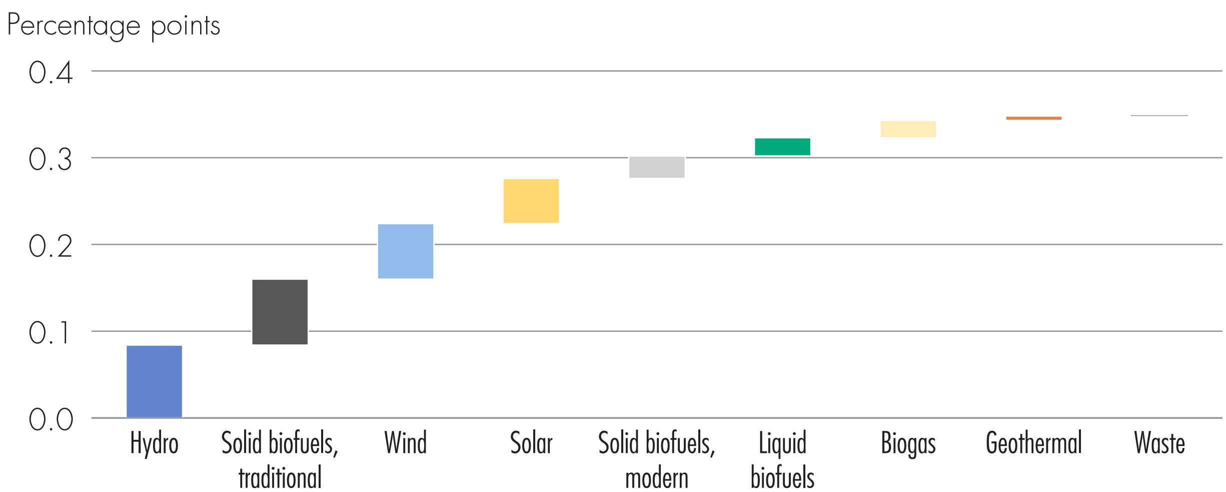
IRENA's REmap 2030 study (2014a)[3] suggests a target renewables CAGR of 3.8 percent (assuming a CAGR for TFEC of around 1.6 percent) over 2010–30 to attain the SE4All objective of doubling the share of RE consumption in TFEC.

Relative to 2000–10, solar and hydro energy consumption accelerated over the tracking period, but growth of all other RE resources slipped. Solar's CAGR doubled from 13.1 percent to 26.9 percent (2010–12) (see figure 2 in annex 1). Wind, biogas, and geothermal grew less rapidly, that of liquid biofuels in particular seeing a large deceleration. Its CAGR fell from 18.3 percent to 3.6 percent, largely due to changes in Brazilian domestic consumption and trade.[4]

Nature of the increase over the tracking period

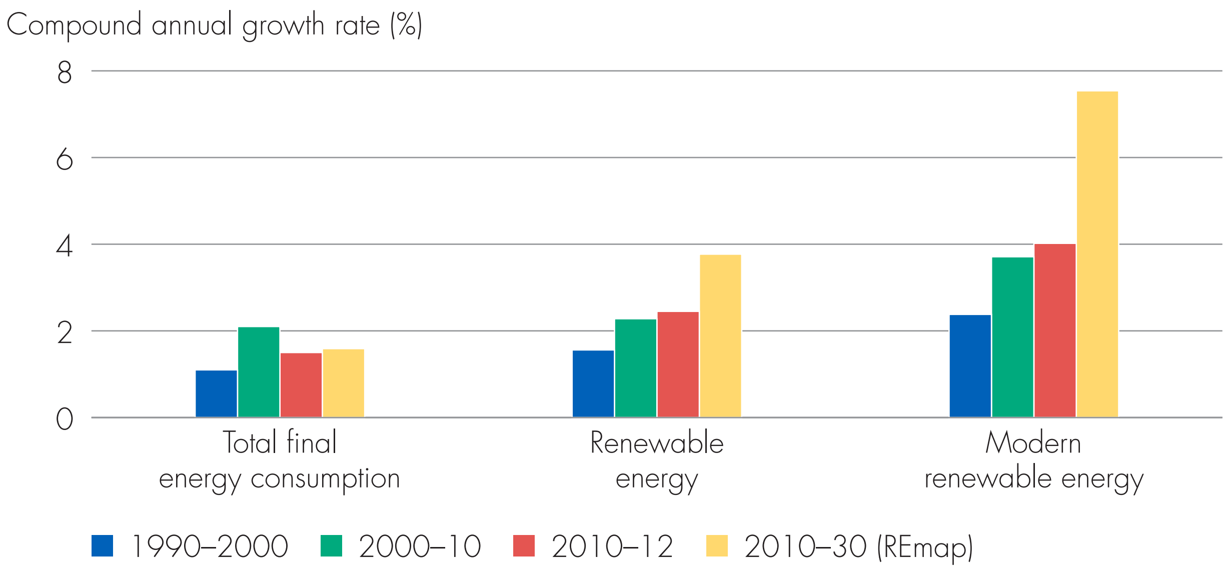
RE consumption increased in all regions except North Africa, increased for all RE resources except marine resources, and increased in all forms of end-use consumption (electricity, heat, and transport). The largest increase in RE consumption was seen in East Asia, followed by Sub-Saharan Africa and the EU. The increase in Sub-Saharan Africa and South Asia was largely among solid biofuels used for traditional purposes. By contrast, Latin America and East Asia heavily cut their consumption of solid biofuels. North America sharply increased its consumption of hydropower, liquid biofuels, and wind energy, but also reduced its consumption of solid biofuels for modern purposes (figure 4.6).

Figure 4.4. **Contribution to renewable energy share increase by source, 2010–12**



Source: IEA and UN data.

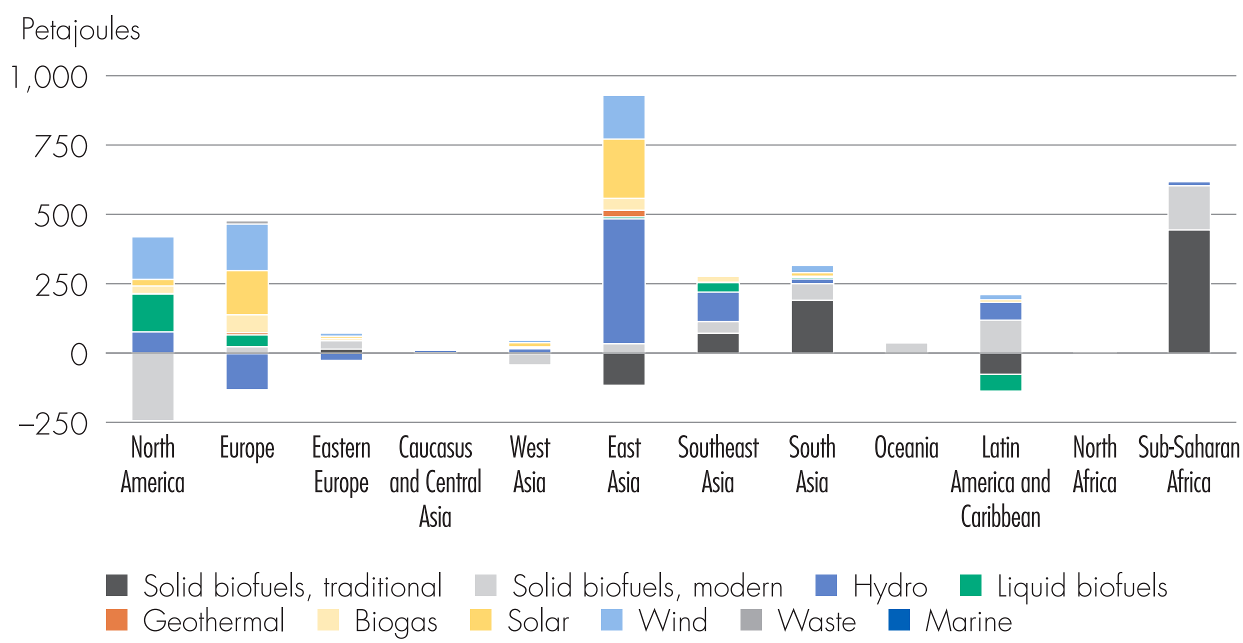
Figure 4.5. **Compound annual growth rate of total final energy consumption and renewable final energy consumption across 1990–2012 and under REmap 2030**



Source: IEA and UN data, 2014; analysis by the International Renewable Energy Agency based on IRENA (2014a).

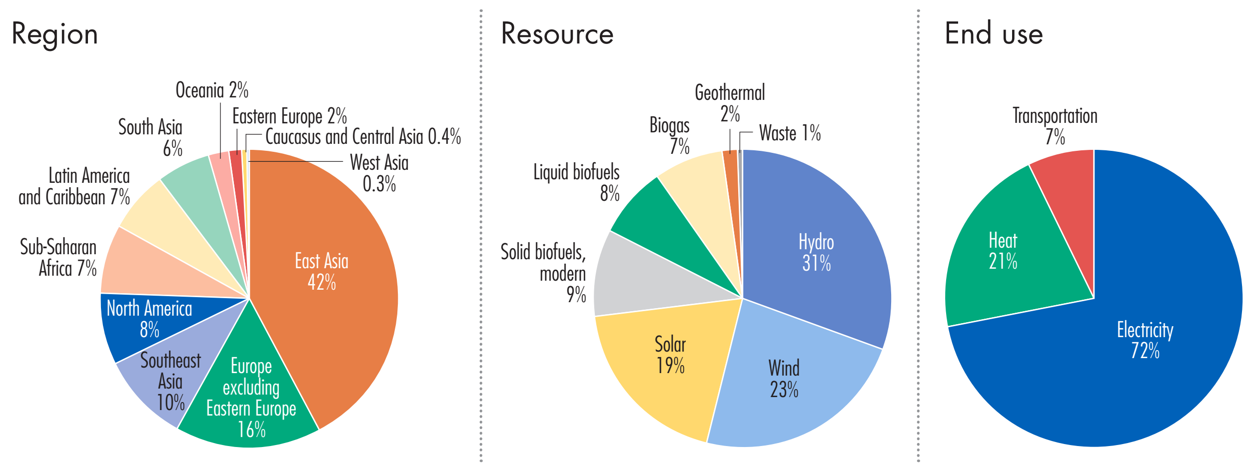
Note: Modern RE excludes traditional uses of solid biofuels.

Figure 4.6. **Renewable energy consumption increases and reductions by region and source, 2010–12**



Source: IEA and UN data.

Figure 4.7. **Composition of the net increment of modern renewable energy consumption, 2010–12**



Source: IEA and UN data.

Note: Excludes traditional uses of solid biofuels.

Excluding solid biofuels used for traditional purposes, the net increase of modern RE consumption is 2.3 EJ. Figure 4.7 presents the composition of this increase by region, technology and end use (figure 3 in annex 1 presents a similar breakdown when including solid biomass for traditional uses).[5] By technology, increases in hydro, wind, and solar resources accounted for roughly three-quarters of the net increase; by end use, increases in electricity generation did the same; and by region, increases in East Asia, the EU, Southeast Asia, and North America also did the same. The share of RE consumption in the electricity sector increased by 1.3 percent over 2010–12, while the heating and transport sectors registered changes on the order of 0.3 percent and 0.1 percent respectively.[6]

Electricity capacity and generation

Global RE generation capacity grew by 19 percent (231 gigawatts [GW]) over the two-year tracking period (from around 1,210 to 1,440 GW) and accounted for half of all capacity additions (figure 4.8). Wind capacity increased by 90 GW globally, while solar and hydropower capacity climbed by 61 GW and 68 GW. Over the decade 2002–12, solar PV saw an extraordinary 40-fold increase in capacity. By the end of 2012, total renewable power capacity had doubled from 10 years earlier.[7] In China, renewable power capacity surpassed that of fossil fuels and nuclear power for the first time in 2014 (REN21 2014a).

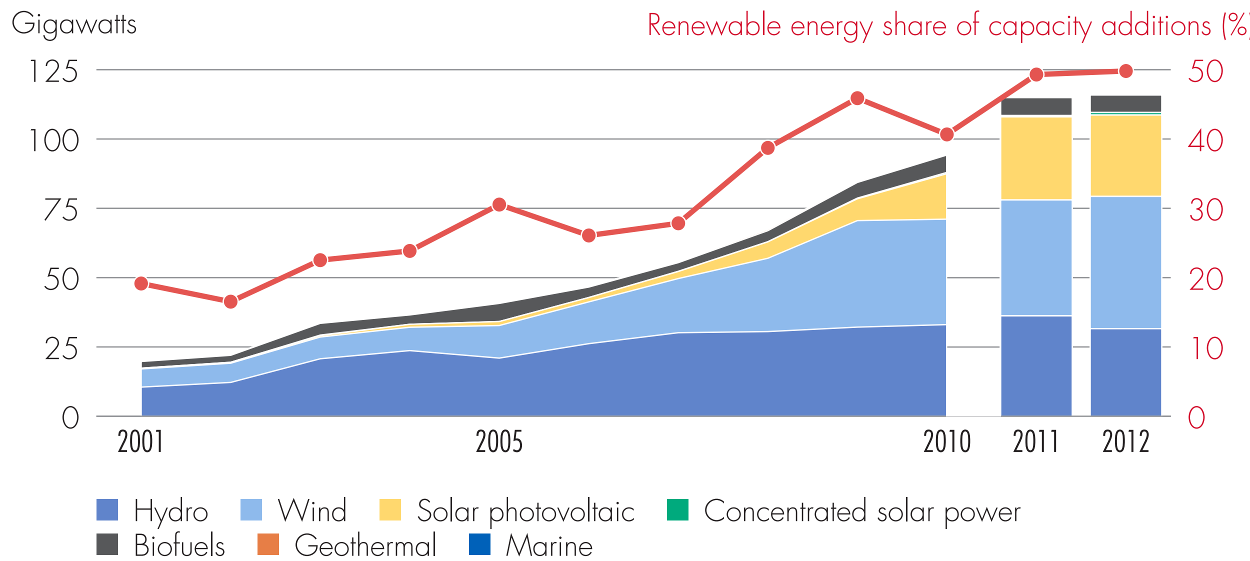
RE generation capacity grew at a CAGR of 9.0 percent in 2010–12, up from 5.0 percent in 2000–10 and more than double the growth rate of fossil fuel capacity over the tracking period. The high growth of RE generation capacity was experienced among all country income groups. Only among LMICs did fossil fuel generation capacity (marginally) outpace that of RE (figure 4.9).

Many countries passed for the first time a 100-MW installed generation capacity threshold for a specific RE technology over 2010–12, including Indonesia (LMIC), Iran (UMIC), and Singapore (HIC) in biomass and waste; Nicaragua (LMIC) and Turkey (UMIC) in geothermal; Egypt (LMIC), Thailand (UMIC), and Slovenia (HIC) in solar; and Honduras (LMIC), Tunisia (UMIC), and Cyprus (HIC) in wind (figure 4.10). This relatively modest threshold, achievable even in small island countries, gives a sense of global adoption of RE technologies

The regions that generated the largest volume of electricity from renewables over 2010–12 were North America, the EU, East Asia, and Latin America and Caribbean, with hydropower as the predominant RE resource (figure 4.11). The first three regions also delivered most of the wind-based generation output. The use of modern solid biofuels for electricity generation remained stable in all four regions.

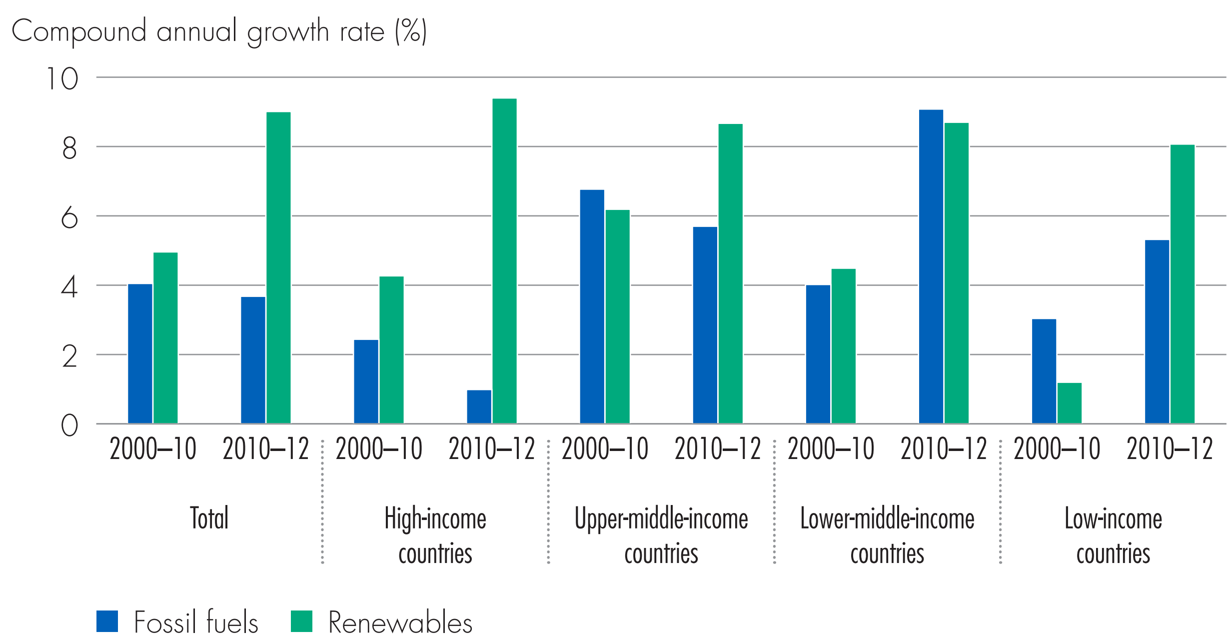
East Asia registered an increase of 18 percent (145 terawatt-hours [TWh]) in hydropower generation in the

Figure 4.8. **Renewable energy capacity additions and share of total capacity additions, 2001–12**



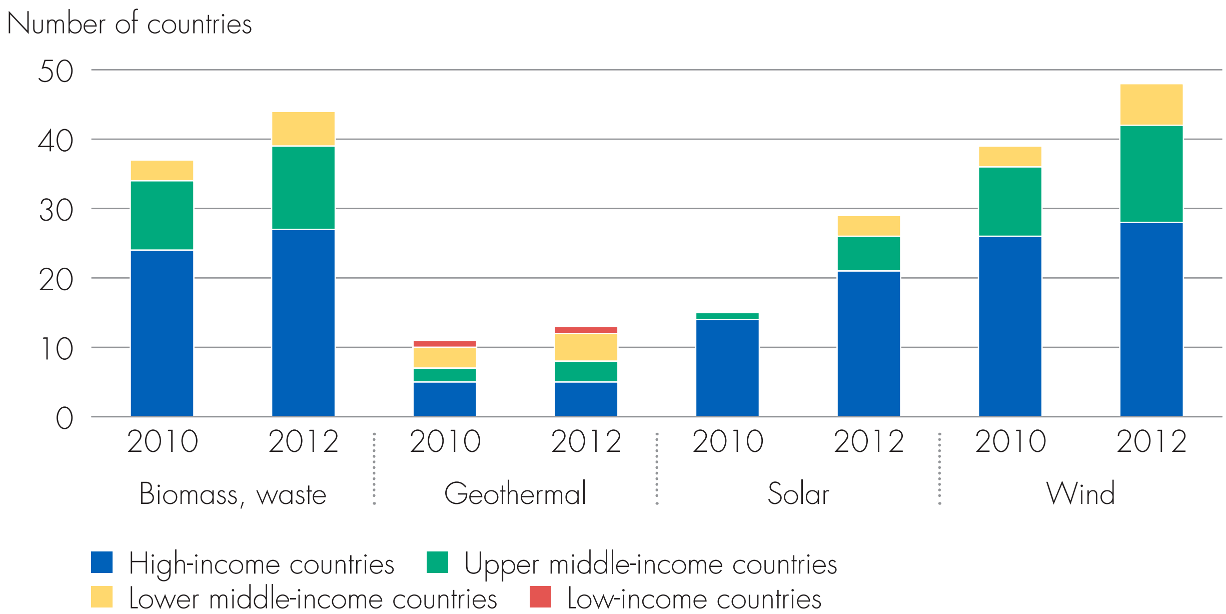
Source: IRENA, IEA, Eurostat, GlobalData, *EPIA*, *GWEC*, and REN21 data.

Figure 4.9. **Compound annual growth rate of renewable versus fossil fuel generation capacity, 2000–12**



Source: EIA 2014.

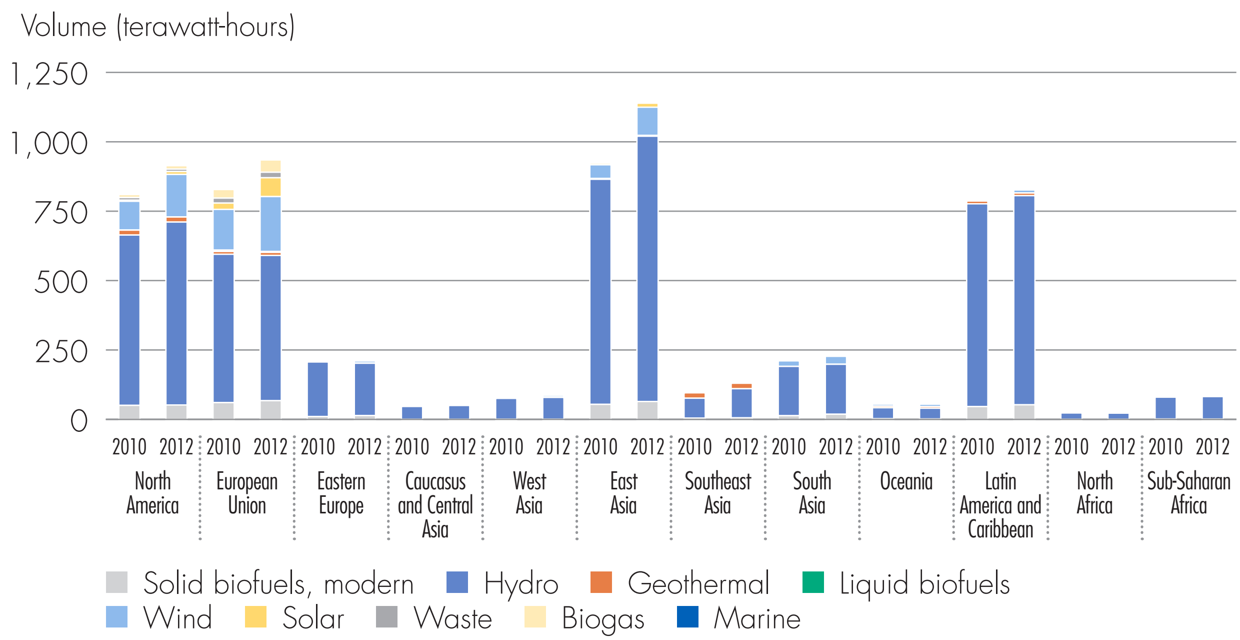
Figure 4.10. **Countries with at least 100 MW renewable generation capacity, 2010 and 2012**



Source: EIA 2014.

Note: For operational and analytical purposes, economies are divided among income groups according to 2013 gross national income (GNI) per capita, calculated using the World Bank *Atlas* method. The groups are: low income, $1,045 or less; lower middle income, $1,046–$4,125; upper middle income, $4,126–$12,745; and high income, $12,746 or more.

Figure 4.11. **Renewable energy electricity generation by region and resource, 2010 and 2012**



Source: IEA and UN data.

tracking period; on wind, the EU and East Asia increased supply by 35 and 106 percent (50 TWh and 52 TWh). The contribution of wind to total RE power generation grew strongly in North America (13 percent to 17 percent), Europe (18 percent to 21 percent), East Asia (5 percent to 9 percent), and Oceania (12 percent to 15 percent). The contribution of solar power generation to the total volume of RE supplied in electricity increased substantially in Europe, from three percent to seven percent.

Country performance

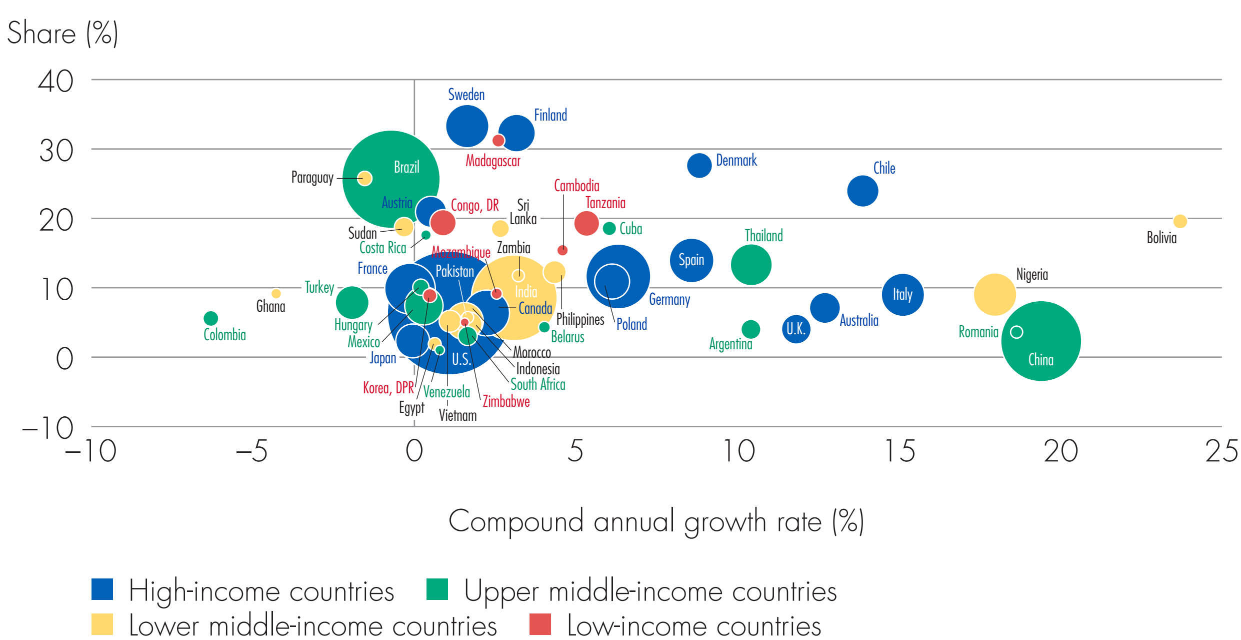
Fast-moving countries

RE resources beyond traditional solid biofuels and hydropower—including solid biofuels for modern uses, liquid biofuels, biogas, waste, geothermal, wind, solar, and marine energy—accounted for 5.2 percent of global TFEC in 2012, an increase of about 0.32 percentage points from 2010. About three-fourths of this volume was produced and consumed by high-income and emerging economies, most notably the United States, the EU, Brazil, India, and China. In 2010–12, Bolivia, Romania, Nigeria, Chile, Italy, and several smaller economies rapidly increased their consumption of non-hydro modern renewables, while the growth rate of consumption for these renewables slumped in China and the United States (the countries had achieved growth rates of 40 percent and 5.5 percent over 1990–2010). Sweden, Finland, Denmark, Madagascar, Brazil, Paraguay, and Chile led in non-hydro modern renewables as a share of energy consumption (figure 4.12).

On hydropower consumption, Vietnam, Myanmar, Ecuador, Kyrgyz Republic, Philippines, the Islamic Republic of Iran, Kenya, China, Colombia, and Ethiopia increased their consumption most rapidly over 2010–12, while China, Brazil, Canada, the United States, Russia, Norway, and India maintained very high volume of consumption (figure 4.13). Tajikistan and Norway have the highest share of hydropower consumption in TFEC.

Figure 4.14 ranks the 20 fastest-moving countries over the tracking period by compound annual growth rate of modern RE consumption. Growth rates for these countries mostly fall in the range of 13–41 percent. Malta and Algeria

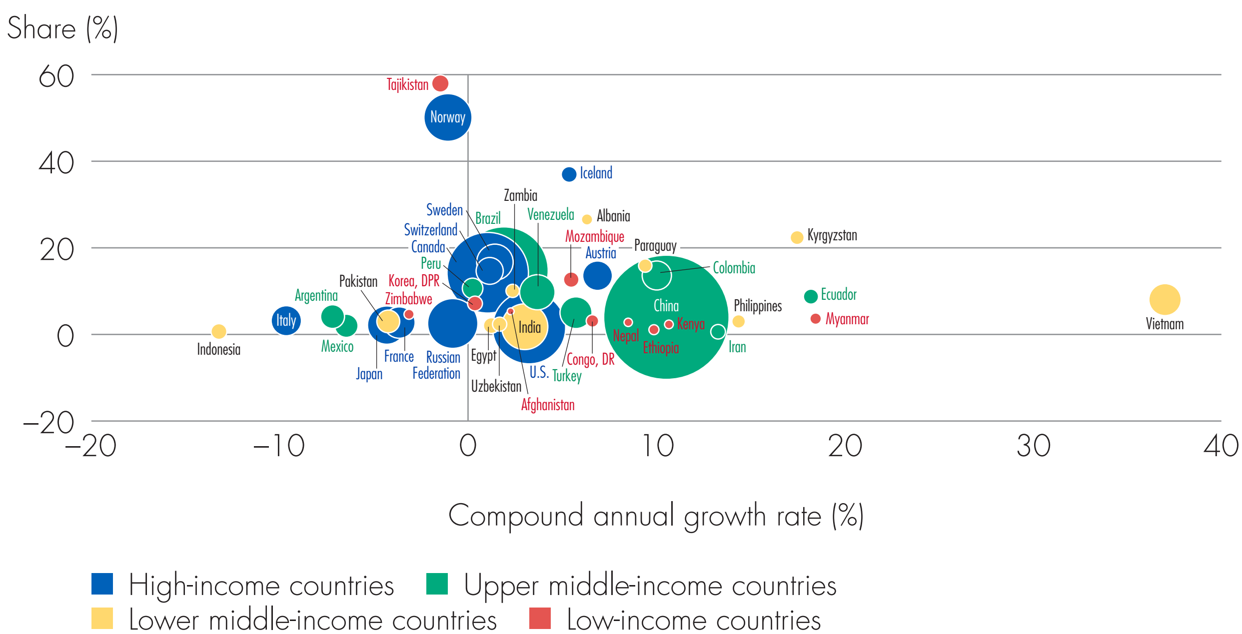
Figure 4.12. **Modern renewable energy share of country total final energy consumption and compound annual growth rate (excluding hydropower), 2010–12**



Source: IEA and UN data (2014).

Note: Excludes hydropower and traditional uses of solid biofuels. Size of bubble reflects 2012 renewable energy consumption by country.

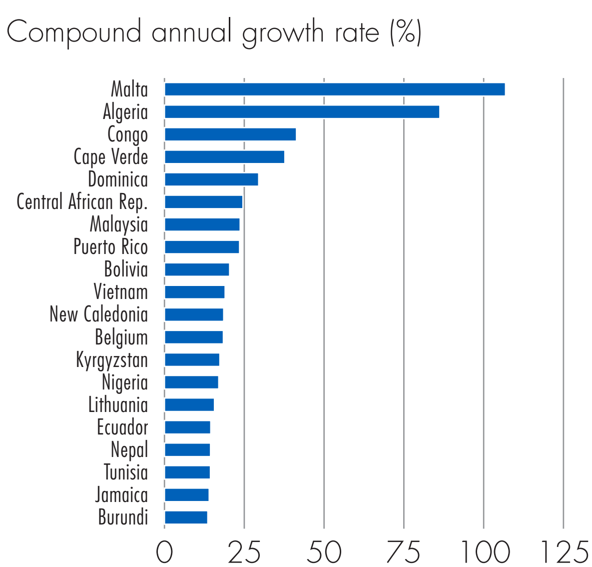
Figure 4.13. **Hydropower share in country total final energy consumption and compound annual growth rate, 2010–12**



Source: IEA and UN data (2014).

Note: Size of bubble reflects 2012 hydropower consumption by country.

Figure 4.14. **Modern renewable energy consumption annual growth in the top 20 fastest-moving countries, 2010–12**



Source: IEA and UN.

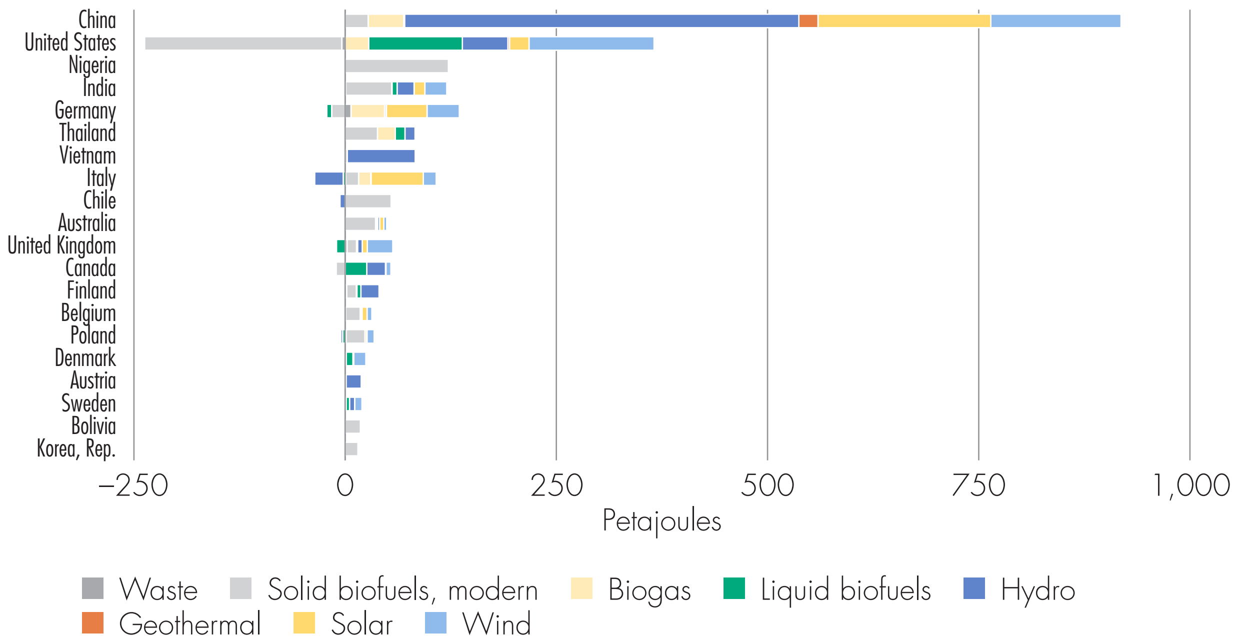
Note: Excludes traditional uses of solid biofuels.

top the chart with rates well above this range. In Malta, renewables started from a small consumption base but saw increased consumption of waste, liquid biofuels, and solar energy, while in Algeria consumption of energy from hydro resources tripled. When including solid biofuels for traditional uses, the renewable energy consumption base in developing countries becomes larger and subsequently top growth rates tend to be lower, in the range of 9–24 (figure A1.5 in annex 1).

In terms of net increase in volume of modern RE consumption, China, the United States, Nigeria, India, and Germany are the top five. China's net increase in modern RE consumption was equivalent to some four-fifths of that of the other 19 countries combined. In Nigeria and India, solid biofuels for traditional activities accounted for a large fraction of the increase, but they remain among the top five in terms of modern RE increase (figure 4.15).

Among countries that made the largest net gains in modern RE consumption, wind, hydro, and solar power accounted for the bulk of the increase, particularly in China, which has introduced bold industrial and RE policies to scale up use of modern renewables. The modern RE consumption increase in the United States would have been

Figure 4.15. **Modern renewable energy consumption increases and reductions by country and source, top 20 countries in terms of net increase, 2010–12**



Source: IEA and UN data.

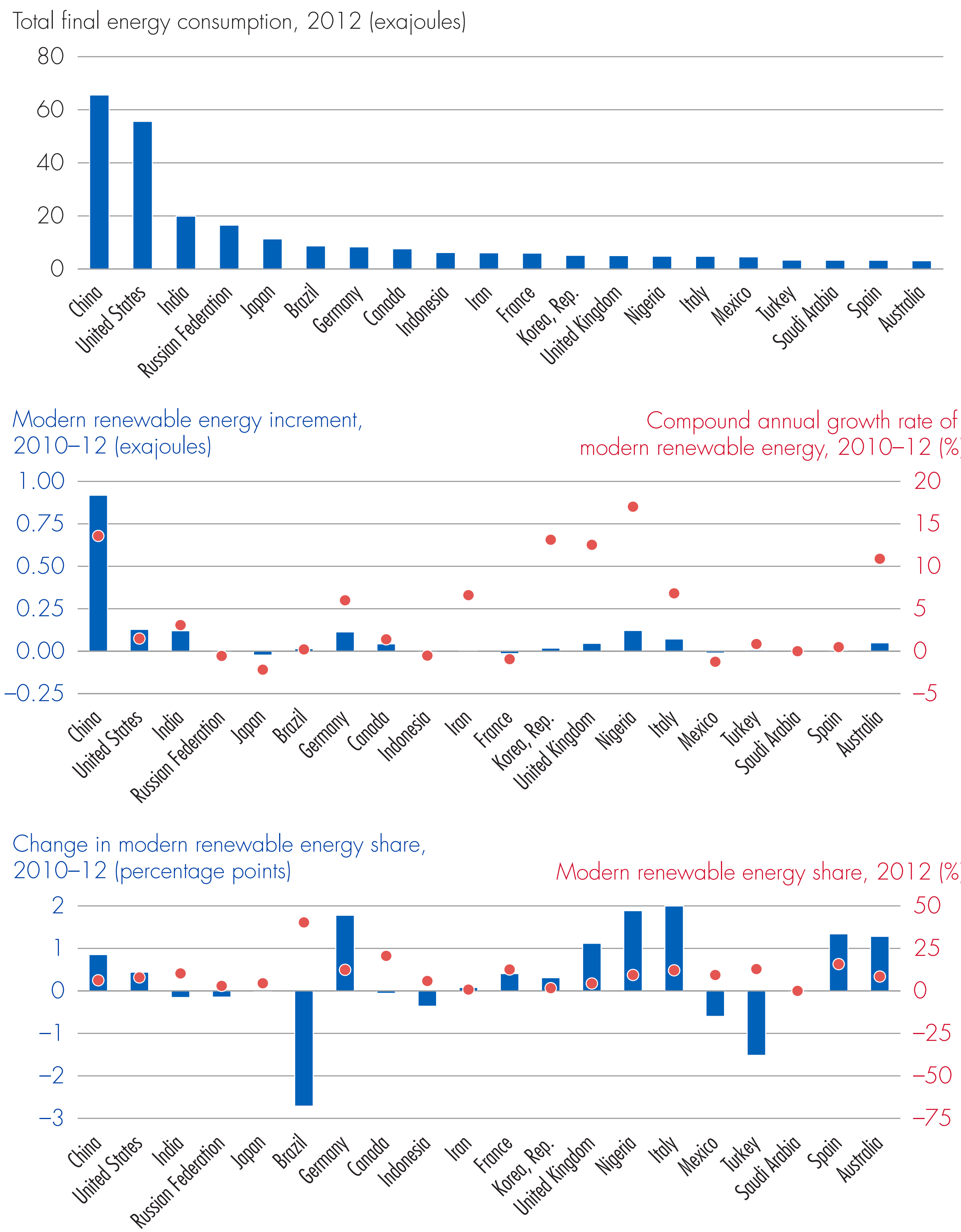
Note: Excludes traditional uses of solid biofuels.

higher but for a large decrease in consumption of solid biofuels for modern purposes.

High-impact countries

Achieving the SE4All objective for RE will depend on the 20 largest energy-consuming economies. Over the tracking period, only eight of these increased their share of RE in TFEC (figure A1.6 in annex 1, bottom panel), and 11 increased their share of modern RE in TFEC (figure 4.16, bottom panel). In China and Nigeria, a high growth rate of TFEC was exceeded by an even higher growth rate of modern RE consumption, leading to an increase in their modern renewables share. In other economies, including India, Russia, Japan, and Turkey, TFEC grew faster than modern RE consumption, causing a decline in their modern renewables share. Germany, the United Kingdom, Nigeria, Italy, Spain, and Australia all added 1–2 percent of modern energy to their RE mixes. Brazil stands out with the largest modern renewables share in TFEC but experienced a nearly three percentage point fall over the tracking period due to a contraction in liquid biofuels consumption, and despite doubling its consumption of wind energy and showing a marked increase in solar energy consumption.

Figure 4.16. **Top 20 energy consuming economies: modern renewable energy increment, 2010–12**



Source: IEA and UN data.

Note: Excludes traditional uses of solid biofuels.

Tracking of complementary indicators

Investment trends and the financing of renewable energy

Global annual investment in RE rose from $227 billion in 2010 to $258 billion in 2012. But investment declined from its 2011 peak of $278 billion, primarily due to a 50 percent drop in European investment over 2011–13, as reported by both the IEA and Bloomberg New Energy Finance (BNEF; figure 4.17).[8]

Two broad trends underlie the decline, which continued through 2013: rapid cost reductions in solar PV and wind projects, either through economies of scale or competitive solicitations; and uncertainty over long-term policy—most notably in Europe, where a few countries suspended or retroactively reduced existing price incentives in response to those cost reductions. Yet European countries invested more in renewables in 2013 ($66.8 billion) than did OECD Americas ($34.4 billion), and China invested even more—$80.2 billion.

By financing source, BNEF reports drops in venture capital, asset finance (new build), and public markets (new equity) of roughly 60 percent, seven percent, and 16 percent over 2010–13. Promisingly, government investment in research and development (R&D) increased by 28 percentage points over 2010–13, but corporate investment by only two points (figure 4.17, lower panel).

Despite the progressive decline from 2011, HICs accounted for the largest share of RE investment in 2013. Investment in UMICs increased substantially in 2013, nearing that of HICs (to a large extent due to China's contribution), while LMICs and LICs are still attracting only limited financing (figure 4.18).

Investment in solar PV exceeded investment in other RE technologies over the tracking period and in 2013. Investment in hydropower increased by 32 percent during 2013, again largely driven by deployments in China. But investment in wind projects fell sharply in 2013 (figure 4.19).

The challenge of financing renewable energy

Many countries' local banking sectors and domestic capital markets lack the necessary depth to meet RE investment needs. Local financial sectors in emerging markets are much smaller than in OECD countries, notably in the least developed countries. Access to debt capital markets via bond issuance and syndicated loans is insufficient to meet investment needs (SE4All Finance Working Group 2014). Non-hydro renewables rely heavily on external financing, particularly debt financing from banks and project finance. Also, the financing of RE infrastructure through retained earnings and equity remains well below that for conventional power plants in OECD countries (IEA 2014b).

Often, wide local institutional investor pools exist but rarely target sustainable energy infrastructure. In addition, commercial banks in less developed countries may have substantial exposure to national utilities, which limits new lending (SE4All Finance Working Group 2014).

Green bonds (including those from international organizations and governments), green asset-backed securities, and clean energy project bonds totaled over $14 billion in 2013. These securities can improve access to debt and equity capital markets, allowing RE projects to connect to large pools of funds, including from institutional investors, at lower capital cost than traditional bank lending or project finance. Their attractiveness depends largely on having secure, long-term revenues from underlying assets through such mechanisms as power purchase agreements, standardized structures, and risk metrics minimizing transaction costs (IEA 2014b).

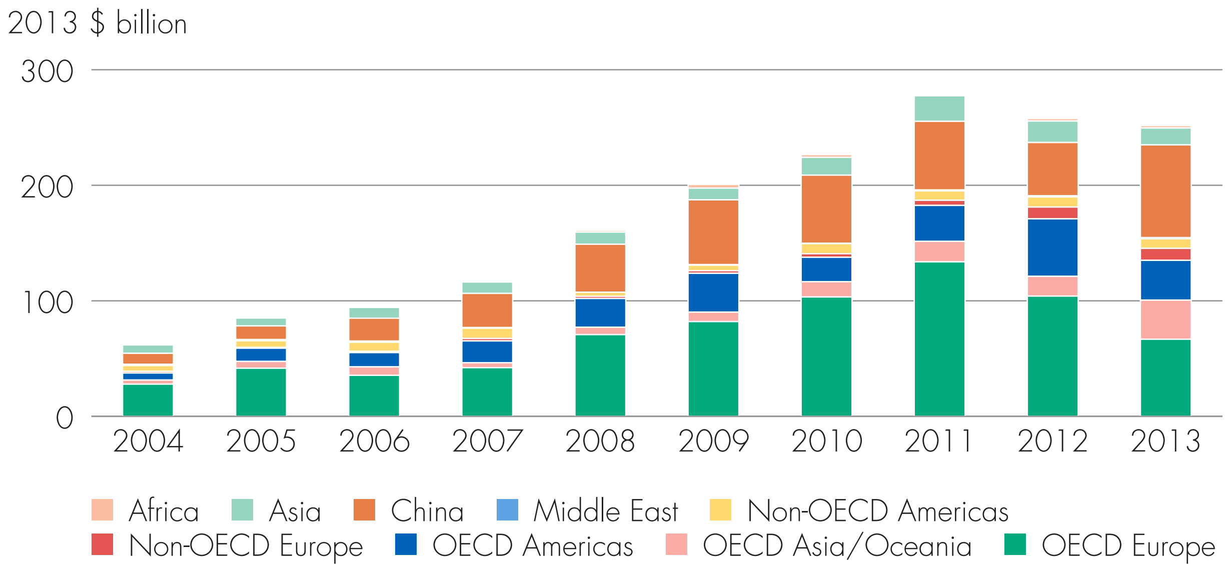
Reducing risk at the country level is thus critical for unlocking existing sources of finance. Among a sample of high-impact countries—those selected by IRENA's REmap 2030 exercise—countries requiring a significant scale up of investments (relative to their GDP) have moderate to very high country risk, expressed as the long-term foreign currency rating issued by Standard and Poor's (figure 4.20).

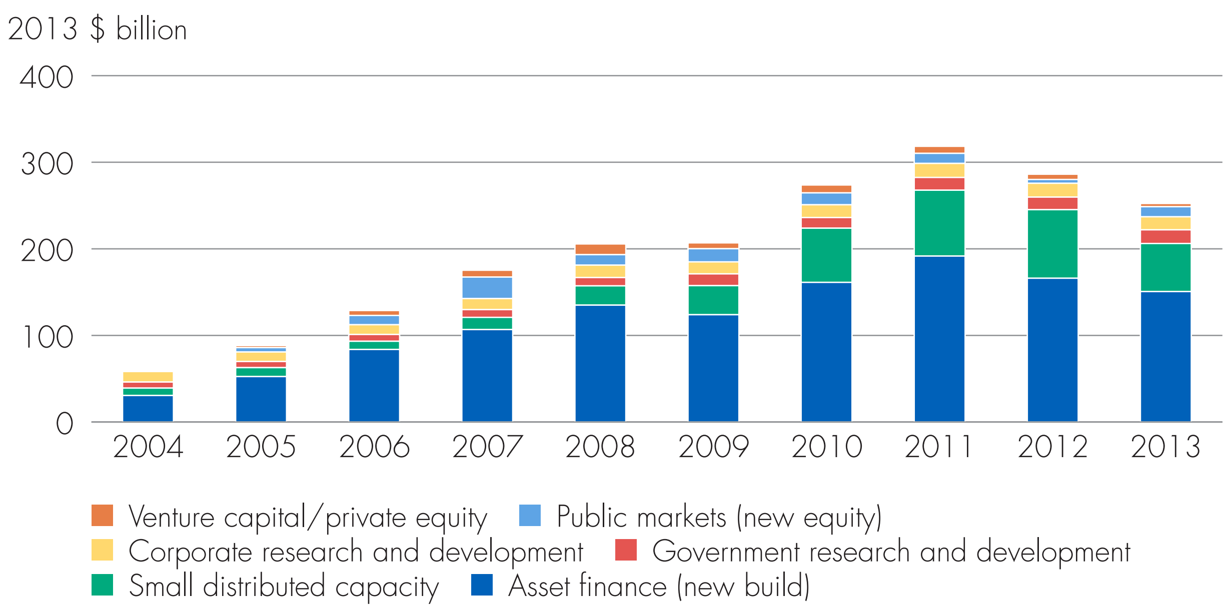
Private investment in RE requires strong action to improve the policy and business environment to reduce risk. A coalition of international organizations has launched an initiative with a 2015 global rollout to track the investment-climate elements necessary to attract investment in sustainable energy (box 4.1).

Policy trends

The number of countries with policies in place to support RE investments increased rapidly between 2010 and early 2014, especially among developing and emerging economies, which now account for 95 of

Figure 4.17. **Annual investment in renewable energy by region and source, 2004–13**

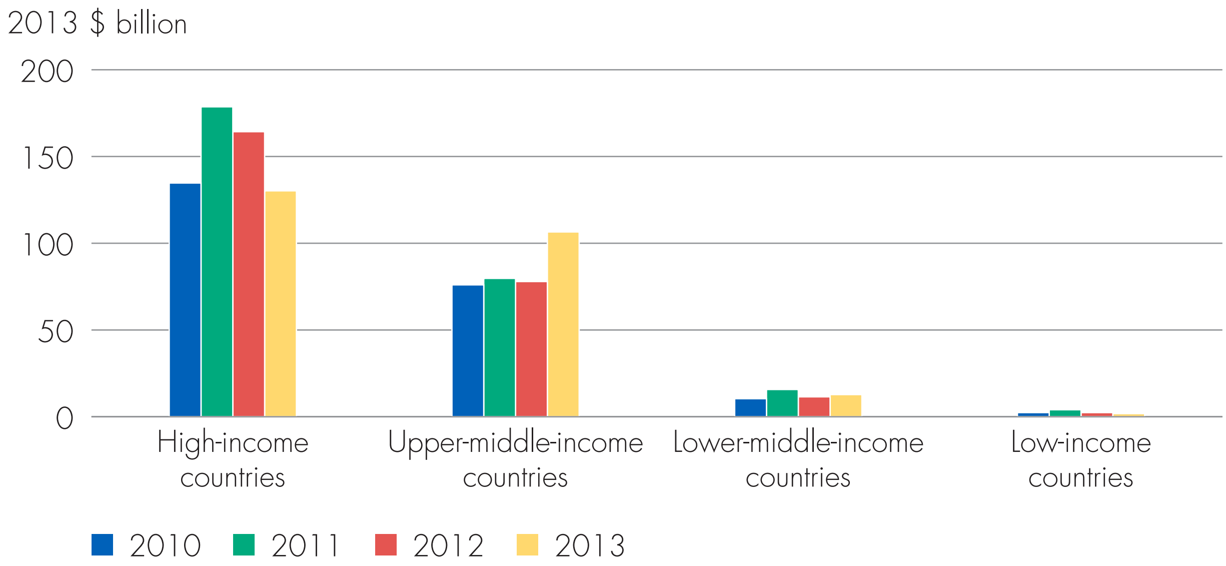




Source: IEA 2014c (top); BNEF 2014a (bottom).

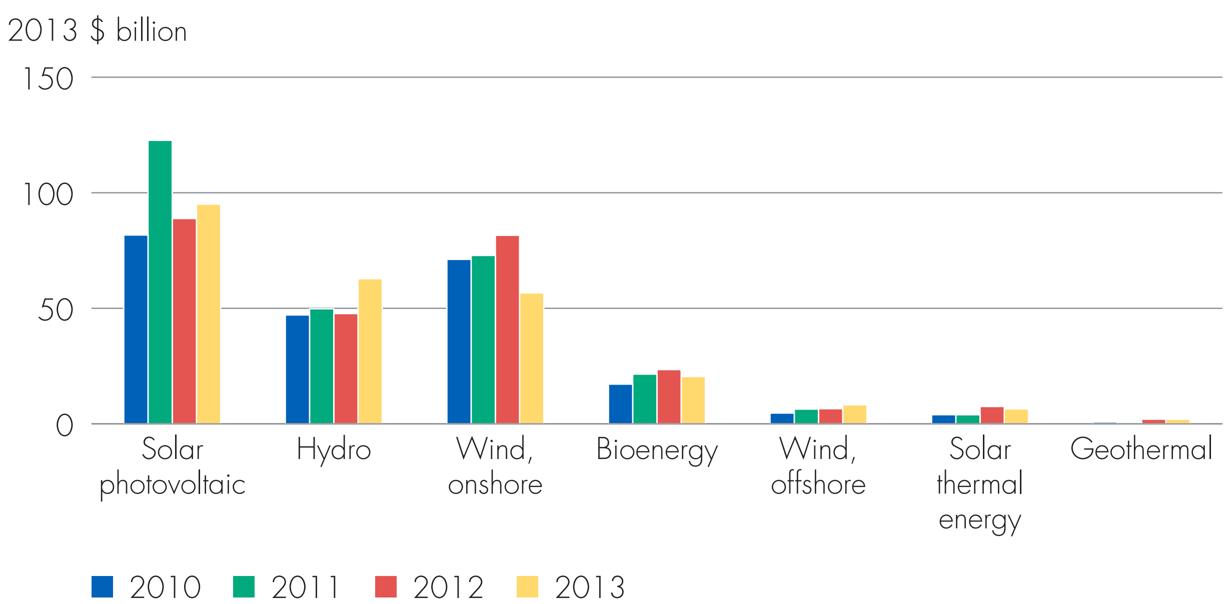
Note. BNEF excludes wind < 1 MW, hydro < 1 MW, hydro > 50 MW, biofuel with capacity < 1 million liters a year, and solar < 1 MW. BNEF estimates are based on annual installation data provided by industry associations and REN21. The discrepancy in total annual investment between IEA and BNEF (as shown by bar totals in each chart) can be explained by the fact that IEA reports actual investment (when funds have been drawn down), while BNEF tracks investments at financial closure as well as by the size of hydropower projects considered.

Figure 4.18. **Annual investment in renewable energy by income group, 2010–13**



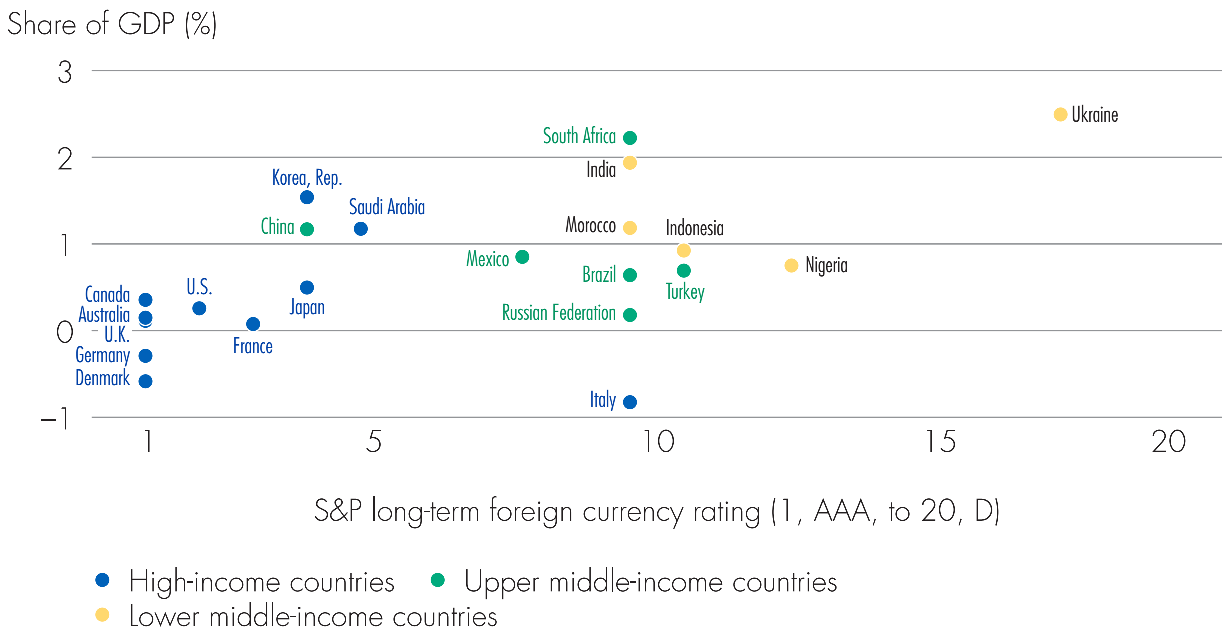
Source: IEA 2014c.

Figure 4.19. **Annual investment in renewable energy by technology, 2010–13**



Source: IEA 2014c.

Figure 4.20. **Annual renewable energy investment gap as a percentage of gross domestic product and country risk, 2012**



Source: IEA 2014a; analysis by IRENA based on IRENA (2014a); Standard and Poor's data (2014).

Note: Covers a sample of 22 REmap 2030 countries. (REmap 2030 countries Malaysia, Tonga, and the United Arab Emirates are not included due to incomplete investment data.)

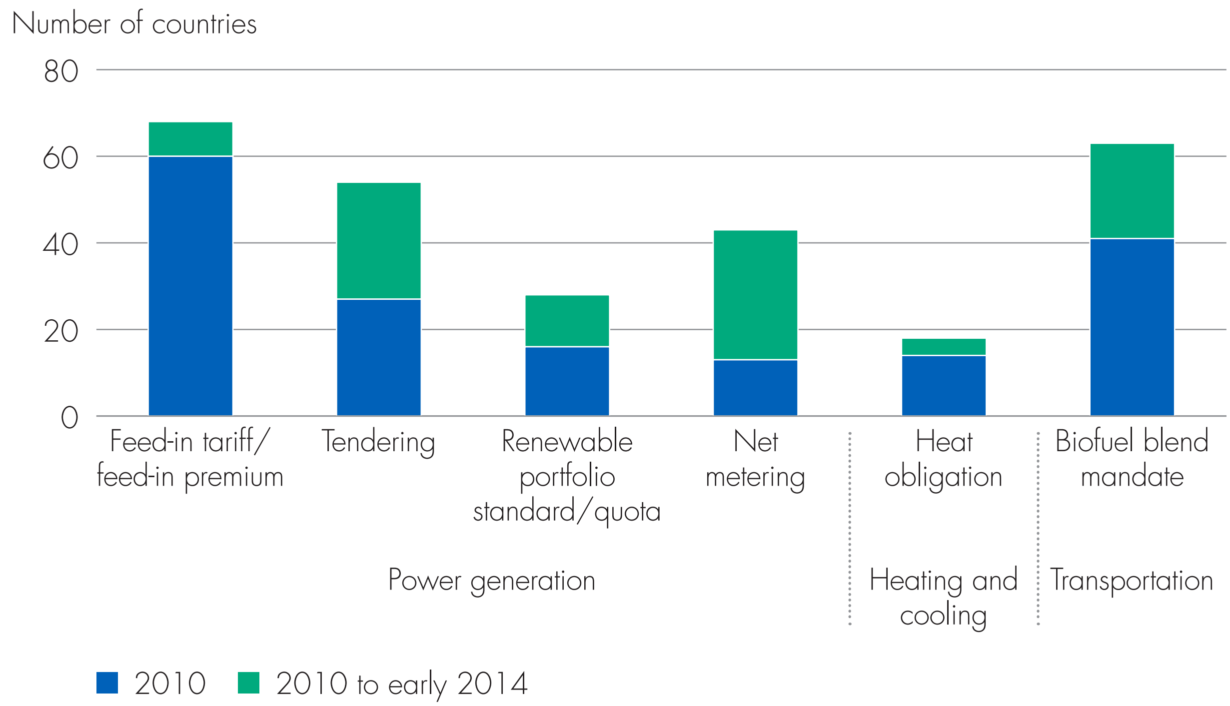
Box 4.1. **Readiness for Investment in Sustainable Energy—RISE**

RISE is a suite of indicators that assesses the enabling environment for investment in sustainable energy—energy access, energy efficiency, and renewable energy—that is within policymakers' spheres of influence. The indicators fall into four broad categories encompassing the multidimensional aspects of the enabling environment: planning, policies and regulations, pricing and subsidies, and procedural efficiency.

In RE policies and regulations, RISE tracks not only whether and what renewable energy support policies types exist (including incentives for grid-connected and distributed generation), but also assesses quality of existing policies along dimensions of predictability (such as frequency of policy incentive modifications), sustainability (such as whether the costs of subsidizing renewables are passed through to consumers and consumer affordability), and accessibility (such as who pays for connecting renewable projects to the grid and sending RE over the grid). RISE will also track a measure of utility viability as a proxy for the risk of being able to sell and receive payment for power to the utility.

Source: World Bank 2014a.

Figure 4.21. **Renewable energy support policies by type, 2010–14**



Source: REN21 2014a.

the 138 countries with such support policies (REN21 2014a). Although feed-in tariffs are the most common instrument, tenders for RE are becoming increasingly popular; the number of countries using them has doubled over that period (figure 4.21). Policies supporting distributed generation are also used more, with net metering policies adopted by 30 countries. Countries are adopting biofuel blend mandates for transport as well. Typically, countries that have implemented incentives for RE also have set a renewables target. Though rarely binding, these may indicate interest in scaling up RE consumption. Over 2010 to early 2014, 35 more countries introduced RE targets, taking the total with such targets to 144.[9]

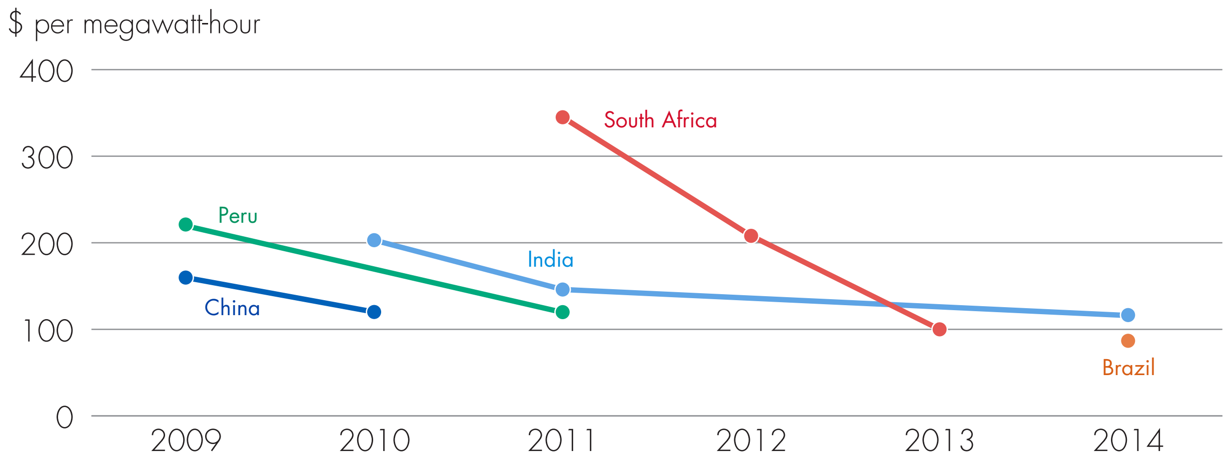
Many countries continue to revise and refine policies, recognizing that as costs of generation fall, gradual tariff reductions become possible. Technological development, economies of scale, and learning by doing are lowering the cost of RE. Rising confidence in the technology is also lowering the financing costs of renewable projects where market rules provide a secure income stream. Renewable electricity generation can more often compete on cost with fossil fuels per kilowatt-hour.

Other countries have changed their originally poor policy designs—usually feed-in tariffs for solar PV, which were incapable of responding to falling technology costs and led to higher-than-expected deployment levels and costs as well as to concerns about affordability. Spain became the first European country to completely suspend its feed-in-tariff and market-premium incentives for new renewable electricity generation; other European countries, including Bulgaria, Greece, and Romania, applied retroactive reductions to existing incentives, modifying baseline expectations on investment returns and undermining long-term investor confidence. These experiences illustrate the need to ensure fiscal sustainability as well as policy affordability and consistency.

The surge in RE auctions indicates a movement toward greater exposure of renewables to competitive pressures. Auctions have proven successful in keeping RE remuneration closer to production costs and aligned with gradual reductions in technology costs (figures 4.22 and 4.23).

Recommendations by the European Commission (EC) on the promotion of RE (EC 2013) call for more market exposure to be imposed on RE producers and emphasize that "competitive energy markets should drive energy

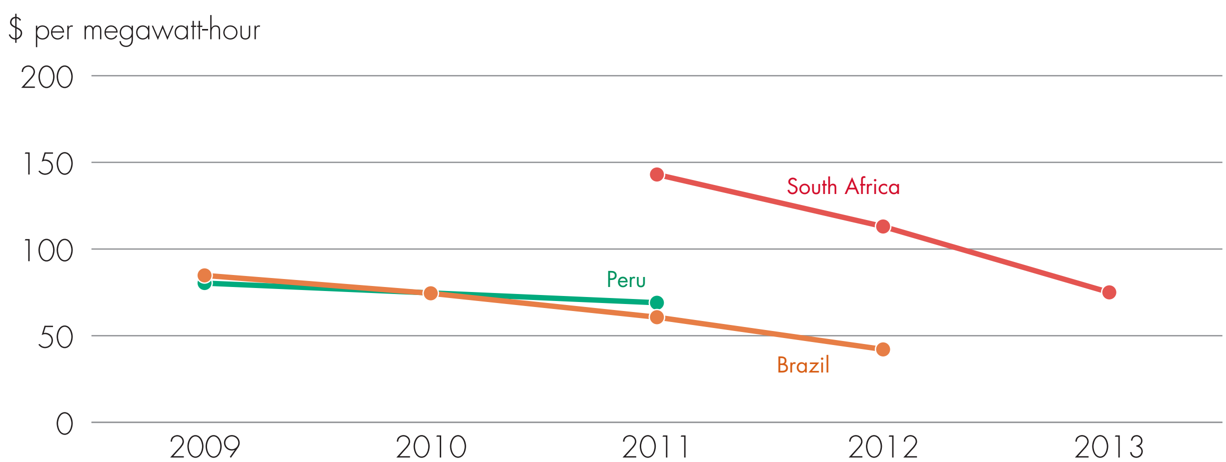
Figure 4.22. **Average price of winning bid for photovoltaic power**



Source: IRENA 2013; World Bank 2014b; Elizondo et al. 2014.

Note: When multiple auctions are held within a year, the plotted values are the unweighted average of the winning bids. For China: Data are from national auctions. Exchange rates assumed are 0.1462 and 0.1463 RMB/USD in 2009 and 2010 respectively. For Brazil: Data cover both technology specific and "alternative energy" auctions. Exchange rates assumed are 1.68, 1.85, and 1.63 BRL/USD in 2008, 2009, and 2011. For India: Data are from National Solar Mission, Phase I and II. Auctioned prices should be interpreted as rough estimates rather than exact values. Exchange rate assumed is 60 INR/USD. For South Africa: Data are from the Renewable Energy Independent Power Procurement Program.

Figure 4.23. **Average price of winning bid for onshore wind power**



Source: IRENA 2013; World Bank 2014b; Elizondo et al. 2014.

Note: When multiple auctions are held within a year, the plotted values are the unweighted average of the winning bids. For Brazil: Data cover both technology specific and "alternative energy" auctions. Exchange rates assumed are 1.68, 1.85, and 1.63 BRL/USD in 2008, 2009, and 2011. For South Africa: Data are from the Renewable Energy Independent Power Procurement Program. Exchange rate conversions are calculated at date arrangements were signed.

production and investment decisions efficiently and cost effectively." The EC explains that "as renewables producers become significant players in the internal energy market, and as the energy market nears completion, public interventions developed to assist immature technologies enter nascent markets need to evolve. Moreover, the efficiency and effectiveness of different instruments varies with circumstances; so as circumstances change, support schemes need to be reformed, instruments need to change and become market-based, and support levels will decline and eventually be phased out."

In January 2012, Germany's Erneuerbare-Energien-Gesetz introduced market premiums as an alternative to the existing feed-in tariff. One of the goals of market premiums is to encourage renewable electricity projects to participate in wholesale power markets. Unlike the existing feed-in tariff, the premium requires RE project owners to seek buyers for their electricity or sell to the electricity exchange. This option will allow Germany to continue achieving reductions in the price incentive offered to PV installations, which has been consistently sought year by yaear (figure 4.24).

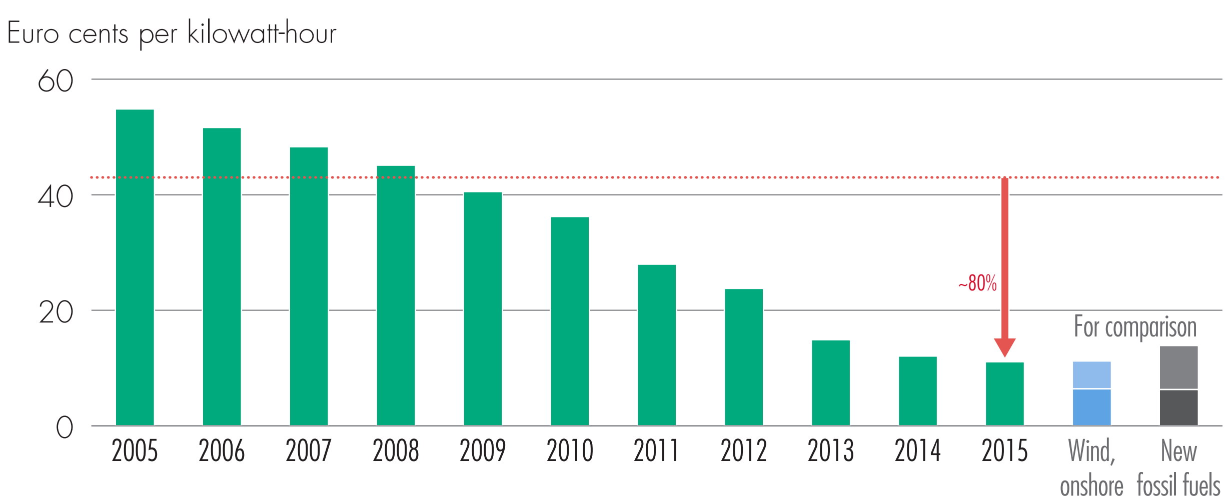
Technology costs

Solar PV and concentrating solar power aside, the cost of most RE technologies remained stable over 2010–12. Hydropower and geothermal electricity at good sites still offer some of the cheapest resources for generating electricity of any source. Technologies to harness these resources are mature and their costs do not change much from year to year. But solar PV in particular has seen rapid cost reductions over recent years, thanks to the declining cost of solar PV modules; their prices have more recently stabilized due to increasing demand and falling manufacturing overcapacity (figure 4.25).[10]

Utility-scale PV can now compete in countries with good solar potential and high energy prices—usually those with high peak demand and expensive fossil fuels or wholesale prices. Research centers and organizations already predict further, sharp decreases in solar PV costs. For instance, even under conservative scenarios and assuming no major technological breakthroughs, Agora Energiewende (2015) predicts PV power costs of 4–6 cents/kWh by 2025 and 2–4 cents/kWh by 2050, depending on annual sunshine (figure 4.26). Distributed PV is also reaching "socket" parity in many countries, which is when the levelized cost of electricity[11] (LCOE) is lower than the variable retail electricity price (IEA 2014b).

The cost of wind turbines has stabilized after nearly doubling between 2004 and mid-2009, reflecting primarily supply constraints and higher commodity prices, particularly in steel and copper. Reduced supply constraints, lower commodity prices, and greater competition reversed this climb in 2010 with costs falling to near 2004 values on

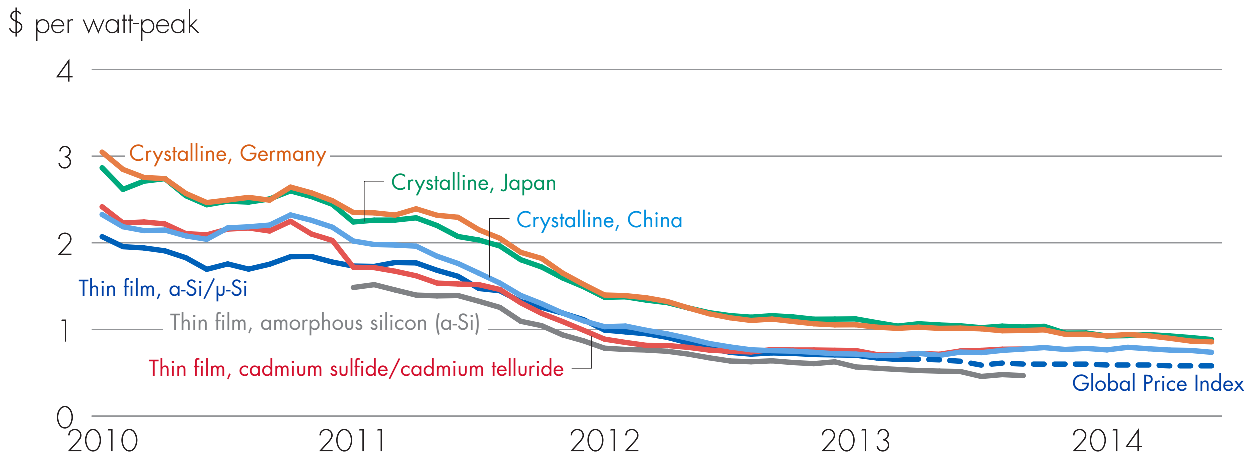
Figure 4.24. **Feed-in tariffs for new large-scale solar photovoltaic projects in Germany**



Source: Agora Energiewende 2015.

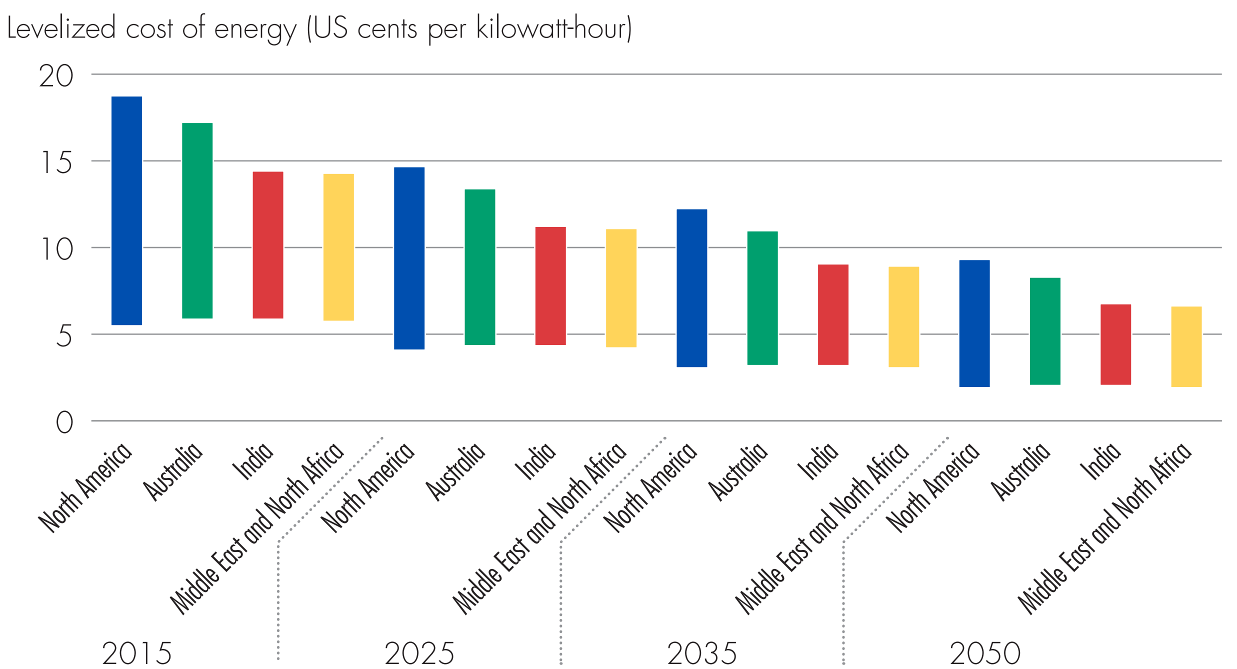
Note: "Wind, onshore" shows a range of feed-in tariffs for onshore wind power. "New fossil fuels" shows a range of costs of producing power through newly built gas or coal power plants.

Figure 4.25. **Solar photovoltaic modules: spot market price trends by material, 2010–14**



Source: pvXchange 2014 and GlobalData 2014.

Figure 4.26. **Expected cost of electricity from new solar power plants**

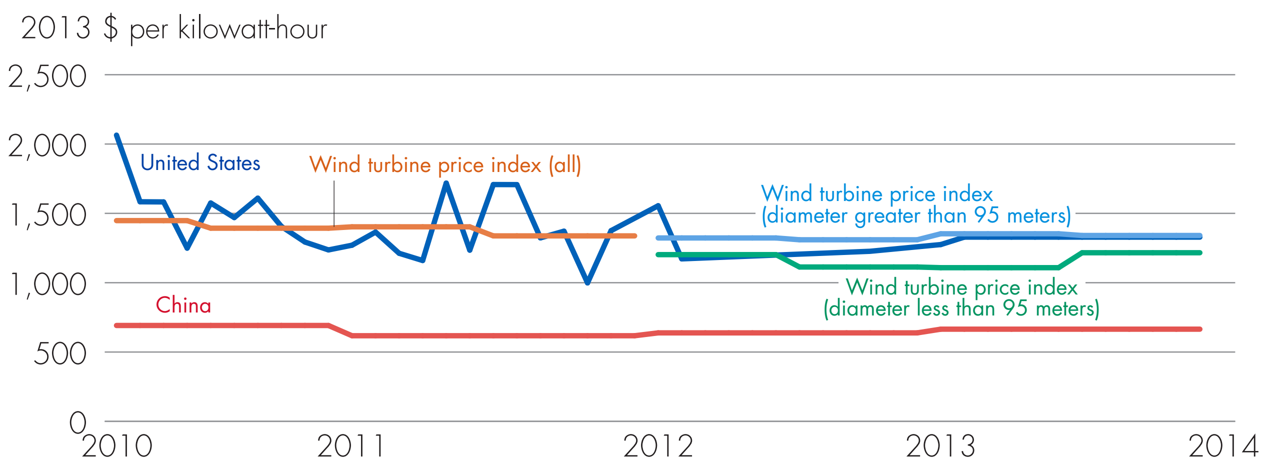


Source: Agora Energiewende 2015.

a $/kWh basis. The price of wind turbines has stayed fairly stable since 2010 (figure 4.27).

Recent turbine designs are capable of producing greater electricity yields, particularly at sites with lower wind speeds, effectively lowering generation costs. Similarly, operation and maintenance (O&M) costs of wind-based projects fell by around 40 percent over 2009–13 largely because of learning effects. Given that O&M accounts for 15–25 percent of the cost of delivered electricity, these

Figure 4.27. **Wind turbine price trends in the United States and China compared to BNEF's wind turbine price index**

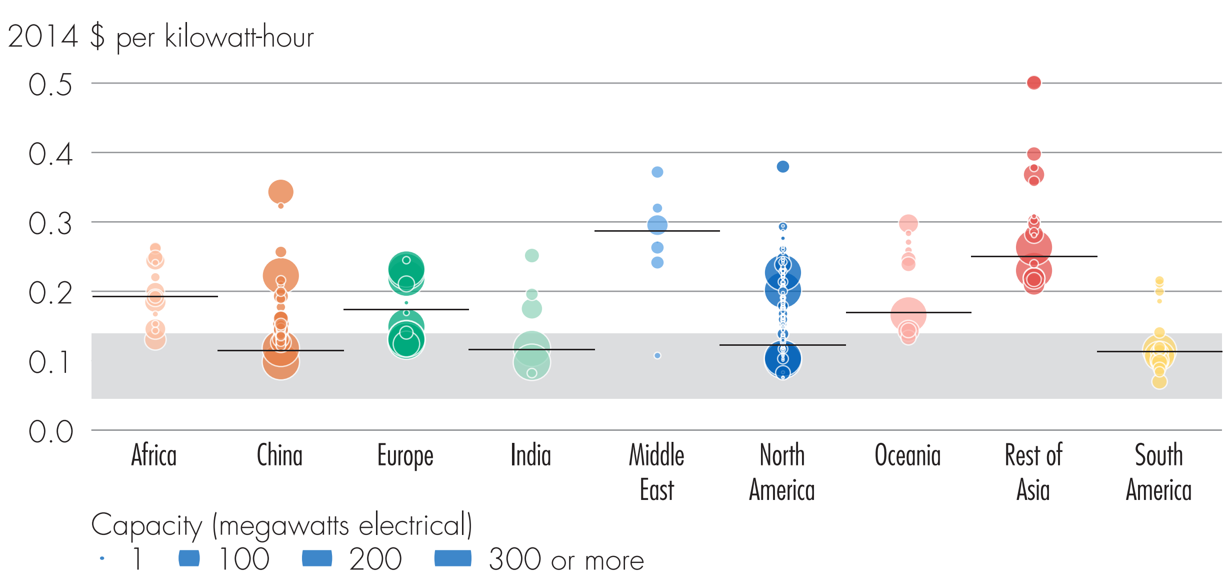


Source: IRENA 2015a; BNEF 2014b; Chinese Wind Energy Association 2014 (personal communication); LBNL 2014; GlobalData 2014.

trends have combined to help bring wind power to new markets and strengthen its position in existing markets. For example, in Brazil wind power has outbid natural gas plants in auctions, and in Australia wind is competitive with new coal- or gas-fired power plants, while in New Zealand and Turkey onshore wind is competing in wholesale power markets without strong incentives (IEA 2014b).

The LCOE generated by renewable resources varies hugely among projects and regions, depending on quality of the resource, investment costs, O&M needs, cost of capital, and capacity factors. In 2013 and 2014, the lowest capacity-weighted average LCOE for solar projects was in China, India, and South America (figure 4.28), and the equivalent LCOE for wind projects was in China and North

Figure 4.28. **Levelized cost of electricity of solar photovoltaic projects by region, 2013 and 2014**



Source: Data on project LCOE for RE technologies from IRENA Renewable Cost Database (IRENA 2015a); background shading reflects range of fossil fuel generation costs based on REmap 2030 (IRENA 2014a).

America (figure 4.29). In all regions except "Other Asia", the capacity-weighted LCOE for recent wind projects has been less than 10 cents/kWh.[12]

Trends in distributed generation and rural markets

RE data on off-grid, mini-grid, and distributed generation systems are scarce and largely focused on solar PV installations. IRENA, the World Bank, and the UN Industrial Development Organization (UNIDO) are attempting to fill some of the gaps—beyond the data that the IEA's Photovoltaic Power Systems Programme (PVPS) and BNEF already provide on PV capacity, though these last two use their own definitions and report data on different capacity scales. IRENA has recently started to consolidate data on distributed RE power generation and will soon start collecting data on a periodic basis (chapter 6). The World Bank launched an initiative in 2014—Readiness for Investment in Sustainable Energy—that will regularly gather data on mini-grids and stand-alone systems, including those that use RE (World Bank 2014a). For its part, UNIDO, with the International Center on Small Hydropower (ICSHP), released in 2014 the launch edition of the *World Small Hydropower Development Report,* which for the first time provides a global snapshot of small hydropower capacity by country. Table 4.1 summarizes the data from these sources.

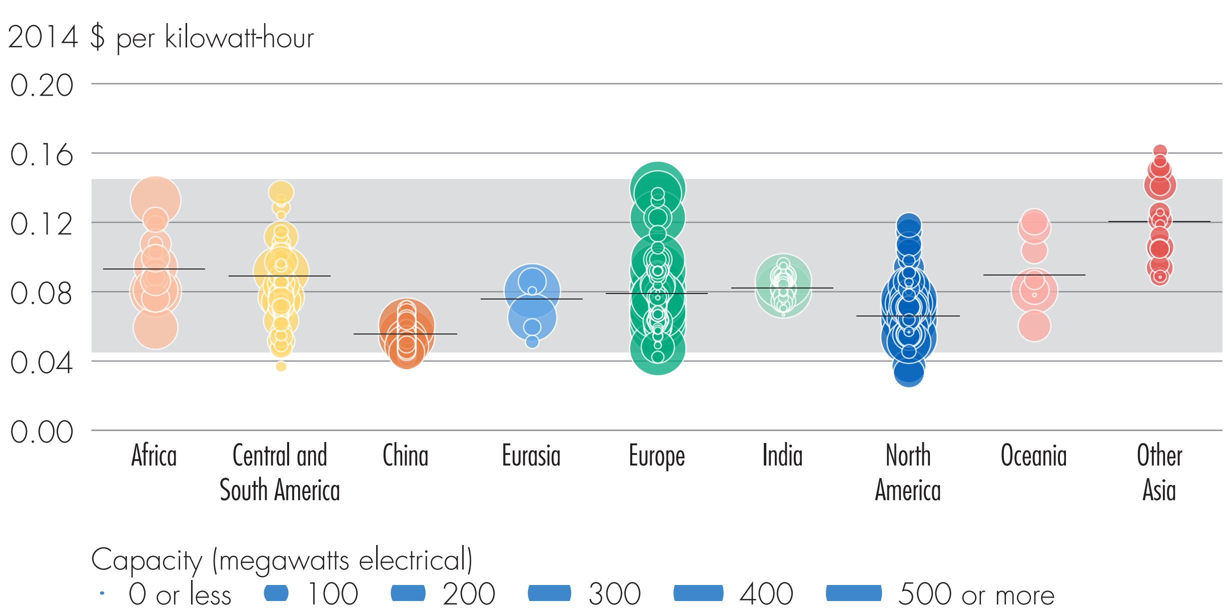
Scale of the challenge

This section considers the role of renewables under various recent scenarios. It compares current and forecast RE growth rates with those likely required to deliver the ambitious objective of doubling the share of renewables in TFEC over 2010–30. The section also identifies key preconditions for meeting the objective and actions needed.

Future scenarios

Scenarios that consider how future energy demands may evolve and the role of RE in the future global energy mix vary widely in their conclusions. They also differ in approach: Some are based on policy considerations, while others are based on a least-cost modeling approach, given a portfolio of technology options. Others still are goal-oriented exercises that place constraints on future scenarios—for example, by setting global emission limits). Scenario analyses also use different assumptions about

Figure 4.29. **Levelized cost of electricity of wind projects by region, 2013 and 2014**



Source: Data on project LCOE for RE technologies from IRENA Renewable Cost Database (IRENA 2015a); background shading reflects range of fossil fuel generation costs based on REmap 2030 (IRENA 2014a).

Table 4.1. **Capacity of renewable energy in distributed generation schemes**

Scheme	Capacity in 2013	Coverage	Source
Off-grid	PV: 404 megawatts	Organisation for Economic Co-operation and Development (OECD) and 29 non-OECD countries	IEA PVPS 2014
	Solar home systems: More than 6 million systems installed	12 developing economies	IRENA 2015b
Mini-grid	Hybrids: 675 megawatts	75 percent in developing economies	IRENA 2015b
Grid-connected/ distributed generation	Photovoltaic residential scale (≤ 20 kW): 38.6 gigawatts	Global	BNEF 2014c
	Grid-connected photovoltaic all sizes: 71.3 gigawatts	OECD countries	IEA PVPS 2014
Other (scheme not specified)	Small hydropower (< 10 megawatts) in grid-connected, mini-grid, or off-grid configurations: 75 gigawatts	152 countries	UNIDO and ICSHP 2014

Source: Prepared by authors.

many of the essential parameters, including those relating to population and economic development and how these are coupled with energy demand, technology availability and costs, and so on.

GTF 2013 provided a short summary of the results of scenario analysis undertaken by many national and international organizations. The summary highlighted the wide range of projections for TFEC in 2030 and associated RE share, from the current 18 percent to as high as 45 percent depending on assumptions about growth in energy demand, growth in RE, and growth in other low-carbon options such as nuclear energy and carbon capture and storage (CCS).

REN21 (2014b) has reviewed these scenarios and notes that their projections tend to reflect the perspectives of those responsible, with existing energy industries anticipating little change in the share of renewables and environmental groups taking a more positive view. The SE4All RE objective lies toward the ambitious end of this range; it will not be achieved without strong efforts by all countries, not only to stimulate RE production but also to reduce overall energy demand through increased energy efficiency.

It is not necessary to review existing scenarios in this edition of *GTF* (but see table 4.2 for an updated summary of current scenarios and their projections). This report presents analysis showing how the role of renewables has evolved within the IEA scenarios in the *WEO* of November 2014. It also summarizes conclusions and insights drawn from IRENA's REmap 2030 study, which includes an analysis consistent with the SE4All objectives.

WEO scenarios

The *WEO* considers three scenarios. The Current Policies Scenario assumes that current policy commitments are maintained but not expanded. Under this scenario, the level of renewables rises slowly; given continuing growth in overall energy demand, the proportion of renewables grows slowly, to only 22.0 percent by 2030.

The New Policy Scenario considers the effects of implemented policy commitments alongside measures announced (but not yet put into action) to improve energy efficiency and deploy a suite of low-carbon technologies. In this case, the proportion of renewables rises to 24.0 percent of TFEC by 2030. This is still far below the SE4All objective, underlining that current and announced policy commitments are not enough to reach the objective.

The 450 Scenario provides an energy pathway with a 50 percent chance of limiting the increases in average global temperature to 2° C from preindustrial levels. It assumes more vigorous policy action up to 2020 and that, thereafter, major economies all set emissions targets consistent with a trajectory in which greenhouse gas levels stabilize at 450 parts per million (ppm) of carbon dioxide

Table 4.2. **Selected forecasts of 2030 renewable energy share of total primary energy demand and total final energy consumption, 2014**

Publication	Scenario	Share of renewables (percent)	
		Total primary energy demand	Total final energy consumption
IEA's *WEO* (2014c)	Current Policy Scenario	15.0	22.0
	New Policy Scenario	17.0	24.0
	450 Scenario	22.4	29.4
IRENA's *REmap 2030* (2014a)	Reference Case	—	21.0
	REmap 2030	—	36.0
EIA's *International Energy Outlook* (2013)	Reference	—	13.5
	High Oil Price	—	13.3
	Low Oil Price	—	13.1
	High Macro	—	12.7
	Low Macro	—	14.0
International Institute for Applied Systems Analysis' *Global Energy Assessment* (2012)	GEA 1	29.8	36.7
	GEA 2	29.7	36.3
	GEA 3	27.9	34.4
	GEA 4	33.3	40.7
	GEA 5	28.1	34.6
	GEA 6	34.7	40.9
World Energy Council's *World Energy Scenarios* (2013)	Jazz	12.0	13.5
	Symphony	17.1	18.6
Greenpeace's *Energy Revolution* (2012)	Reference	14.4	18.9
	Energy Revolution	40.6	45.1
OPEC's *World Oil Outlook* (2014)	Reference	14.3	—
ExxonMobil's *Outlook for Energy* (2014)	—	14.3	16.2
BP's *Energy Outlook* (2014)	—	13.0	—
Shell's *New Lens Scenarios* (2013)	Mountains	14.1	—
	Oceans	16.6	—
Statoil's *Energy Perspectives* (2014)	Reference	17.0	—
	Low Carbon	21.0	—
	Policy Paralysis	15.7	—

Note: — is not applicable.

equivalent. Renewables rise sharply from 18 percent today to 29.4 percent but still fall short of the SE4All objective.

The *WEO 2014* figures for the share of renewables in TFEC are much higher in all three scenarios than the *WEO 2011* figures discussed in *GTF 2013*, reflecting the rapid deployment and associated cost reductions for wind and PV since 2011.

As well as higher consumption of renewables and greater energy efficiency, the 450 Scenario assumes deployment of a full range of low-carbon technologies, including CCS, and increased nuclear generation. Other low-carbon scenarios assume that such options may be restricted by political, technological, and economic barriers and therefore use higher consumption of renewables to meet their emission targets. The IEA Energy Technology Perspectives 2DS Scenario, for example, is broadly consistent with the 450 Scenario, with 42 percent of electricity coming from renewables in 2030. But the 2DS HiRen Scenario assumes that deployment for nuclear and CCS is constrained, and so renewables play a greater role. Under HiRen, with renewables providing 50 percent of electricity, their role depends on speed of deployment, success in reducing energy demand, and on the other low-carbon technologies deployed.

IRENA's REmap 2030

IRENA's REmap 2030 provides a roadmap to double the global RE share in TFEC over 2010–30. It considers two scenarios discussed here: a business-as-usual Reference Case assuming a continuation of policy and a more aggressive case, REmap 2030.

The Reference Case is based on a bottom-up analysis of the national energy plans of the 26 largest energy markets, which account for 75 percent of global TFEC. Under this scenario, with current policies as well as policies currently under consideration assumed to be in place, the global RE share only reaches 21 percent in 2030.

The REmap 2030 pathway considers a "realistic" RE potential estimate for each country by taking into account such factors as a country's resource availability, capacity stock turnover, planning procedures, and environmental considerations. Each technology option is also characterized by its costs. The analysis concludes that deploying the whole package of REmap 2030 measures would be cost effective, with net savings of $120 billion–$740 billion by 2030 when external effects are taken into account. The carbon dioxide mitigation benefits from deploying the options would be very high, on a par with those from achieving the energy efficiency objective alone.

If all the policies supporting renewables are implemented, the global RE share can reach 30 percent by 2030. And with the right policy mix and increased energy efficiency and increased modern energy access, the global share can be as much as 36 percent—double the current 18.1 percent. In other words, the RE share can be doubled only by meeting all three SE4All objectives.

Doubling the RE share of global consumption requires adopting a range of technology options. The impact of each option is defined by its contribution to the total RE share increase: Reference Case, 20 percent; REmap 2030, 52 percent; achieving modern energy access, 12 percent; and achieving energy efficiency improvements, 16 percent.

Doubling the RE share in the global TFEC implies a total final RE use of 132 EJ in 2030, up from 63 EJ in 2010. Renewables for power generation represent around 40 percent of total final RE use (53 EJ), and renewables in end-use sectors the other 60 percent (79 EJ), with liquid biofuels, solid biofuels heat (including cogeneration), and solar thermal heat playing key roles (figure 4.30).

Current and forecast trends in use of renewable energy

IEA Medium-Term Renewables Market Report: Market Analysis and Forecasts to 2020

The IEA produces a *Medium-Term Renewable Energy Market Report* (*MTRMR*; IEA 2014b) that tracks the markets for renewable electricity, heat, and biofuels based on IEA statistics for generation and capacity. The report also provides a forecast to 2020 by looking bottom up at likely developments in key markets. This differs from the approach of other scenarios discussed in this chapter, which tend not to consider individual market issues in detail.

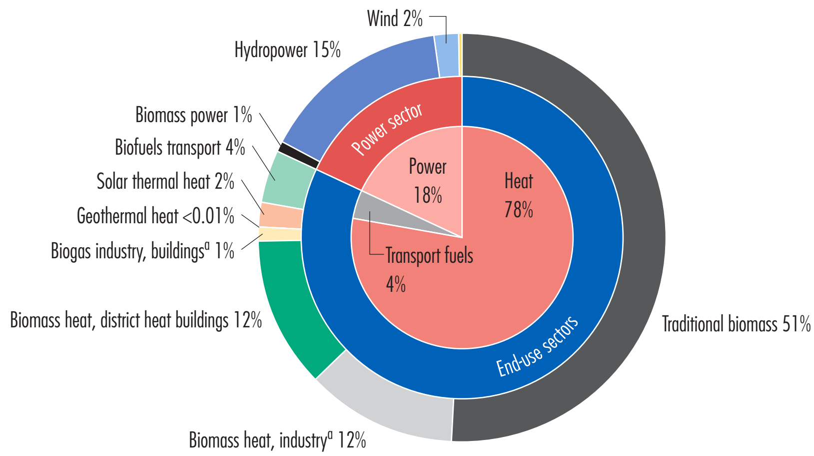
The global RE electricity market grew at a CAGR of 4.9 percent over 2005–10 to 4,302 TWh and at six percent over 2010–12 to 4829 TWh a year. It is forecast to grow to 5,723 TWh a year by 2015 (CAGR of 5.9 percent over 2012–15) and then slow to a CAGR of five percent to 2020, reaching 7,213 TWh (figure 4.31).

The steep annual capacity additions of recent years are expected to stabilize over the forecast period, slowing sharply in many OECD countries due to changing policy support. By contrast, many emerging and developing economies are seeing electricity demand grow strongly and renewables increasingly able to compete with the full costs of new power generation from fossil fuels. In these markets, renewables are expected to contribute a substantial share of new electricity generation capacity. But renewables deployment is at an early stage in some areas, so the potential for rapid scaling up over the next few years is constrained. The net effect is stabilized capacity additions and slow growth.

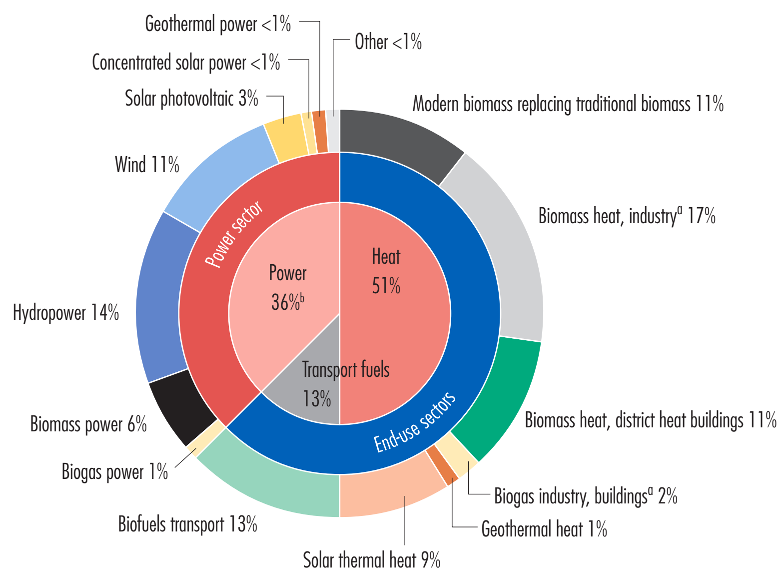
In the renewable heating sector, *MTRMR 2014* projects a continuing gradual reduction in traditional uses of solid biofuels, offset by steady, unspectacular growth in generation from modern renewable sources of heat, with the overall CAGR for modern renewable heat around three percent

Figure 4.30. **REmap 2030: Global total final renewable energy consumption by technology and sector, 2010–30**

2010: 63 exajoules



REmap 2030: 132 exajoules



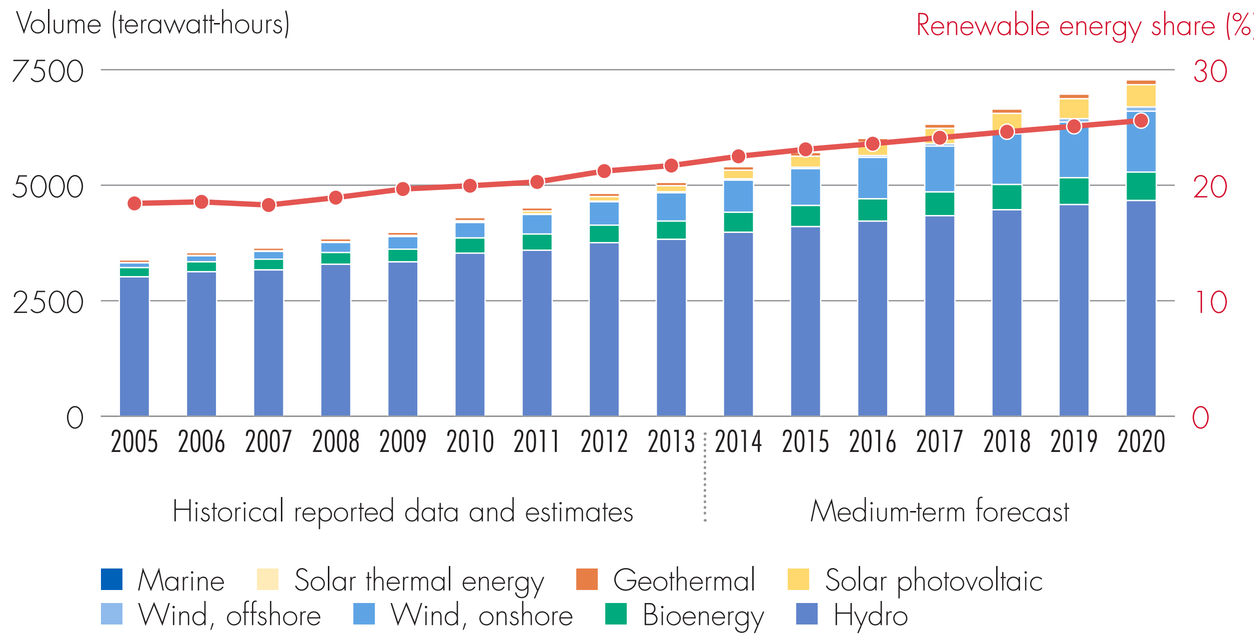
Source: IRENA 2014a.

a. Includes combined heat and power and district heat.

over 2012–20. Growth is focused particularly in housing, driven by developments in the EU and China, with slower progress in industrial applications.

Global biofuel production grew rapidly over 2005–10 but then slowed sharply. It picked up again in 2013, after a period of stagnation caused by unfavorable climatic events affecting production in Brazil and the United States as well as policy uncertainties due to concerns over the sustainability of biofuels from food-based feedstocks in Europe. *MTRMR 2014* projects a return to slow growth in these established markets owing to continuing uncertainties in policy frameworks linked to sustainability concerns in Europe and blending constraints (the "blend wall") in the U.S. market. This is coupled with slow progress in bringing the first large "advanced" biofuels plants on line and providing

Figure 4.31. **IEA *MTRMR* 2014: Global renewable electricity production volume, historical and projected, 2005–20**



Source: IEA 2014b.

the appropriate market and policy signals needed to create a favorable investment climate in the short to medium term. But there are signs of growth in biofuels in several Asian and African markets, where biofuels are seen as a way to reduce fossil-fuel imports. This market is expected to grow at a CAGR of only 1.5 percent over 2015–20, a marked slowdown from the last decade.

Overall prospects

Actual deployment and levels forecast in the *MTRMR* indicate that growth rates are likely to remain at around five percent for electricity and three percent for renewable heat (figure 4.32). Biofuels are likely to see much slower growth than in recent years due to policy uncertainties and risky market conditions in many major markets. Overall growth is heavily weighted by the heating sector. Together these rates point to overall growth of around 2.3 percent over 2013–20.

Comparison of current and forecast growth rates with SE4All doubling objective

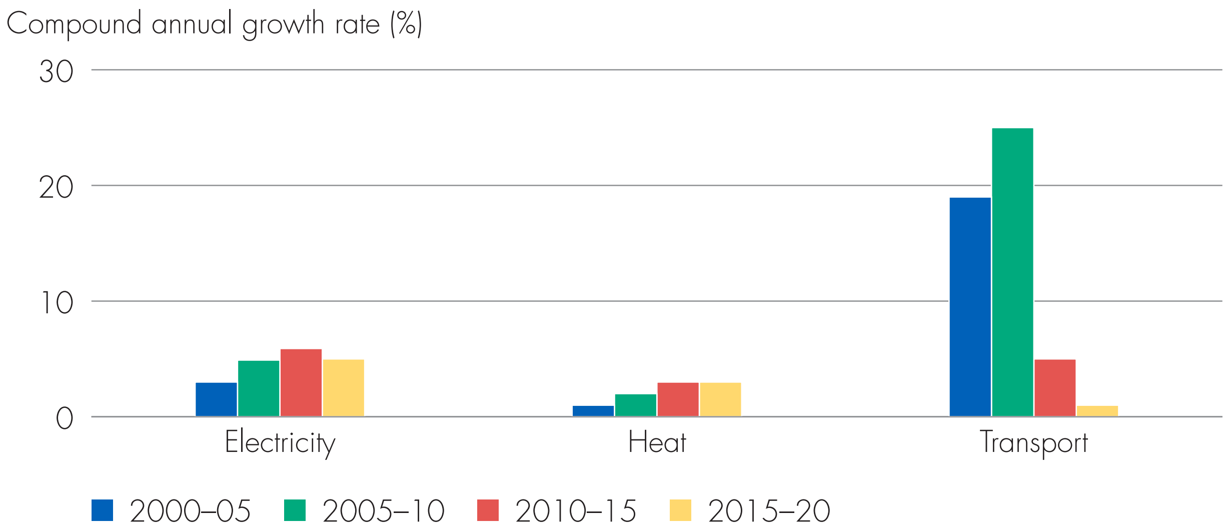
If this forecast growth of 2.3 percent continues over 2020–30, RE would contribute some 93 EJ to global energy consumption. Total energy demand has been growing at around 1.5 percent during the past five years. If this rate continues, total energy demand will reach about 481 EJ by 2030, with RE contributing around 19.3 percent. To reach the doubling objective for RE, the CAGR for renewables must increase to about six percent (2.6 times as fast as now). In an extreme energy efficiency situation, where total global demand was capped at 2013 levels, RE consumption would need to reach 125 EJ by 2030, requiring growth of only four percent (1.75 times as fast as at present; figure 4.33).

The results of this analysis are very similar to those in *GTF 2013*. Meeting the SE4All RE objective remains hugely challenging and becomes more so each year without substantial changes in deployment patterns. Without much stronger effort by countries already making progress and by countries in the early stages of deployment, the objective is unlikely to be reached. Action is needed to take RE deployment far higher and to reduce global energy consumption via energy efficiency gains—underscoring the links among the SE4All objectives for RE, energy efficiency, and energy access.

Key challenges and actions

Doubling RE's contribution to TFEC by 2030 requires a fundamental change in the way energy is produced and used. RE consumption needs to grow at 1.6–2.6 times

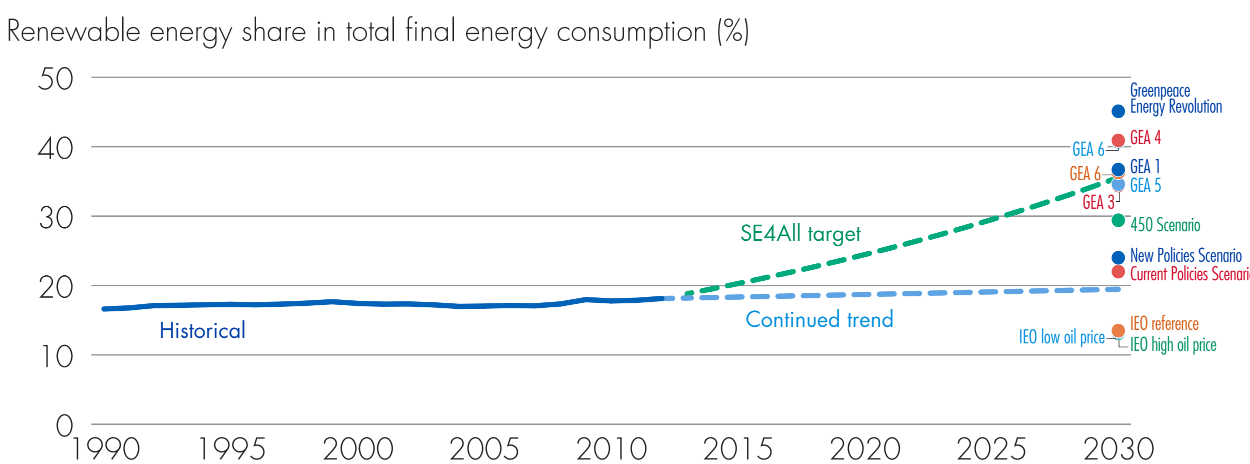
Figure 4.32. **Historical and forecast growth for renewable electricity, heat, and biofuels**



Source: IEA analysis based on *MTRMR* (IEA 2014b).

Note: Renewable energy consumption corresponds to modern use of renewables for heat only.

Figure 4.33. **Trends in renewable energy share by scenario**



Source: Greenpeace 2012; IIASA 2012; IEA 2014c; EIA 2013.

Note: GEA is *Global Energy Assessment*; IEO is *International Energy Outlook 2013*.

current rates. While renewable electricity production has been growing strongly, the growth in renewable heat and in the transport sector is much slower; more policy focus and innovation are needed to increase penetration. Continuing past trends will not be enough: A more fundamental revolution in energy systems is needed. Increasing the use of electricity and breaking down institutional, planning, and operational barriers between the three end-use sectors are needed to improve the overall efficiency of energy use and to optimize the way in which RE sources can be used. This revolution will challenge all actors in the field to embrace change and identify opportunities for action and advances rather than maintain entrenched practices.

Technology and innovation

Delivering the needed transformation will require a full suite of new technologies to fulfill renewables' potential for technology performance and cost reduction. We have seen remarkable progress in performance and cost by now well-established technologies such as wind and solar PV. But broadening their application to new locations (such as solar in desert conditions, wind in offshore locations, or lower wind speed sites) requires continued industry-led R&D attracting local actors in adapting technology to local requirements. Remaining challenges linked to less-deployed technologies, like advanced sustainable biofuels and marine energy technologies, need intense work supported by both private and public actors.

More technology and innovation are also required at system level to optimize the role of individual renewable and energy-saving technologies. Past gains have shown that increasing the penetration of renewables is no longer a question of technology or economics only but also of developing more flexible markets and smarter energy systems—increasing demand-side integration, making power grids more flexible, and integrating power systems with other sectors.

Given the weight of heat and transport in TFEC—currently nearly half of total global energy demand—much more needs to be done to increase the role of renewables in these sectors. Some well-designed policies have already been effective, particularly for mandatory building regulations (REN21 2014a). But though well-proven and cost-effective technologies are ready to be deployed, renewable heat still receives much less attention from policymakers than it should.

In addition to opportunities in the building sector, there is tremendous potential to provide low-temperature heat to industrial processes. But applications largely have been confined to industries that use large quantities of biomass as raw material, such as paper and timber. There is great potential for using biomass, solar thermal, and heat pump technologies in a broader range of industrial applications.

The use of biofuels in transport remains controversial, with continuing concerns over sustainability. Methodological uncertainties need to be resolved and sustainability best practices applied in planning and executing the production and use of biofuels. At the same time, new biomass-based fuels and technologies that do not compete with food production (such as cellulose-based ethanol) need to be developed. Continued technical innovation combined with policies to help these processes and products find a place in the market are needed. Increased electrification of heating, cooling, and transport will also grant RE a bigger role, helping achieve the overall doubling objective.

Finance

The REmap 2030 analysis estimates that finance rising to $650 billion a year will be needed to deploy RE in line with meeting the SE4All objective—which must be seen against the *MTRMR*'s estimates of current finance of $230 billion in the electricity sector alone. *WEO 2014* estimates that RE investment of some $8.2 trillion, mostly for power generation, is needed to deliver the New Policy Scenario to 2040. Getting the financing will be difficult, and a broader range of sources must be tapped, including pension funds and bond issuance.

The trajectory is further complicated because a growing share of the investment will be needed in emerging and developing economies rather than OECD and other developed economies. The investment climate is often less favorable there, with multiple political and business risk factors, exchange-rate risks, and so on.

Beyond financing, the task ahead is to fund projects at reasonable rates. The cost of energy delivered from renewable systems is very sensitive to the cost of capital, given that most RE systems entail high initial capital costs but very low operating costs.

While some of the factors that can lead to higher financing costs are country specific and difficult to manage, the policy and regulatory framework can play an important role in reducing perceived project risks as far as project income levels are concerned (for example, a well-designed tender scheme for renewable electricity in South Africa). Carefully prepared projects, where risks are minimized and allocated to those best able to manage them, are also easier and cheaper to finance. International organizations have a key role in developing and promoting best practice in policy design and preparation to help keep down financing costs.

Business models

The desired increase in RE production will require a huge system transformation, particularly in the electricity sector, upon which business models will have to capitalize. Electricity systems will move away from centralized generation and unidirectional transmission and distribution to widely distributed generation from renewable sources.

These changes will require use of real-time pricing that values flexible generation and use as well as different ways of charging for grid services. Incumbents must respond to these changes or see their businesses—largely based on high shares of fossil fuel–driven base-load power generation—falter.

Moving to distributed renewable generation also opens up new opportunities for distributed generation and mini-grid systems in remote communities to increase energy access. In rapidly growing electricity markets, opportunities will arise to establish the necessary generation mix and transmission infrastructure best suited to high shares of RE.

Integration and transformation

Integrating relatively high levels of variable RE generation (10–20 percent of electricity supply, depending on system characteristics) into electricity systems can be achieved without radical reform if straightforward technical and regulatory measures are put in place, as shown by recent IEA work on flexible RE power systems (IEA, 2014d). Moving beyond those levels requires more radical changes that include higher flexible generation, power storage, demand-side integration, and a transmission and distribution system well adapted to the new generation paradigm. At this point, a whole-of-system approach can limit the costs of transformation.

Moving to high rates of renewable generation with very low marginal costs will have profound effects on electricity markets, which tend to respond to short-term marginal cost fluctuations and can be influenced by carbon prices. In a system where most generation has low marginal costs and low carbon emissions, novel market and regulatory solutions will be required to ensure investment not only in RE generation but in all components to maintain a well-functioning system.

Integration is also a key issue for other RE sectors. Some transport markets are already reaching the limit for conventional biofuels (ethanol and biodiesel) to be blended with conventional fuels—for instance, the 10 percent "blend wall" for ethanol, in which current technologies, market forces, and policy combine to limit the rate at which ethanol can be blended with gasoline. Encouraging higher levels requires widespread changes to the vehicle stock (like the use of "flexfuel" vehicles in Brazil) or the development of fuels that directly replace fossil fuels, especially in advanced applications like air travel. Producing such fuels is challenging both technically and economically. Similarly, electrification of road transport will require a completely new infrastructure.

Integration may be a less pressing issue for renewable heat, though there is considerable potential for optimizing renewable heat in efficient urban energy systems where current distinctions between electricity heat and fuels become blurred—no doubt leading to changes in technology priorities, with bioenergy combined heat and power (CHP), heat pumps, and solar heating and cooling having enhanced roles.

Policy

Meeting the doubling objective will require nearly all countries to adopt cost-effective policies to encourage RE deployment. Countries have a wealth of policy experience on which to draw. Creation of policy assessment frameworks—such as the World Bank's RISE—is one important step in this trend, and international bodies in different regions should cooperate to refine and harmonize these frameworks.

Policies must adapt to changes in markets and technologies. For example, priorities change as a market matures and deployment expands. Integration issues are not significant at low deployment but become critical with substantial development. For countries that have already started rolling out renewables, the priority is to maintain and adapt policies so that market momentum is maintained and the costs of policy implementation are minimized as technology costs fall. Countries with higher deployment must adopt policies appropriate to high shares of variable capital-intensive renewable generation, and these will include fundamental changes to how energy is regulated and how energy markets function. Experience in this "mainstreaming phase" is limited, and a concerted effort will be required to achieve optimal policy mixes.

In a recent report, IRENA (2014b) distinguishes four key challenges faced by RE policymakers in dynamic markets:

accounting for rapidly falling renewable generation costs, addressing the tax- or ratepayer burdens of financial support for renewables, accounting for renewable energies' cost competitiveness, and integrating variable RE electrical power.

Given the importance of heat and the low priority governments currently assign to renewable heat policies, countries should carefully review the potential for renewable heat in their economies and institute policies to support market development and reduce noneconomic barriers to rollout.

Stable policies are needed to resolve issues of sustainability of biofuels that can be used in transport, to set up robust certification systems ensuring that biofuels are produced and used sustainably, and to catalyze deployment of biofuels technologies.

Impact of oil prices on renewable energy development

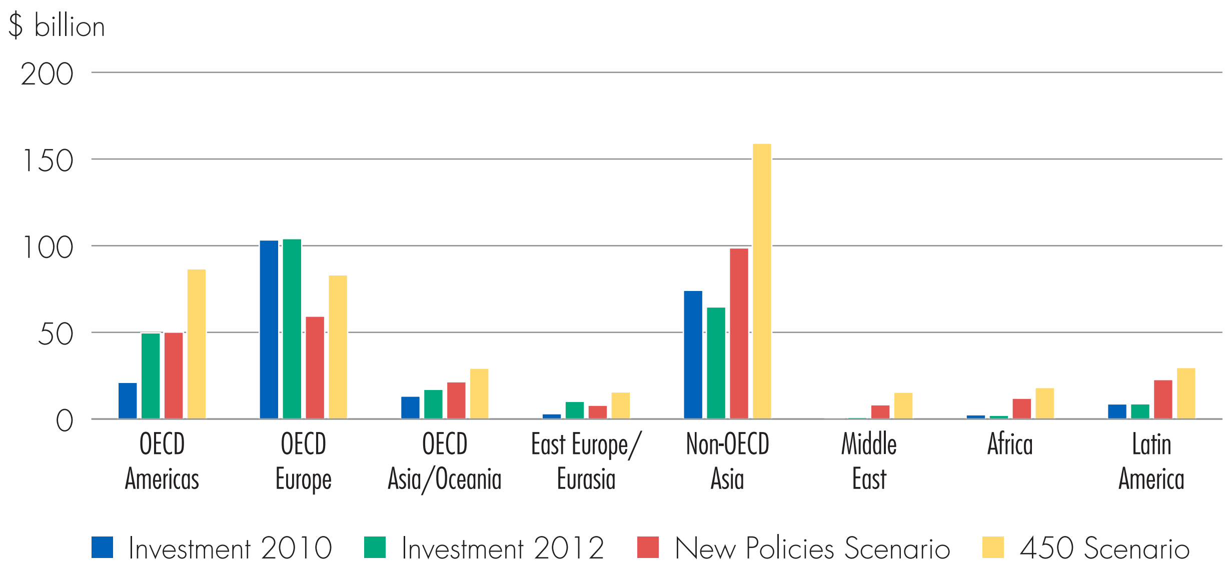
The price of oil has tumbled in the past few months, from about $100 per barrel before September 2014 to $50 in early 2015. Increased production of unconventional natural gas and close ties between natural gas and oil prices put further downward pressure on natural gas prices as well. How these trends affect RE will depend on the country. For instance, in the United States or EU, renewables face little competition from oil in electricity generation, because oil is rarely used for this purpose. Natural gas may be a substitute for renewables, but it

Table 4.3. **Required investment: 450 Scenario and REmap 2030**

	450 Scenario (IEA)	REmap 2030 (IRENA)
2030 share of RE in TFEC (%)	29.4	36.0
2012 RE investment ($ billion)	258	258
Required annual investment ($ billion)	442	650
Annual investment gap ($ billion)	184	392

Source: IEA 2014c; IRENA 2014a.

Figure 4.34. **Annual renewable energy investment, actual (2010 and 2012) and required by *World Energy Outlook*'s New Policies and 450 Scenarios**



Source: IEA 2014a.

Note: Regional classification is consistent with *WEO*.

may also complement renewables due to the ability of "fast-cycling" gas plants to backstop the intermittency of renewables.

Market effects aside, it is also important to consider policies in place to support renewables. Where renewables are not competitive at market prices, renewable energy policies may offer price support that is relatively impervious to the price fluctuations of hydrocarbons. Evidence of dampened renewables growth in response to lower oil prices is limited to date. One measure of the health of the RE sector is the S&P Global Clean Energy Index, which, despite a dip in 2014, stands at a three-year high at the time of this writing.

Investment requirements

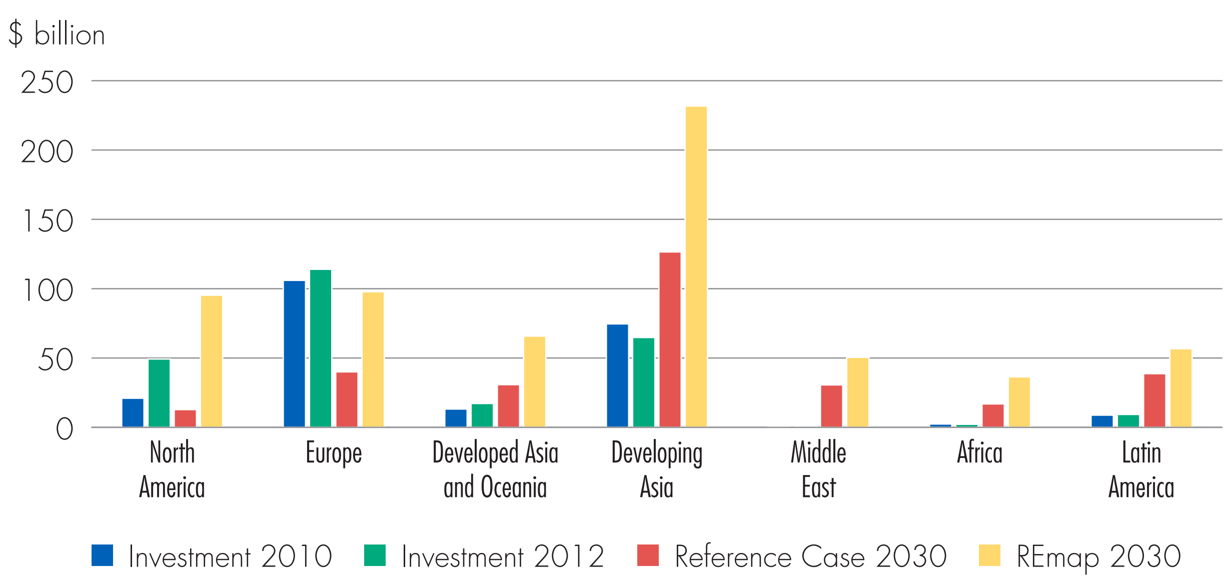
Over 2010–12, global annual investment in RE increased by 13 percent, from $228 billion to $258 billion, but even this substantial progress is nowhere near enough: global annual investment in RE needs to nearly double to reach the 450 Scenario target of $442 billion (IEA 2014a) and increase 2.5-fold to achieve the SE4All objective of $650 billion (REmap 2030; IRENA 2014a) (table 4.3).[13]

In the 450 Scenario, the share of RE in TFEC increases to 29.4 percent by 2030, less than the 35.8 percent target of the SE4All agenda, so the 450 Scenario estimate presented here should be taken as a conservative figure. Even so, the 450 Scenario requires annual investment of $442 billion, implying a $184 billion investment gap spread across all regions (except OECD Europe), especially non-OECD Asia (figure 4.34). Broad policy commitments and plans announced by countries in the New Policies Scenario do not change the overall picture, as global investment in that scenario totals only $281 billion annually.[14]

REmap 2030 provides a pathway for scaling up use of renewables to double the renewables share in TFEC. Under REmap 2030, annual investment in renewable energy must be close to $650 billion, pointing to a nearly $400 billion investment gap in 2012 and requiring a 2.5-fold increase over 2012's investment volume. As in the WEO 450 scenario, the 2012 investment gap is highest in developing Asia. But REmap 2030 requires relatively higher scale-up in the economies of the Middle East, Africa, and Latin America (figure 4.35).

REmap's higher investment requirements compared with those of the 450 Scenario stem from the difference in

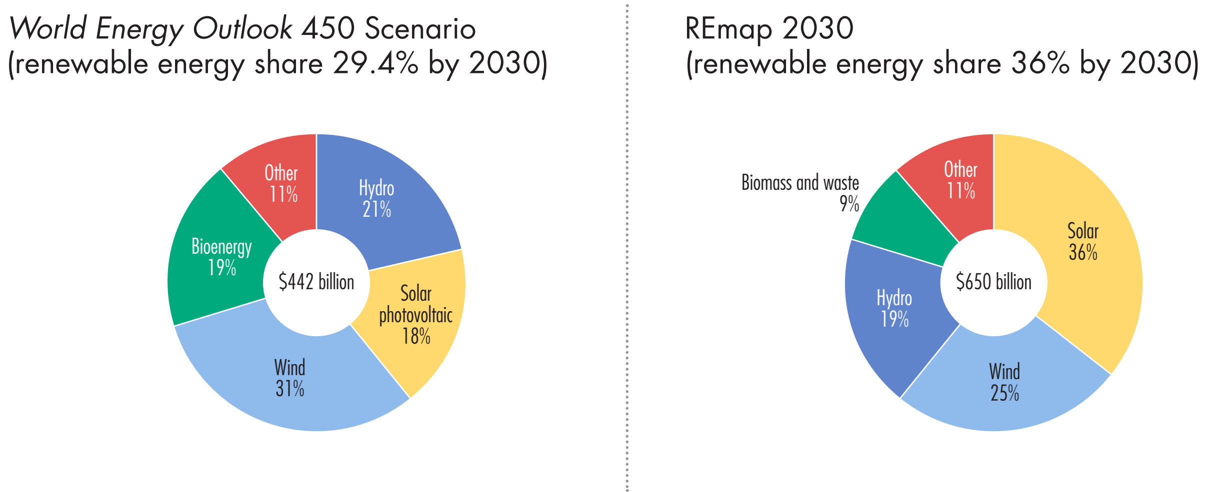
Figure 4.35. **Annual renewable energy investment, actual (2010 and 2012) and required by REmap 2030**



Source: IEA 2014a and analysis by IRENA based on IRENA (2014a).

Note: Regional classification approximates that of *WEO* 450.

Figure 4.36. **Annual renewable energy investment requirement by technology**

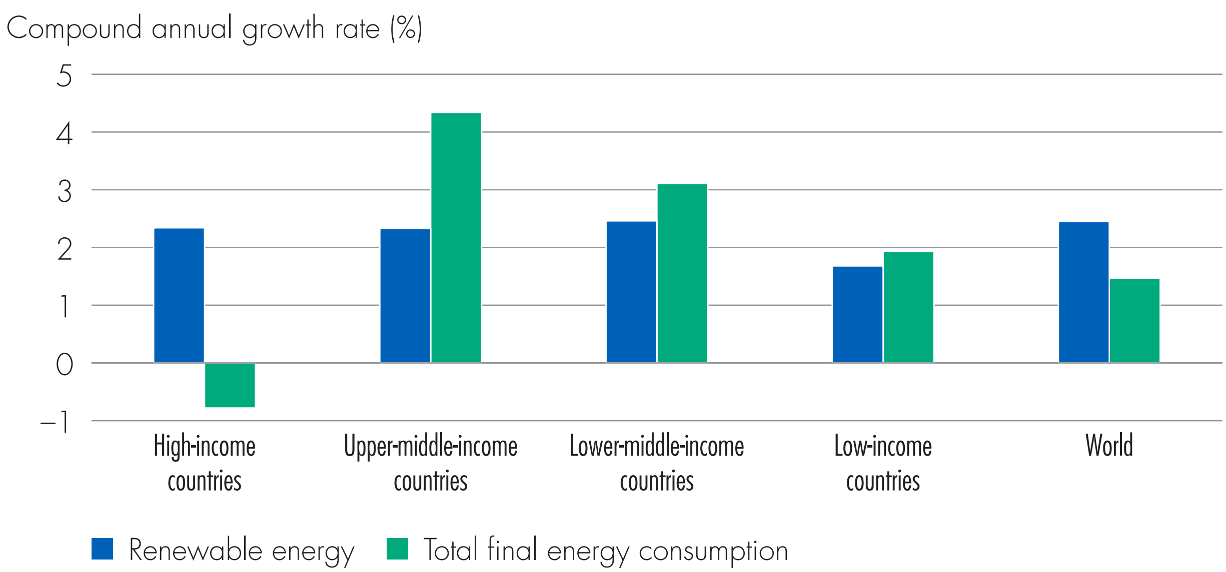


Source: IEA 2014a; analysis based on IRENA (2014a).

their targets. Both the 450 Scenario and the REmap 2030 Option analyses predict that more than a third of investment will occur in developing Asia and that the bulk of investment will focus on the power sector. But the pathways differ with regard to technologies. Where the *WEO* predicts wind and hydro power to be the largest recipient technologies of RE investment, REmap 2030 sees solar PV attracting the most investment, followed by wind (figure 4.36). What is clear from both analyses is that current investment is below what is required, and current and planned policies to scale up RE remain insufficient to close the gap.

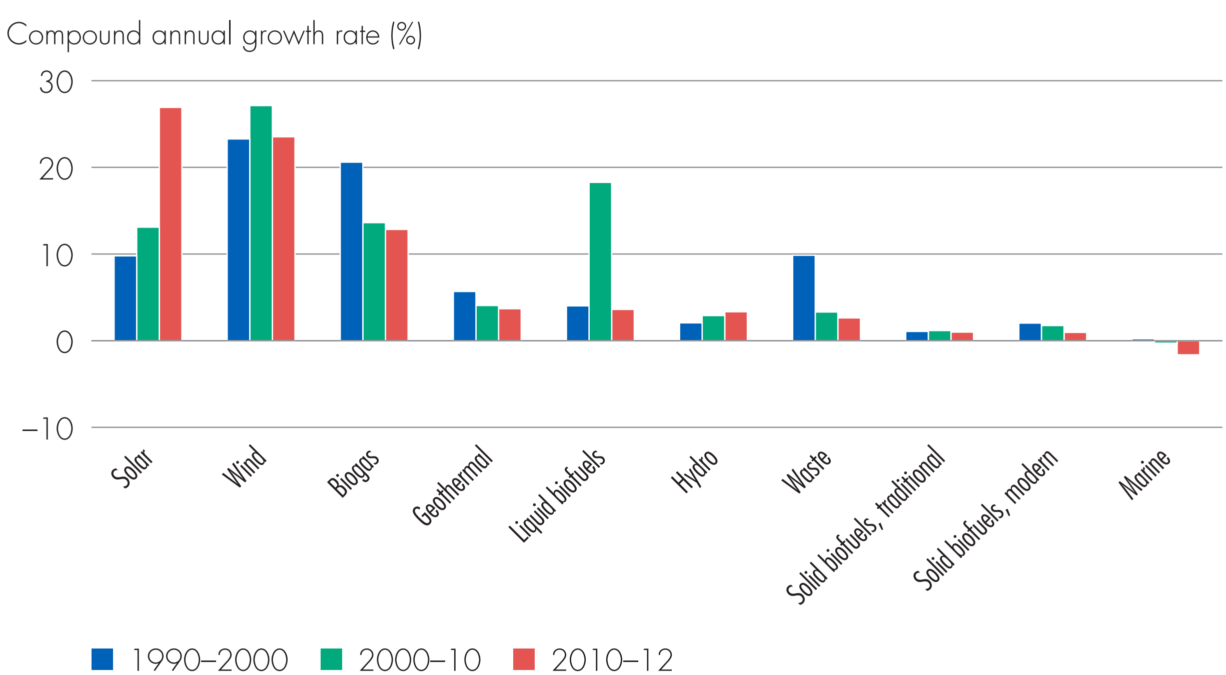
Annex 1. Additional information and charts

Figure A1.1. **Compound annual growth rate of renewable energy consumption and total final energy consumption, 2010–12**



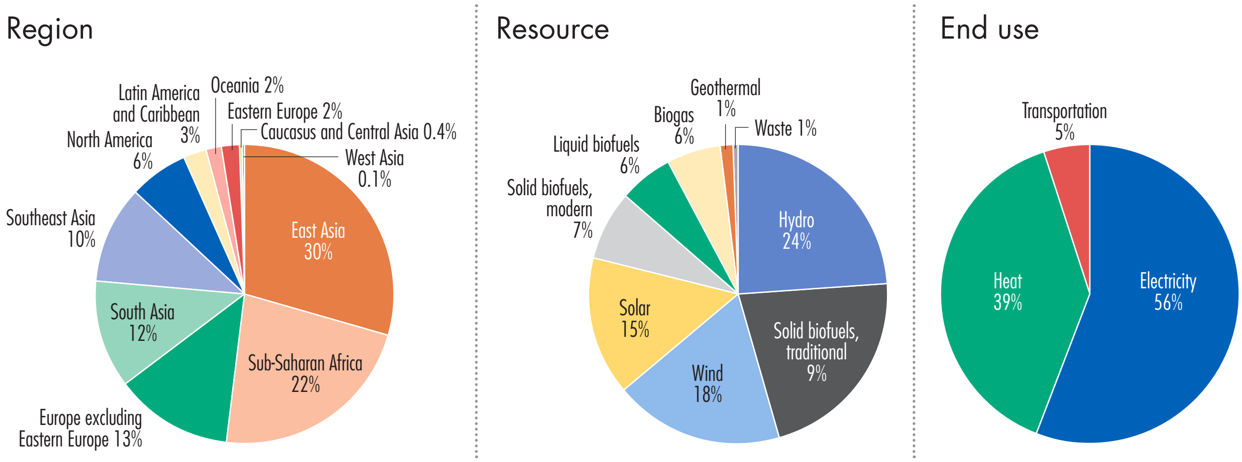
Source: IEA and UN data.

Figure A1.2. **Compound annual growth rates of renewable energy consumption by source**



Source: IEA and UN data.

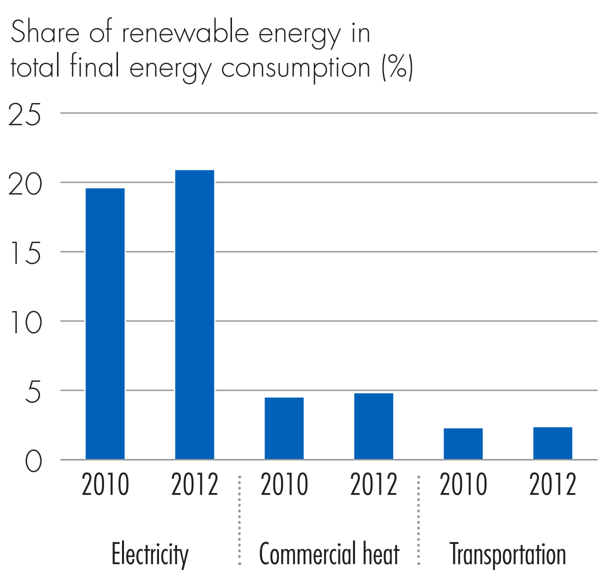
Figure A1.3. **Composition of the net increment of renewable energy consumption, 2010–12**



Source: IEA and UN data.

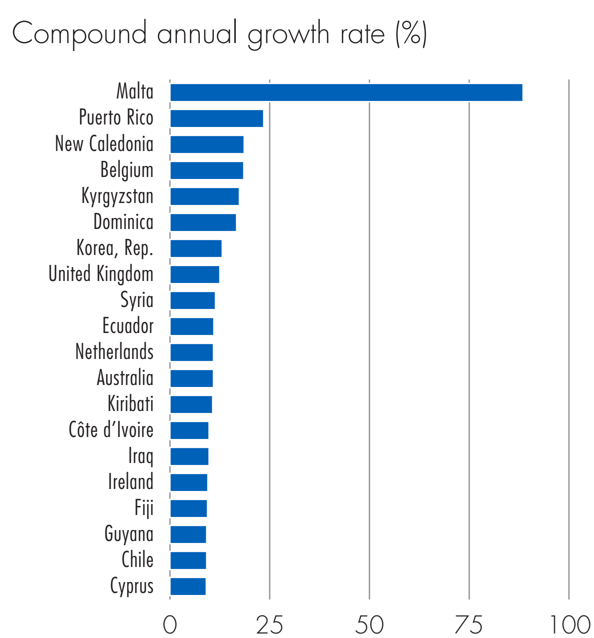
Note: Includes traditional uses of solid biofuels.

Figure A1.4. **Renewable energy share of total final energy consumption by end sector, 2010–12**



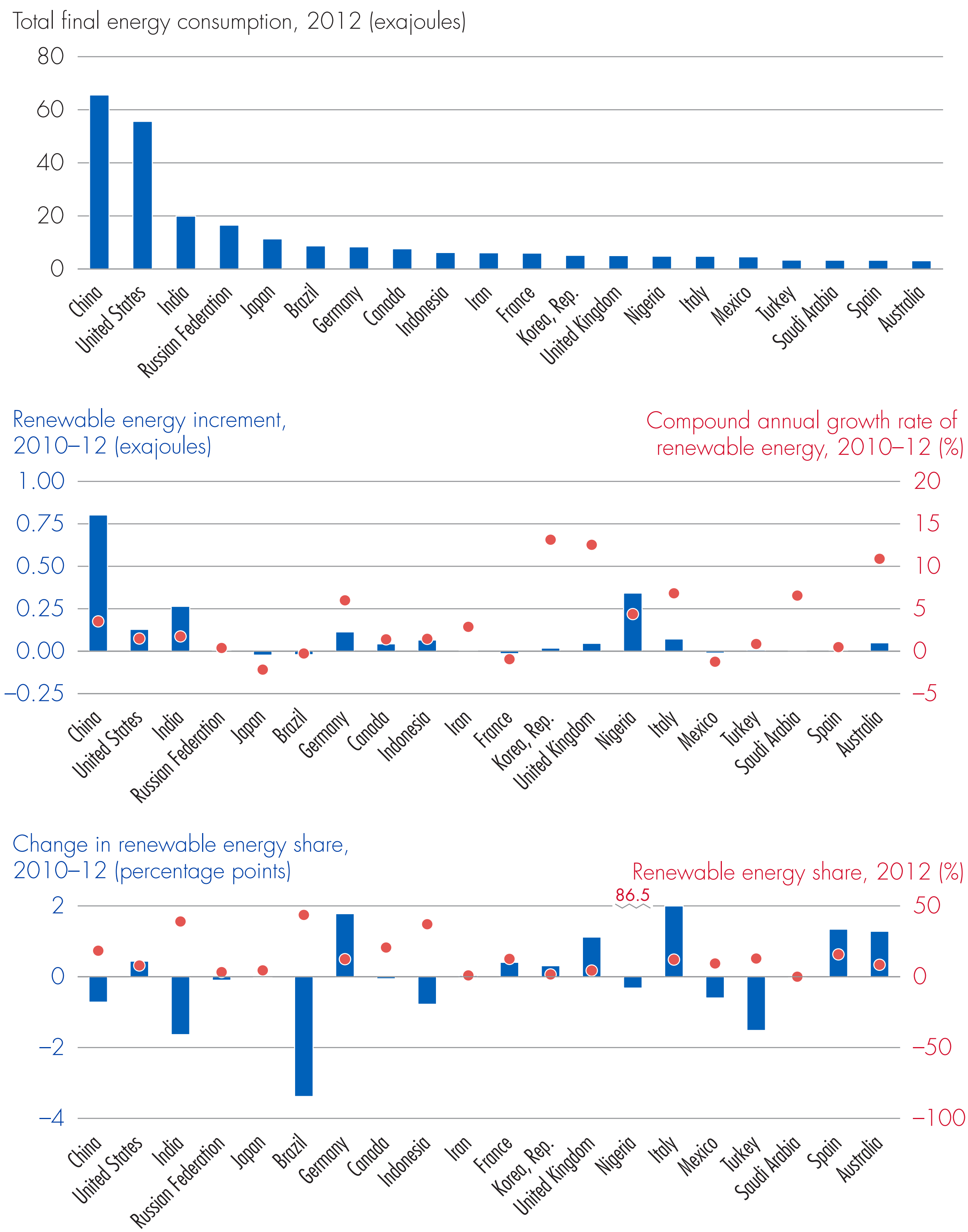
Source: IEA and UN data.

Figure A1.5. **Renewable energy consumption compound annual growth rate, top 20 fastest-moving countries, 2010–12**



Source: IEA and UN data.

Figure A1.6. **Top 20 energy-consuming economies: Renewable energy increase, 2010–12**



Source: IEA and UN data.

Notes

1. Although *GTF 2013* reported an RE share of 18 percent in 2010, with routine adjustments to data applied by the IEA and UN the revised baseline figure for 2010 stands at 17.8 percent, implying that the share of renewables in TFEC increased by only 0.35 percentage points (from 17.78 to 18.13) over 2010–12.
2. The UN Food and Agriculture Organization defines solid biofuels used for traditional purposes as "woodfuels, agricultural by-products, and dung burned for cooking and heating purposes." In developing countries, these fuels are still widely harvested and used in unsustainable and unsafe ways. They are traded informally and noncommercially. So-called solid biofuels for modern purposes, by contrast, is produced in a sustainable manner from solid wastes and residues from agriculture and forestry. The informal term "modern renewables" as used in this report denotes all renewables except solid biofuels used for traditional purposes.
3. REmap 2030 presents a roadmap for doubling the share of RE over 2010–30. It is the first global study based on a bottom-up analysis of official national sources to analyze RE options. The roadmap encompasses 26 countries representing three-quarters of current energy demand. For each country, national plans are used to determine a business-as-usual Reference Case. Then additional technology options are investigated, defined as REmap 2030. See "Future Scenarios" in section 4.4.
4. Brazil is the largest producer of biofuels in Latin America and Caribbean (LAC). It converts sugarcane into ethanol for domestic consumption and for export mainly to the United States and EU. Over the past few years, several factors have reduced demand for ethanol: cheap gas and oil from shale formations accessed by hydraulic fracking in the United States cut the demand for ethanol, while Brazil's government, in response to the global economic crises, used Petrobras (Brazil's semipublic energy corporation) to import refined gasoline and sell it at a discount, prompting the transport sector to switch to gasoline and reducing ethanol demand and therefore output in response.
5. Analyzing the net increment with and without solid biofuels used for traditional purposes (primary solid biofuels and charcoal) is important, because these generally are used nonsustainably by the residential sector in developing economies. Chapter 4 discusses in more detail the challenge of defining and measuring bioenergy.
6. The estimate of the contribution of heat to RE share of TFEC considers the total heat produced by the installation (CHP plants and heat plants) and includes the heat used by the installation's auxiliaries that use a hot fluid (such as space heating or liquid fuel heating) and losses in the installation/network heat exchanges, as well as heat from chemical processes used as a primary energy form.
7. RE capacity grew from 790 GW in 2002 to 1,439 GW in 2012.
8. IEA defines investment as "overnight" capital expenditures on new renewable power plants or the replacement of old power plants. When a renewable technology comes to the end of its *technical* lifetime, it is replaced or refurbished with an equal amount of capacity at reduced cost. Investment outlays are counted in the year that a capacity addition becomes operational and do not include O&M costs, financing costs, or spending on transmission and distribution grids (IEA 2014a).
9. Chapter 5 examines the typology and distribution of RE targets introduced globally.
10. Reductions in the price of PV system components are illustrated with the case of Italy in figure A1.4.
11. Levelized cost represents the per kilowatt-hour cost of building and operating a generating plant over an assumed financial life and duty cycle.
12. A conventional comparison using an LCOE metric does not take into account the full range of costs and benefits associated with the operation of different conventional and RE-based generation options. For instance, LCOEs do not consider the variability of wind and solar resources and integration costs, the constraints in fossil fuel supply, volatility in fuel oil prices, or even externalities such as reductions in greenhouse gas emissions or local pollution. The merits of intermittent generation technologies depend on a range of factors, including the pace of energy demand growth, how well the renewable resource meets the demand profile, whether base load or peak energy demand needs to be met, existing assets in the system and extent of system integration and carbon pricing mechanism.
13. The investment requirements consider only the amount necessary to deploy renewables to meet the *WEO* 450 and REmap 2030 targets; they do not consider the investments foregone resulting from the displacement of a business-as-usual mix of supply options
14. IEA 2014a.

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CHAPTER 5

TOWARD A DATA REVOLUTION IN SUSTAINABLE ENERGY

Toward a data revolution in sustainable energy

Highlights

- The multitier framework for measuring energy access unveiled in the first edition of the *Global Tracking Framework* (World Bank and International Energy Agency [IEA] 2013) was a big step forward in defining and measuring global access to energy. It resolved the shortcomings of binary reporting (yes/no) by replacing these categories with tiers of energy supply performance. Higher tiers feature progressively higher performance, as the energy supply accommodates an increasing number of energy applications. The framework has been piloted in several locations, and the resulting data show a wide divergence from binary measurement. After piloting has been completed, a global access survey will allow standardized framework data to be collected and disseminated in many countries.

- Energy intensity is a proxy for energy efficiency. It is influenced by many factors in addition to changes in actual physical efficiency, but the data required for its calculation are readily available at national level. Decomposition analysis—stripping away the influence of an economy's structural trends—can reveal underlying changes in energy efficiency. Better tracking of energy efficiency requires detailed reporting on sectoral activities, sectoral energy consumption, and individual end uses. This in turn requires resource-intensive efforts by countries to collect and report data and by international organizations to aggregate information from disparate sources into comparable values. Progress can be made by tracking initially those sectors and countries that most influence global progress toward the Sustainable Energy for All (SE4All) energy efficiency goal (that is, the top energy-consuming countries and activities).

- The main methodological constraint in measuring and tracking the SE4All objective for renewable energy (RE) is that it is difficult to distinguish accurately between modern and traditional uses of solid biofuels, due to the lack of consistent definitions and data and to complexities in measuring and tracking sustainability. International organizations, statistics groups, and national governments have begun to agree on methodologies to account for the sustainable use of solid biofuels in energy statistics. Two other data and methodological challenges to RE stand out: First, the need to improve definitions and data collection in distributed RE power and heat generation for grid-connected and off-grid systems; second, the need to implement and promote a harmonized approach to target setting.

- Attaining the achievement of the SE4All objectives will require countries to access cutting-edge technologies and knowledge relevant to sustainable energy. A combination of indicators can be used as a proxy for a preliminary perspective on the extent to which countries are accessing and applying the key technologies. These indicators include international trade flows, tariff and nontariff barriers to trade, and scientific journal citations and engineering qualifications that give a sense of whether countries have the capacity (beyond access) to absorb and utilize a technology. Data are already available in international data repositories to measure and track these indicators.

Introduction

The first edition of the SE4All *Global Tracking Framework (GTF 2013)* proposed a system of regular global reporting of indicators that are technically rigorous, are computable from current global data energy databases, and offer scope for gradual improvement (table 5.1). The report also identified methodological challenges in measuring and tracking the selected indicators, and proposed remedial actions (table 5.2).

So that tracking could be truly global, the philosophy behind *GTF 2013* was to strike a balance between an ideal metric that best captures progress in the energy sector and the real limitations of the data sets already available for all countries in the world. A workable solution was achieved, with indicators that provided reasonable and widely available proxies to reflect progress toward sustainable energy for all. But it was always acknowledged that these indicators—and their methodological approaches—were less than ideal, and it was agreed that the framework should aim to continuously improve data over time.

The 2014 report "A World That Counts," produced by the Independent Expert Advisory Group on a Data Revolution for Sustainable Development for the United Nations (UN) Secretary General, underscores the pressing need to improve capacity and resources to better document the

Table 5.1. **Overview of the central GTF indicators developed in 2013: Rationale and data sources**

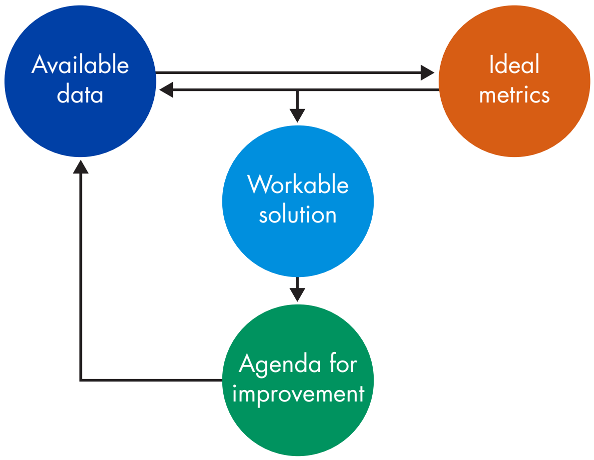
<table>
<tr><th>Objective</th><th>Central indicator</th><th>Methodological considerations</th><th>Data source</th></tr>
<tr><td rowspan="2">Universal access to modern RE sources, including electricity and fuels for cooking</td><td>Percentage of population with an electricity connection</td><td>• The presence of an electricity connection is a prerequisite for receiving electricity supply, but it does not guarantee it.</td><td rowspan="2">National household surveys following internationally standardized questionnaires (such as Demographic and Health Surveys, Income and Expenditure Surveys, Living Standard Measurement Surveys, Multi-Indicator Cluster Surveys) and some censuses</td></tr>
<tr><td>Percentage of population primarily using non-solid fuels</td><td>• Solid fuel usage for cooking in the developing world (wood, charcoal, dung, crop residues, etc.) tends to be associated with inefficiency and undesirable health impacts, although the extent of these depend on the characteristics of the cook stove used as well as the behavioral practices of the user.
• Non-solid fuels tend to be associated with efficient and healthy cooking practices—with some exceptions, such as kerosene.
• Many households rely on multiple fuels for cooking, hence the focus on the fuel on which the household primarily relies.</td></tr>
<tr><td>Double rate of improvement of energy efficiency</td><td>Compound annual growth rate (CAGR) of primary energy intensity as a percentage of gross domestic product (GDP) in purchasing power parity (PPP) terms</td><td>• Energy intensity is a proxy for energy efficiency.
• Primary energy demand also captures energy that is lost in various energy transformation processes.
• PPP measures of GDP avoid undervaluing the output of developing economies.</td><td rowspan="2">National energy balance data collected in standardized form by the International Energy Agency for larger countries and the UN for smaller countries; World Bank and UN GDP databases and PPP estimates</td></tr>
<tr><td>Double share of RE in global energy consumption</td><td>Percentage of total final energy consumption (TFEC) from renewable sources</td><td>• Renewable sources are all those replenished as they are consumed (including wind, solar, hydro, geothermal, biofuels, and marine power).
• Assessing and measuring the sustainability of bioenergy production and use is complex given its multifaceted and context-specific nature.</td></tr>
</table>

dimensions of sustainable development. Improving data measurement and tracking is a development agenda in its own right (figure 5.1) and will enhance the targeting of available budgetary and concessional resources and spur new economic opportunities. Data gaps can only be closed through new investments and strengthened capacities. The SE4All framework seeks to catalyze this data revolution for the energy sector.

This chapter describes emerging methodological approaches and proposes a practical agenda for improving data availability and quality. Section 2 describes a new approach to measuring access to electricity and modern cooking solutions based on the multitier framework as well as on the results of its piloting in several countries.

Section 3 describes the decomposition analysis typically used to get a precise measure of the role of energy efficiency in energy consumption trends, as well as how to move toward the goals described in *GTF 2013* for improved tracking of energy performance. It sets out some of the indicators and underlying data needs.

Figure 5.1. **Iteratively improving measurement and tracking**



Source: Prepared by authors.

Section 4 reviews the data and methodological challenges in RE and proposes a pragmatic approach for addressing the issue of sustainability in bioenergy. It also introduces improved definitions for RE in distributed generation and rural markets and sets forth principles for a harmonized approach to the setting of policy targets.

Reaching the SE4All objectives will require countries to access cutting-edge technologies and knowledge for sustainable energy. Section 5 examines indicators that could help on this front.

Methodological improvements in energy access

Historically, due to the need to accommodate data deficiencies, the term energy access has had no universally agreed-upon definition that reflected users' diverse energy needs and energy solutions. Global databases provided information only on whether a household was connected to the electricity grid and what fuel was used for cooking. No information about stand-alone electricity supply solutions (such as solar lanterns and solar home systems) or the quality of electricity received (such as hours of supply or voltage) was available. Thus *GTF 2013* could only measure access based on binary metrics:

- Access to electricity, defined as availability of an electricity connection at home or the use of electricity as the primary source for lighting
- Access to modern cooking solutions, defined as relying primarily on non-solid fuels for cooking

GTF 2013 used a range of data sources—primarily household surveys (including national censuses) and, in a few cases, utility data—for measuring energy access. Two global databases, one on electricity and another on non-solid biofuels, were used: the World Bank's Global Electrification Database and the Global Household Energy Database of the World Health Organization (WHO). IEA data on energy access were reviewed in preparing these databases. Both databases encompassed three data points for each country—around 1990, around 2000, and around 2010. Because surveys were carried out infrequently, statistical models were developed to interpolate missing data points.

GTF 2013 acknowledged the limits of these binary metrics: the metric for electricity fails to take into account whether the connection provides adequate and reliable service and does not appropriately register access achieved through decentralized solutions such as solar lanterns, solar home systems, and mini-grids. For cooking, the metric fails to capture improvements in cookstoves that burn solid biofuels, the use of multiple cooking solutions, or the time and effort required in securing such fuels. Even allowing that the binary approach served the immediate purpose of setting a baseline for tracking progress under the SE4All initiative, *GTF 2013* highlighted a growing consensus in favor of measuring energy access as a continuum of improvements. A multitier metric to address the above shortcomings was proposed in *GTF 2013* for medium-term development.

Because the data constraints that necessitated binary metrics in 2013 persist, this edition uses the same binary metrics for energy access. However, over the past two years, the multitier frameworks for household access to electricity and cooking solutions proposed in *GTF 2013* have been refined and piloted in some areas in some countries. The new metrics are flexible and allow country-specific targets to account for diverse energy challenges. In addition, frameworks for access to energy for household space heating and stand-alone lighting solutions have been conceptualized. A global household energy survey is planned to gather data for all household energy needs and to support multitier measurement and reporting. Multitier frameworks for productive engagements and community facilities are also proposed by *GTF 2015* to be piloted and then rolled out for regular tracking over the medium term.

Table 5.2. **Agenda for improving data**

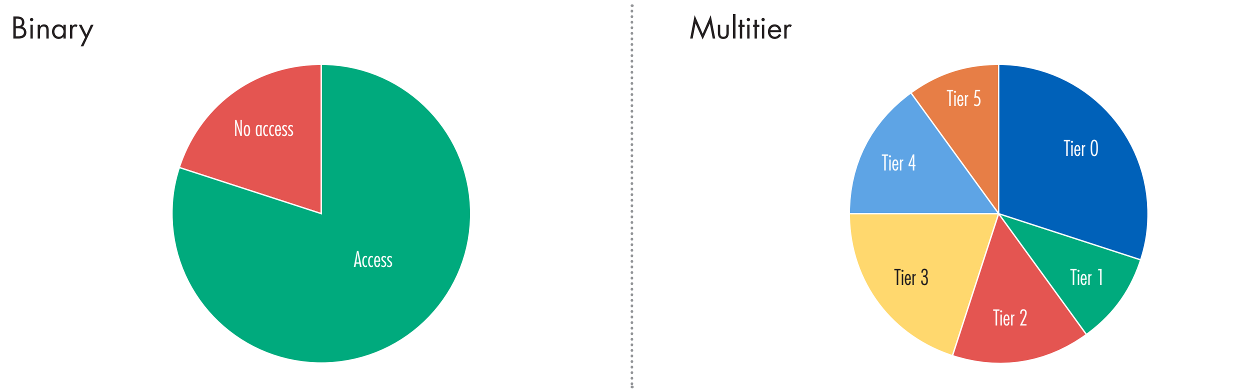
	Challenge	Actions
Energy access	Binary measurement of energy (that is, with/without connection) does not capture the nuances of energy supply.	Early proposals for multitier frameworks for electricity and modern cooking solutions were presented in GTF 2013 and have been refined since. Survey instruments for data collection and approaches for data analysis have been piloted in some areas of some countries. Preparations are under way for a global survey that will improve ability to assess energy access. New multitier frameworks for space heating, productive engagements, community facilities, and small lighting solutions are presented in this edition (*GTF 2015*). These frameworks will be pilot-tested before global rollout.
Energy efficiency	Energy efficiency is the relationship between energy inputs and physical or service outputs; its calculation requires more-disaggregated data across countries.	A consensus-building process will decide on the indicators, the key sectors, segments, activities, and countries for developing meaningful global tracking indicators. The process will prioritize country data and identify organizations to carry out associated capacity building as well as provide the technical assistance needed to set up and maintain surveying and reporting capacities. This process will identify the necessary resources—and sources—including investment capital.
Renewable energy	• Measurement and tracking of the sustainable use of solid biofuels is based on the assumption that solid biofuels consumed in developing economies are used in a "traditional" way. • Other data and methodological constraints • Target setting	International organizations, international and regional statistics agencies, specialized groups, and national governments have initiated steps to develop methodologies to progressively account for the sustainable use of solid biofuels in energy statistics. A roadmap base on piloted approaches could include the following actions: • *Short term:* Rely on a mix of proxy, semiquantitative, and qualitative measurements to track use of solid biofuels. Indicators might include share of land use following established good practice, and share of land under sustainability certification schemes. • *Medium term:* Progressively conduct the assessment and monitoring of bioenergy sustainability at national level in high-impact countries (that is, those using the largest volume of solid biofuels in a traditional manner) using Global Bioenergy Partnership (GBEP) indicators. As this cannot yet be done annually (due to complexities and funding needs), periodic tracking would be more challenging under this approach. • Achieve improved definitions and data collection for distributed RE power generation in both grid-connected and off-grid systems. • Convert the range of RE targets into a common metric for global tracking. This chapter outlines principles for a harmonized approach to target setting.

Multitier approach to measuring energy access

GTF 2013 highlighted the need to collect further data for its proposed multitier frameworks by periodic measurement at national level to assess a range of attributes of energy access, establish a baseline, and subsequently measure progress. As with projects and programs, the data obtained could be used before the event for better prioritizing of investments and designing better interventions, and afterward for tighter monitoring and evaluation. In this manner, periodic measurement could contribute substantially to the success of energy interventions and achieving the SE4All access goal.

The World Bank/Energy Sector Management Assistance Program (ESMAP) team has continued refining the frameworks for household access to energy. The team has also

Figure 5.2. **Binary versus multitier measurement, example**



Source: Prepared by authors.

developed other frameworks for space heating, household lighting, productive engagements, and community facilities. (figures A1.1–A1.6; a report on these has been compiled and will be released later this year.) The team prepared survey questionnaires and ran pilot testing in areas such as Kinshasa in the Democratic Republic of Congo and selected districts in the Indian state of Bihar. (Further pilots are planned.) It has also prepared energy access diagnostic reports for these areas, using the multitier metrics to suggest approaches for strengthening access.

The multitier approach expands the binary definition (and measurement) of energy access to *the ability to obtain energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy, and safe for all required energy applications across households, productive engagements, and community facilities.*

In the multitier approach to measuring energy access, tiers are essentially levels of access reflecting the added dimensions of this expanded definition. They are defined according to a combination of attributes to rate the performance of the energy accessed from tier 0 (no or very low level of access) to tier 5 (very high level of access; figure 5.2). Progressively higher attributes appear in higher tiers, each tier marking the ability of the energy accessed to serve more energy applications. Such a metric allows different energy solutions (which can possess varying energy attributes, depending on technological capabilities) to be assessed on the performance of the energy they deliver.

Multitier frameworks have been devised for access to energy at different locales: households (electricity, cooking, and heating), productive engagements, and community facilities. The frameworks are technology-neutral and allow objective assessment of energy sources, from solar lanterns to grids and from improved cookstoves to natural gas stoves, while keeping the focus on energy applications to ensure the approach is meaningful to energy end-users. The multitier framework matrices for household electricity and household cooking are shown in tables 5.3 and 5.4; similar formulations for other locales are presented in annex 1 (see figures A1.1–6). The energy access tier rating for a particular household is determined by the highest tier for which all the attributes are met by the household.

Using the multitier metrics, energy access levels may be assessed at any locale for any geographic area—a cluster of villages, block, city, district, province, country, region—even the whole world. The multitier framework yields data a wide range of uses, including in-depth disaggregated analysis (that examines each attribute separately) and aggregated indexes of access (that combine data across attributes into a single number). Disaggregated and aggregated analyses together facilitate planning and strategy, project design, progress monitoring, impact evaluation, and comparisons across areas and over time.

The multitier framework also allows a nuanced understanding of what constitutes an energy access project. Such projects are typically thought of as either providing

Table 5.3. **Multitier matrix for access to household electricity supply**

Attributes		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
1. Peak capacity	Power		Very low power, minimum 3 watts	Low power, minimum 50 watts	Medium power, minimum 200 watts	High power, minimum 800 watts	Very high power, minimum 2 kilowatts
	and Daily capacity		Minimum 12 watt-hours	Minimum 200 watt-hours	Minimum 1.0 kilowatt-hours	Minimum 3.4 kilowatt-hours	Minimum 8.2 kilowatt-hours
	or Services		Lighting of 1,000 lumen-hours per day	Electrical lighting, air circulation, television, and phone charging are possible			
2. Duration	Hours per day		Minimum 4 hours	Minimum 4 hours	Minimum 8 hours	Minimum 16 hours	Minimum 23 hours
	Hours per evening		Minimum 1 hour	Minimum 2 hours	Minimum 3 hours	Minimum 4 hours	Minimum 4 hours
4. Affordability					Cost of a standard consumption package of 365 kilowatt-hours per annum is less than 5 percent of household income		
3. Reliability						Maximum 14 disruptions per week	Maximum 3 disruptions per week of total duration less than 2 hours
5. Legality						Bill is paid to the utility/prepaid card seller/authorized representative	
6. Health and safety						Absence of past accidents/ no perception of high risk in the future	
7. Quality						Voltage problems do not affect use of desired appliances	

additional grid connections or delivering off-grid solutions, such as solar lanterns or solar home systems. But other types of projects also contribute to improving energy supply and may have a positive effect on access by directly or indirectly improving one or more electricity supply attributes. For example, a generation project may allow longer hours of supply and improved voltage; a transformer upgrade project may improve voltage as well as reliability. Similarly, a program for improved ventilation in kitchens may generate health benefits, qualifying as improved energy access. Such contributions, which cannot be accounted for under the traditional binary definition, are reflected in the multitier approach. Thus, beyond merely enabling expansion of electricity connections, projects on electricity generation, transmission, and distribution—as well as projects strengthening markets, regulations, and load management—can count as energy access projects if they move households to higher tiers of access by improving attributes of the existing system.

Aggregate analysis using multitier indexes

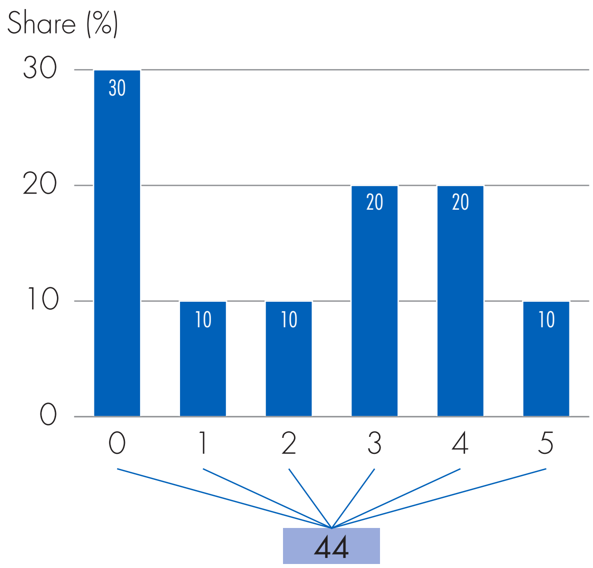
To compile the information captured by the multitier framework for any locale in a given geographic area into a single number, a simple index can be calculated by taking the

Table 5.4. **Multilevel matrix for access to cooking solutions**

Attributes		Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
1. Indoor air quality	$PM_{2.5}$ ($\mu g/m^3$)		[To be specified by a competent agency such as WHO based on health risks]	[To be specified by a competent agency such as WHO based on health risks]	[To be specified by a competent agency such as WHO based on health risks]	< 35 (WHO IT-1)	< 10 (WHO guideline)
	Carbon monoxide (mg/m^3)					< 7 (WHO guideline)	< 7 (WHO guideline)
2. Cookstove efficiency (Not to be applied if cooking solution is also used for space heating)			Primary solution meets tier 1 efficiency requirements [to be specified by a competent agency consistent with local cooking conditions]	Primary solution meets tier 2 efficiency requirements [to be specified by a competent agency consistent with local cooking conditions]	Primary solution meets tier 3 efficiency requirements [to be specified by a competent agency consistent with local cooking conditions]	Primary solution meets tier 4 efficiency requirements [to be specified by a competent agency consistent with local cooking conditions]	
3. Convenience: • Fuel acquisition and preparation time (hrs/wk) • Stove preparation time (minutes/meal)				< 7 < 15	< 3 < 10	< 1.5 < 5	< 0.5 < 2
3. Safety of primary	IWA safety tiers			Primary solution meets (provisional) ISO Tier 2	Primary solution meets (provisional) ISO Tier 3	Primary solution meets (provisional) ISO Tier 4	
	or Past accidents (Burns and unintended fires)					No accidents over the past year that required professional medical attention	
4. Affordability						Levelized cost of cooking solution (including cookstove and fuel) < 5 percent of household income	
6. Quality of primary fuel: variations in heat rate due to fuel quality that affects ease of cooking						No major effect	
7. Availability of primary fuel						Primary fuel is readily available for at least 80 percent of the year	Primary fuel is readily available throughout the year

Note: ISO is International Organization for Standardization; IWA is International Workshop Agreement on Cookstoves; PM is particulate matter.

Figure 5.3. **Index of access**



Source: Prepared by authors.

average tier rating of users and adjusting it to a base of 100 using the following formula:

$$\text{Index of energy access} = \sum_{k=0}^{5}(20 * P_k * k),$$

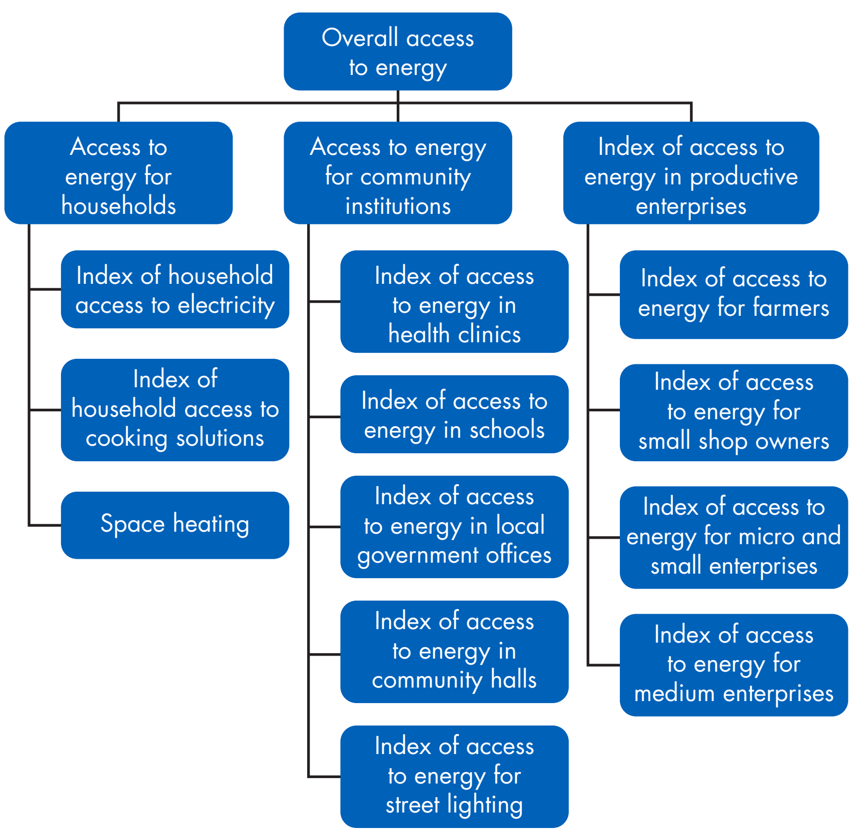
where k is the tier number and P_k is the proportion of households at k^{th} tier.

By combining the proportion of users with the tier of access, the index evaluates both the number of users having access as well as the intensity of such access.

Separate indexes may be calculated for access to energy in specific locales (households, productive engagements, and community facilities) to obtain an overall picture of energy access in a geographic area (figure 5.3).

For households, three sub-locale categories are considered—electricity, cooking solutions, and space heating. In view of their importance as a first step toward higher levels of electricity access, task lighting and phone

Figure 5.4. **Indexes of access**



Source: Prepared by authors.

charging solutions (such as solar lanterns) are given special treatment by allowing continuous measurement between tier 0 and tier 1.

For productive engagements, the energy access tier rating for each survey respondent is taken as the lowest of tier ratings across all "relevant" applications (as determined by significant impact on productivity, sales, cost, or quality, as reported by the user). The aggregate index across respondents in the geographic area is calculated as the average of the tier ratings across all respondents. Separate indexes may also be calculated for specific productive activities such as agriculture, small shops, artisanal activities, and so on by collating information only for respondents working in these activities (figure 5.4).

For community facilities, five sub-locales are considered—schools, health clinics, local government offices, community institutions, and street lighting. The index can be calculated for each; the aggregate index is then calculated as the average of these five.

Disaggregate analysis of attributes

Beyond their use in calculating indexes, data can be employed to assess deficiencies in energy supply. Various indicators may also be calculated, such as the proportion of users using various electricity sources (such as grid, mini-grid, diesel generators, solar home systems, rechargeable batteries, or solar lanterns) as their primary source, percentage of households using different types of fuel as a primary cooking fuel, penetration of tested cookstoves, proportion of legal connections to the grid, average daily hours of electricity supply, average time spent obtaining cooking fuels, share of households receiving electricity during the evening, proportion of households reporting unreliable supply or voltage problems, average frequency and duration of unscheduled interruptions, share of households that cannot afford minimum levels of electricity consumption, and percentage of households using energy services (such as lighting, phone-charging, television, air circulation, refrigeration, or food processing).

Simulating an approximate multitier measurement with binary data

In addition to using the multitier metric as a measure of energy supply quality, the multitier metric can also represent a continuum of electricity consumption, with higher tiers linked to higher consumption. The tiers can be defined by an indicative use (in hours) of a minimum package of services (in watts). Thus, each minimum consumption package threshold can be made roughly consistent with the applications that become feasible with corresponding tiers of electricity supply. An index of electricity consumption can then be calculated as the average consumption tier for the selected population, adjusted to a scale of 100 (see table A1.2). The approach is used here to illustrate how multitier metrics can capture global progress on energy access.

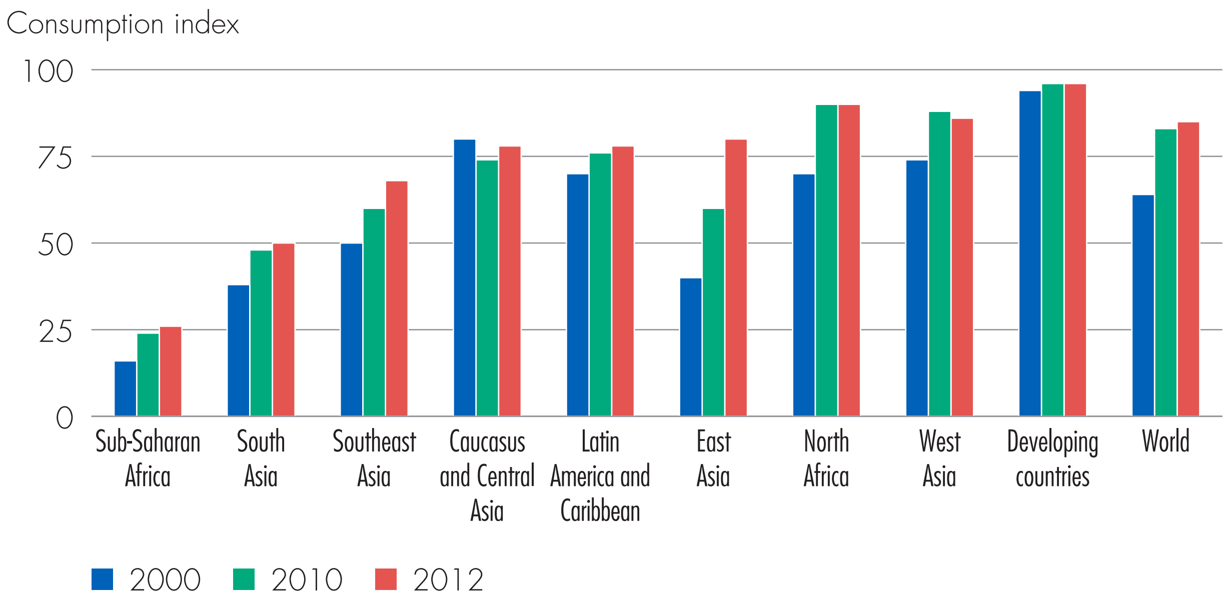
In 2010, the index of electricity consumption stood at 83, up from 64 in 2000, and in 2012 was estimated at 85; this movement was largely underpinned by East Asia, where the consumption index rose from 60 to 80 over 2010–12 (figure 5.5). Consumption in South Asia and Sub-Saharan Africa hardly budged in those two years. Unsurprisingly, households in developed countries are very close to tier 5, reporting a consumption index of 96 in both 2010 and 2012. At the other end is Sub-Saharan Africa, where the consumption index stood at 26 in 2012. In that region, not only are many people not connected to the central grid, but consumption is low for those who are connected to the grid. South Asia reported a consumption index of 50 in 2012, higher than Sub-Saharan Africa but lower than every other region.

Data collection for the multitier frameworks

Data required for a multitier assessment of energy access can be obtained either through supply- or demand-side data. Most existing data derive from broader household surveys (such as the Living Standards Measurement Study, Demographic and Health Surveys, and Multiple Indicator Cluster Surveys), which collect some demand-side data on energy.

Supply-side data. Data collected from energy-solution providers (such as utilities, equipment manufacturers, and energy-access programs) to identify attributes of energy supply delivery to a target population are supply-side data. Assessments are based mainly on the specifications of delivered solutions (such as the capacity of a solar home system or the efficiency of a cookstove) or on characteristics of the energy supply as routinely reported by utilities (such as hours of supply per day or number of outages per week). Supply-side data are relatively easy and inexpensive to gather, because suppliers and utilities collect such data as a part of accounting for their regular operations.

Figure 5.5. **An approximate multitier index based on average consumption**



Source: Authors' calculations.

However, in many cases supply side data may not be collected accurately, reported regularly, or disclosed publicly by the utilities. Supply-side data also may not capture all attributes of energy. For example, it may not capture information about illegal connections, voltage problems, and safety concerns, whereas information about duration and reliability of supply may not be reported accurately and correctly by suppliers to avoid accountability for service quality. Supply-side sources also do not collect data on energy applications used by households, productive engagements, and community facilities—data required for disaggregate analysis. They also fail to capture important consumer characteristics such as income level (for assessing affordability) and use of multiple energy solutions. Similarly, cookstove manufacturers/providers may be unable to capture fuel stacking (multiple fuel use) or the time spent collecting fuel. Complementary demand-side research carried out through focus groups or small-sample surveys can round out supply-side information.

Demand-side data. Periodic demand-side surveys can capture the actual experience of users. Demand-side data on energy attributes are collected through end-user surveys—customized questionnaires for multitier analysis administered to households, productive engagements, and community facilities. While end-user surveys can provide insight into users' experience, they are limited by respondents' awareness, perceptions, and willingness to report and may suffer from biases, inaccuracies, and subjectivity. Some technical data can be better obtained by deploying sensor-based instrumentation to capture duration of supply, consumption, voltages, and disruptions for electricity, and indoor air quality and efficiency for stoves.

Pilot implementation—the example of Kinshasa

The multitier frameworks for household electricity and cooking have been tested alongside the associated survey instruments through pilot testing in selected areas of Kinshasa, Democratic Republic of Congo; Uganda; and selected districts in the Indian state of Bihar. The complete survey instrument, which also incorporates questions on productive engagements and community facilities, has been tested in some villages in Malawi. This pilot testing has validated the multitier frameworks and questionnaires and demonstrates that multitier measurement and analysis can analyze access deficiencies. The Kinshasa pilot supports a gap analysis to reveal access deficiencies and indicate approaches for alleviating them.[1]

Binary measurement based on grid connection information alone would indicate that 90 percent of the people in

Kinshasa have access to electricity, implying that an incremental access challenge of only 10 percent remains. But many streets of Kinshasa are dark most nights, and few households are unlimited in the range of appliances they can use; the multitier metric captures this with an electricity supply index of 30 on a scale of 0 to 100 (figure 5.6). It is clear households in the surveyed area have poor access to electricity despite a high grid-connectivity rate (close to 87 percent), while another three percent are connected through off-grid solutions. More than half (58 percent) of households occupy tiers 2 and 3, while another 41 percent are on tier 0 and 1, and only 1 percent occupy tiers 4 and 5.

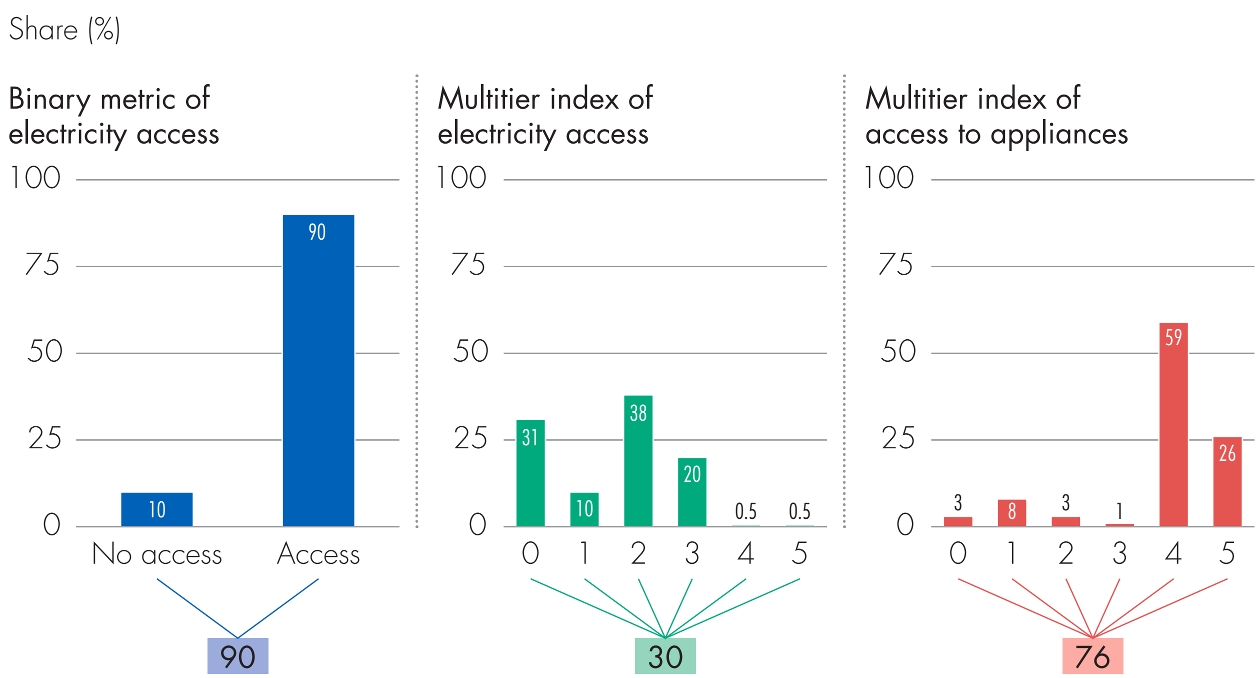
Based on reported ownership of appliances, an index of access to appliances similar to the index of access to electricity supply may be calculated. The tier framework used for this calculation is based on the highest tier of ownership of appliances, as shown in table A1.1. Using lighting, television, air circulation, or water heating requires access to electricity supply as well as the appliance itself. In Kinshasa, while people generally have access to appliances (index = 76), they do not have adequate access to electricity supply (index = 30). Figure 5.7 shows a dashboard of attributes for which these data were collected.

An attribute-wise analysis of data (figure 5.8) shows that nearly 87 percent of the households are connected to the grid. But nearly two-thirds of the grid-connected households get fewer than eight hours of supply each day, with a quarter receiving less than four hours (see figure 5.7). Low voltage is another endemic problem reported by nearly 85 percent of the grid-connected households. Across the four districts of the city, including urban and peri-urban areas, low and fluctuating voltage affected most consumers. About half the households reported reliability problems as well.

At the prevailing tariffs, almost all households in the sample can afford consumption of at least 1 kWh per day. The survey did not identify any significant incidence of illegal connections, though such cases may not have been disclosed by respondents.

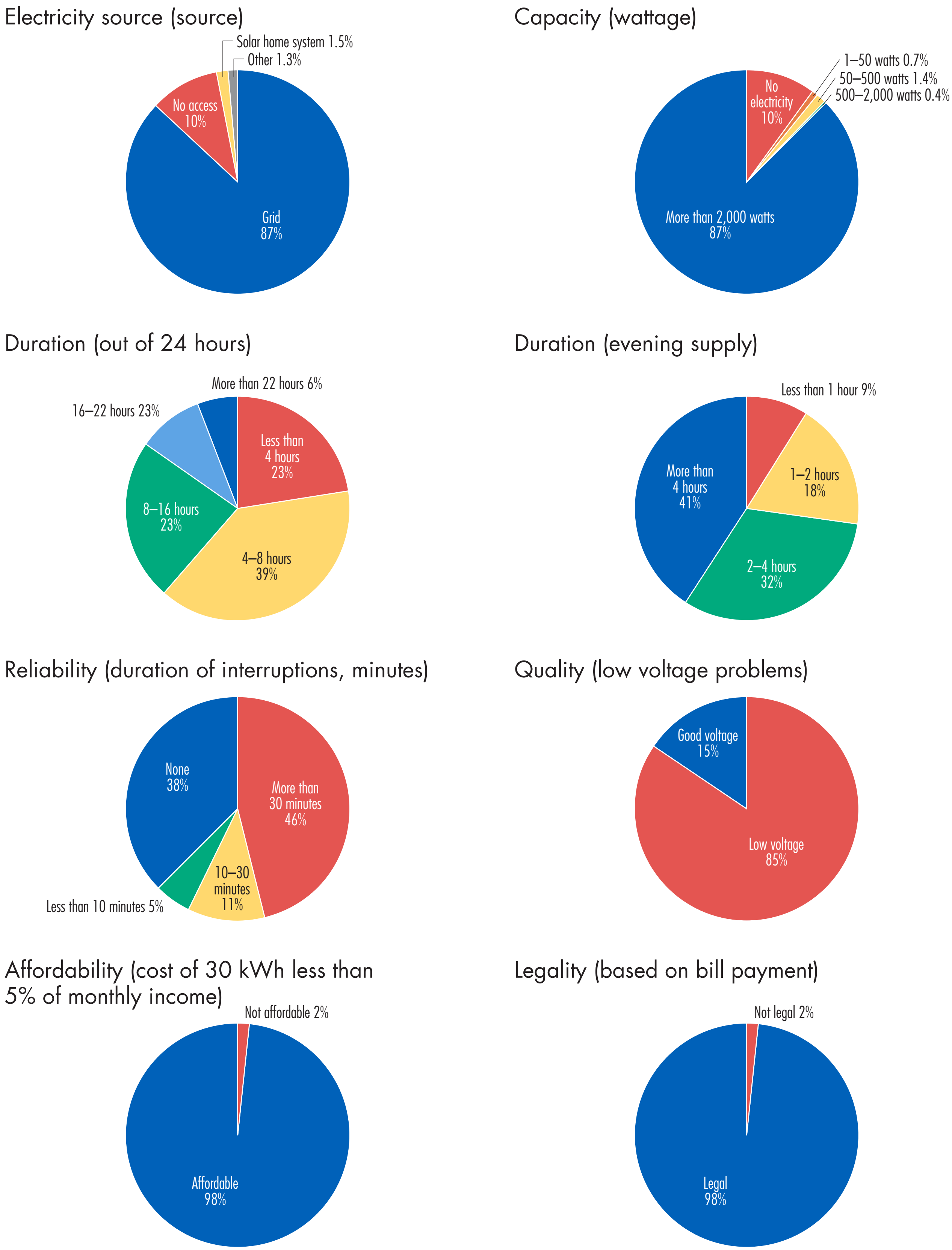
One response to these revealed deficiencies could be as straightforward as a transformer renovation program and better load management to improve voltage and reliability. But nearly 30 percent of households receive fewer than four hours of supply or fewer than two hours in the evening. This problem could be resolved by systematic supply rationing so that all grid-connected households receive at

Figure 5.6. **Binary versus multitier access measurements, Kinshasa**



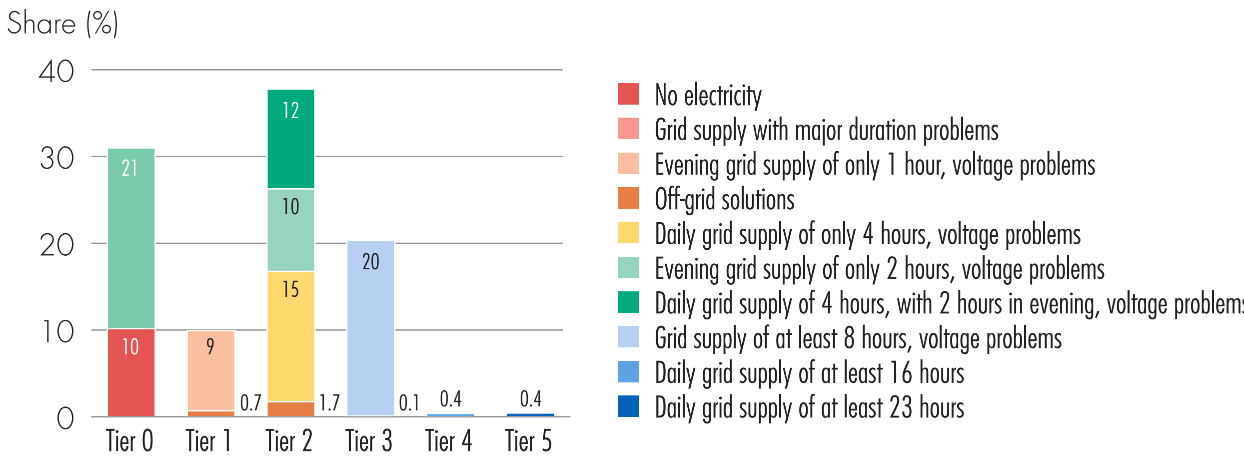
Source: Prepared by authors.

Figure 5.7. **Dashboard of attributes**



Source: Prepared by authors.

Figure 5.8. **Gap analysis for energy access, Kinshasa**



Source: Prepared by authors.

least four hours daily, including two in the evening, but additional generation and transmission capacity to augment peak supplies could also be needed. Households that are not connected to the grid at all can be serviced with solar lanterns, solar home systems, or new grid connections.

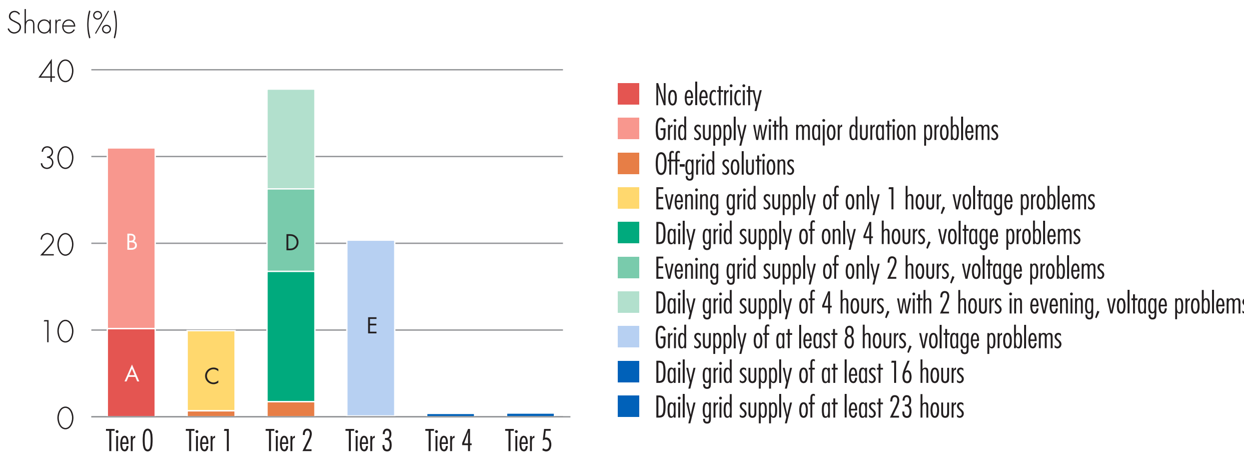
These findings can be used to conduct a gap analysis examining the reasons households are stuck at lower tiers and indicating interventions to address them. Five sets of households (labeled as A–E in figure 5.9) can be identified on the lower access tiers according to deficiencies. The first set contains 10 percent of the households: those not connected to the central grid and lacking an off-grid supply of electricity. The second contains 21 percent of households held at tier 0 despite being connected to the grid, because they receive fewer than four hours of supply each day or less than one hour in the evening (major duration problems). A third set is the nine percent of all households that receive at least four hours daily supply and one hour of evening supply. Thirty-seven percent of households constitute the fourth set and are held at tier 2 due to duration and quality issues (voltage problems). The fifth set is made up of the 20 percent of households that face voltage and reliability problems but do receive 8–16 hours of daily supply.

Assuming (only for the purpose of illustration) that the survey sample is representative of the city of Kinshasa, the investment needs for citywide tier enhancement can be broadly estimated (see table, figure 5.9). For all households, based on underlying cost assumptions, estimates range from \$9.3 million for minimum tier 1 (off-grid) access to \$1.2 billion for citywide tier 5 access. For tiers 2–5, \$50 million is needed for new grid connections to the unconnected 10 percent; \$5 million is needed for strengthening the load dispatch systems to ensure that supply is evenly distributed throughout the day, including evening hours; and \$174 million is needed for transformer upgrade and distribution strengthening to address voltage and reliability issues. Additional generation capacity of an estimated 60–970 MW would be needed in the area under different target-tier scenarios.

Medium-term data agenda for the multitier framework

Use of the multitier framework for measuring energy access is constrained by a scarcity of data, most of which come from existing omnibus household surveys (mentioned above). *GTF 2013* proposed implementing the multitier framework over the medium term by alleviating these data constraints. It proposed developing standardized survey instruments, conducting periodic household energy surveys, analyzing data to assess specific aspects of energy access, and putting such data in the public domain. Apart from the data needs of multitier tracking, such surveys could serve multiple stakeholders, including governments, regulators, utilities, project developers, civil society organizations, developmental agencies, financial institutions, appliance manufacturers, international programs, and academia. Detailed frameworks and survey instruments have been prepared, piloted, and validated, strengthening data availability and supporting wider use of multitier measurement as envisaged in *GTF 2013*.

Figure 5.9. **Access to household electricity: Estimating investment needs**



	Number of house-holds	**Targeted minimum tier of access**				
		Tier 1	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**
A	100,000	Solar lanterns at $30 per lantern Total cost: $3 million	Solar home systems at $200 per system Total cost: $20 million *or* grid connections at $500 per connection Cost: $50 million *and* add 15 megawatts capacity Cost: $15 million Total cost: $65 million	Grid connections at $500 per connection Cost: $50 million *and* add 30 megawatts capacity to ensure evening supply Cost: $30 million Total cost: $80 million	Grid connections at $500 per connection Cost: $50 million *and* add 70 megawatts capacity to ensure evening supply Cost: $70 million Total cost: $120 million	Grid connections at $500 per connection Cost: $50 million *and* add 100 megawatts capacity to ensure evening supply Cost: $100 million Total cost: $150 million
B	210,000	Solar lanterns at $30 per lantern Total cost: $6.3 million	Improve load dispatch to ensure evening supply Cost: $5 million *and* add 31.5 megawatts capacity to ensure evening supply Cost: $31.5 million Total cost: $36.5 million	Improve load dispatch to ensure evening supply Cost: $5 million *and* add 63 megawatts capacity Cost: $63 million Total cost: $68 million	Improve load dispatch to ensure evening supply Cost: $5 million *and* add 147 megawatts capacity Cost: $147 million *and* transformer upgrade for quality and reliability at $200 per connection Cost: $42 million Total cost: $194 million	Improve Load Dispatch to ensure evening supply Cost: $5 million *and* add 210 megawatts capacity Cost: $210 million *and* transformer upgrade for quality and reliability at $200 per connection Cost: $42 million Total cost: $257 million

(continued)

Figure 5.9. **Access to household electricity: Estimating investment needs**

	Number of households	Targeted minimum tier of access				
		Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
C	90,000		Add 13.5 megawatts capacity to ensure evening supply Cost: $13.5 million Total cost: $18.5 million	Add 27 megawatts capacity Cost: $27 million Total cost: $27 million	Add 63 megawatts capacity Cost: $63 million *and* transformer upgrade for quality and reliability at $200 per connection Cost: $18 million Total cost: $81 million	Add 90 megawatts capacity Cost: $90 million *and* transformer upgrade for quality and reliability at $200 per connection Cost: $18 million Total cost: $108 million
D	370,000			Add 111 megawatts capacity Cost: $111 million Total cost: $111 million	Add 259 megawatts capacity Cost: $259 million *and* transformer upgrade for quality and reliability at $200 per connection Cost: $74 million Total cost: $333 million	Add 370 megawatts capacity Cost: $370 million *and* transformer upgrade for quality and reliability at $200 per connection Cost: $75 million Total cost: $444 million
E	200,000				Add 140 megawatts capacity Cost: $140 million *and* transformer upgrade for quality and reliability at $200 per connection Cost: $40 million Total cost: $180 million	Add 200 megawatts capacity Cost: $200 million *and* transformer upgrade for quality and reliability at $200 per connection Cost: $40 million Total cost: $240 million
Investment		$9.3 million	$75 or 120 million	$286 million	$908 million	$1,200 million
New grid capacity (megawatts)		0	60	231	679	970
Power needed during peak hours (watts)		*3*	*150*	*500 (300 in short term)*	*1,200 (700 in short term)*	*2,000 (1,000 in short term)*

Setting the multitier baseline for SE4All requires a global household survey covering at least the top 30–40 energy access–deficit countries and representing about 80–90 percent of the binary energy access–deficit population. This global survey can be centrally administered through a suitable survey agency with outreach in these countries. Due to the likely high costs of implementation, the survey questionnaire and sample size in each country will be small. Therefore, a simplified version of the framework and survey instrument would be used for the survey, concentrating on only the most important attributes to be assessed. The simplified framework can also be used for country- or project-level surveys where resource constraints do not allow use of the comprehensive multitier framework. A protocol for energy access survey designs that can be used in different contexts (such as omnibus surveys, national household energy surveys, project level surveys, and global energy surveys) is also being developed by the World Bank/ESMAP team.

The global baseline survey and funding are planned for 2015. Similar surveys should be organized every three or four years for tracking progress under SE4All. Data from the baseline survey can be supplemented with information from other sources for countries included in the survey. During the years between global surveys, energy access information can be updated through information from omnibus surveys, country-level surveys, and project/program surveys, as well as supply-side data from projects, programs, companies, and government agencies. Such updates can be reconciled with the next global or country survey.

Methodological improvements in energy efficiency

Energy efficiency is the ratio between useful outputs and associated energy inputs. Rigorous measurement of this relationship is possible only at the level of individual technologies and processes, and only a handful of countries have the data for such measurement. Even where data are available, they result in hundreds of indicators—too many to readily be used to summarize a national situation.

For these reasons, energy intensity (typically measured as energy consumed per dollar of GDP) has traditionally been used as a proxy for energy efficiency in international comparisons. It is an imperfect proxy, because it is affected not only by changes in the efficiency of underlying processes, but also by other factors such as changes in the volume and sectoral structure of GDP. These concerns can partly be resolved by statistical decomposition methods that allow removal of confounding effects. Also, complementing national energy intensity indicators with sectoral ones helps provide a more nuanced picture of energy efficiency.

Calculating energy intensity metrics requires suitable measures for GDP and energy consumption. GDP can be expressed at market exchange rates or at PPP. Market exchange rate measures may undervalue output in emerging economies due to lower domestic price levels, thus overstating energy intensity. But PPP measures are not as readily available, because the associated correction factors are updated only every five years. (Annex 2 details the data and methods used by GTF 2015 for energy efficiency indicators and analysis.)

Energy consumption can be measured in primary or final energy terms. While it may make sense to use primary energy for highly aggregated energy intensity measures (relative to GDP), because it captures intensity in both production and use of energy, it is less meaningful when measuring energy intensity at sectoral or subsectoral level, where final energy consumption is more relevant.

Based on a careful analysis of these issues and of global data constraints, the SE4All *GTF* for energy efficiency:

- Relies primarily on energy intensity indicators
- Uses PPP measures for GDP and sectoral value added (see annex 2 for a discussion of added value)
- Uses primary energy supply for national indicators and final energy consumption for sectoral indicators
- Complements those indicators with energy intensity of supply and of the major demand sectors where data are available
- Employs decomposition analysis to strip out confounding effects on energy intensity

Global tracking data for 1990–2010 have been compiled from energy balances published by the IEA and UN for 181 countries. These are complemented by data on national and sectoral value added from the World Bank's World Development Indicators (WDIs). Looking ahead, wide international efforts are needed to improve the availability of energy input and output metrics across the main economic sectors to allow for more meaningful measures of energy efficiency (box 5.1).

The next section explains the use of energy intensity to represent macro trends in energy efficiency, including a description of the decomposition analysis typically used to arrive at a more precise measure of energy efficiency in energy consumption. The following section outlines how to move toward the *GTF 2013* goals for improved tracking of energy performance—broken down by industry, household, services, and transport sectors—by setting out some of the indicators, underlying data, and resources needed.

Box 5.1. **A global pathway to better energy efficiency indicators**

Many national and international entities already participate in building capacity to better track energy performance. But national governments have the ultimate responsibility and authority to collect and publicly report the statistics needed to construct energy efficiency indicators.

International organizations (such as the IEA and the International Partnership for Energy Efficiency Cooperation) and regional organizations (such as the Asia Pacific Energy Research Center, Eurostat, the Latin American Energy Organization, the Regional Center for Renewable Energy and Energy Efficiency in Cairo, the Economic Community of West African States, and the Economic Research Institute for ASEAN and East Asia) contribute to developing and promulgating common, standardized approaches to energy efficiency indicators. The IEA collects official, standardized energy efficiency indicator data from its member countries.

The UN Statistics Division (UNSD) could engage more, but the resources available for this are limited. Other organizations that should expand their participation include the following:

- Other UN agencies: the UN Environment Programme (UNEP), the UN Development Program, and the UN Industrial Development Organization
- The UN Foundation
- International financial institutions: World Bank, the Inter-American Development Bank, the Asian Development Bank, the African Development Bank, the European Bank for Reconstruction and Development, the European Investment Bank
- Bilateral development agencies
- SE4All Hubs: the Copenhagen Center for Energy Efficiency, capacity-building and training hubs, regional hubs
- Energy and industry associations such as the World Energy Council and the World Business Council for Sustainable Development
- Expert and academic organizations
- Nongovernmental and civil society organizations

Identifying a need for a particular indicator and establishing a national program to fill the need takes years, even if capable organizations and budgetary resources already exist. For an international initiative like SE4All to produce detailed tracking indicators requires sufficient information from a plurality of the most important countries, participation by the above organizations, and enough resources, accompanied by a mandate to sustain reporting activity.

To proceed, a consensus-building process is needed to enable stakeholders to come to decisions—first, about which indicators to develop for meaningful, global tracking, and second, in which countries to pursue them. This would include prioritizing data needed from countries, identifying organizations to perform capacity-building, and securing technical assistance to support surveying and reporting capacities. This process would also identify resource needs, including investment capital, and possible sources.

Meeting the SE4All energy efficiency goal will mean capturing as much economically viable long-term efficiency potential as possible. To better track these efforts, resources must be directed toward improving energy efficiency indicators for sectors and activities that, worldwide, have the greatest potential for contributing to that goal. The process should prioritize key sectors, segments, and activities in the biggest energy-consuming countries.

Energy intensity as a proxy for tracking energy efficiency

The first edition of the *GTF* examined available methods and data for tracking energy efficiency. As stated, data constraints and methodological challenges preclude energy efficiency from being distilled into a single number at national or global level. Largely for this reason, primary energy intensity was selected as the "headline" indicator (that is, a proxy) for tracking global progress toward the SE4All efficiency goal. Energy intensity in the *GTF* is measured in PPP to facilitate a fair comparison across countries with disparate levels of economic development.

Energy intensity is not the same as energy efficiency, but is influenced by changes in energy efficiency, as well as by other factors including weather variability, exchange rate fluctuations, shifts in economic structure, and changes in the mix of primary energy sources. Yet energy intensity has the advantages of being, first, readily available and second, able to reveal high-level energy consumption developments in simple terms. It must be interpreted with care, of course, to avoid using it inappropriately as an equivalent to physical energy efficiency (such as the amount of fuel required to generate a kWh of electricity or to ship a ton of freight one kilometer).

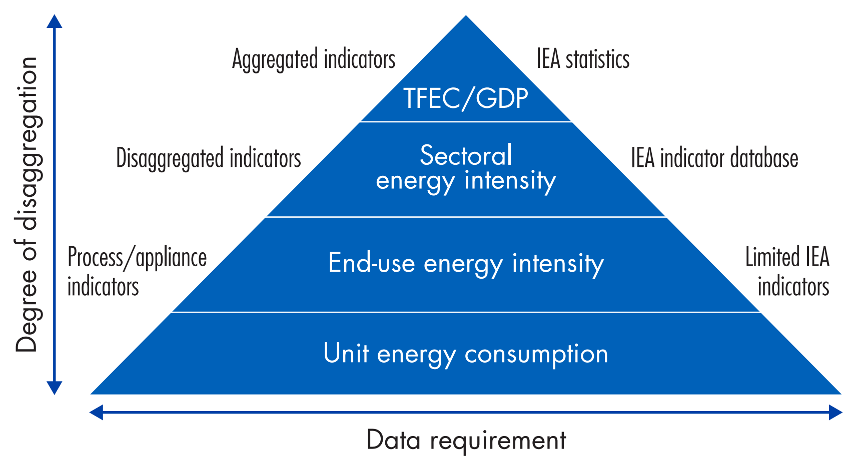
As discussed in *GTF 2013,* more-detailed (that is, disaggregated) information is required to understand the key drivers of energy consumption trends and to create policies to influence these trends. The IEA has developed an "indicators pyramid," a hierarchy of energy indicators from most to least detailed, to conceptualize the relation between disaggregation and data requirements (figure 5.10).

At the top of the pyramid are aggregate data, typically from national accounts, energy balances, and censuses of the sort used in calculating energy intensity values. At lower levels are more disaggregated data on energy consumption and resulting physical and economic outputs. Their scope is typically much narrower, sometimes pertaining to a single facility or building, and they are obtained through surveys and direct measurements. But only limited progress has been made in improving the global data sets needed for the sectoral indicators identified as medium-term priorities in *GTF 2013.*

Energy intensity may fluctuate from year to year owing to short-term influences. Tracking the compound annual growth rate (CAGR) over a long period reduces this fluctuation. Except where noted, *GTF 2015* measures energy intensity CAGR from 1990, the base year in the first *GTF,* to 2012, the latest year for which energy consumption data are available for all countries in the analysis.

The values for the indicators reported in this volume are not precisely the same as in *GTF 2013,* mainly due to the adoption of 2011 values for GDP in PPP terms.[2] Moreover,

Figure 5.10. **Energy efficiency indicators pyramid**



Source: IEA 2014a.

Note: TFC is total final consumption.

as a normal practice, national statistical agencies update historical data series in light of more accurate data and improved methods. Also, a somewhat different set of countries was adopted for the energy intensity decomposition analysis. Although the derived intensities, CAGRs, and other indicators are not precisely comparable to those previously published, the results and implications for 1990–2010 remain unchanged.

Analytic decomposition of energy intensity trends can help exclude the influence of at least a portion of structural changes and help clarify the role of efficiency in reducing energy consumption. The same fundamental decomposition method used in the first edition was applied, but steps were taken to more precisely capture effects in the transport and household sectors. In *GTF 2013*, decomposition analysis highlighted the role of energy efficiency by estimating and excluding the impact on energy demand of changes in levels of activity and economic structure. For this edition, commercial and public services, transport, and households were treated separately (they were aggregated into a single large sector in *GTF 2013*).

For services, intensity remains expressed in economic terms—energy consumed per unit of value added. For transport, energy intensity is treated separately for the passenger and freight subsectors, as they have very different characteristics. For households, intensity is represented as energy consumption per household.

The intensity component that results from this analysis is not entirely due to changes in physical energy efficiencies (such as kWh per m^2 of residential and commercial floor area or MJ per ton of cement manufactured), but it produces an indicator that is closely aligned with efficiency at an aggregate level. Table 5.5 updates the framework in *GTF 2013* for indicators to track energy efficiency in the immediate and medium terms, globally and at country level.

Better tracking of energy efficiency performance—activity-level indicators and decomposition analysis[3]

To better track improvements in efficiency, it is important to understand the sectors and activities that most influence energy demand. Quite a few countries have made headway in building more-detailed end-use data and energy efficiency indicators for understanding past trends, assessing future savings, and enhancing policy efforts. Some of the key subsectors and activities in tracking overall energy

Table 5.5. **Immediate and medium-term tracking, global and country levels**

Tracking level	Immediate	Medium term
Global	National and energy intensity indicators for overall economy, end-use sectors (industry, agriculture, services, transport, and households), and efficiency or loss-rate indicators for electricity and gas supply. Apply Divisia decomposition method (see annex 2) to track underlying energy efficiency component of energy intensity.	Improve integration of data systems on energy use and associated output and activity indicators (such as passenger and freight traffic volumes, number and size of households, commercial and residential floor space, and water supply volumes). Improve and widen scope of data on specific energy consumption (physical energy efficiency) of energy-intensive products, equipment and appliances, as well as energy supply, including oil refining and district heating.
Country	Convene relevant national and international organizations to plan collection and tracking of key indicators in selected countries, demonstrating the approach.	Strengthen country-level information systems and capability to collect data on sectoral and subsectoral intensities and process efficiencies. Improve data on country-level outputs and activities. Improve data on energy efficiency objectives, policies, investments, and institutional frameworks. Track key indicators in selected countries.

Source: GTF 2013.

efficiency at national (or global) level are shown in figure 5.11 As no single indicator can provide a comprehensive basis for policymaking, several indicators are typically needed for each sector.

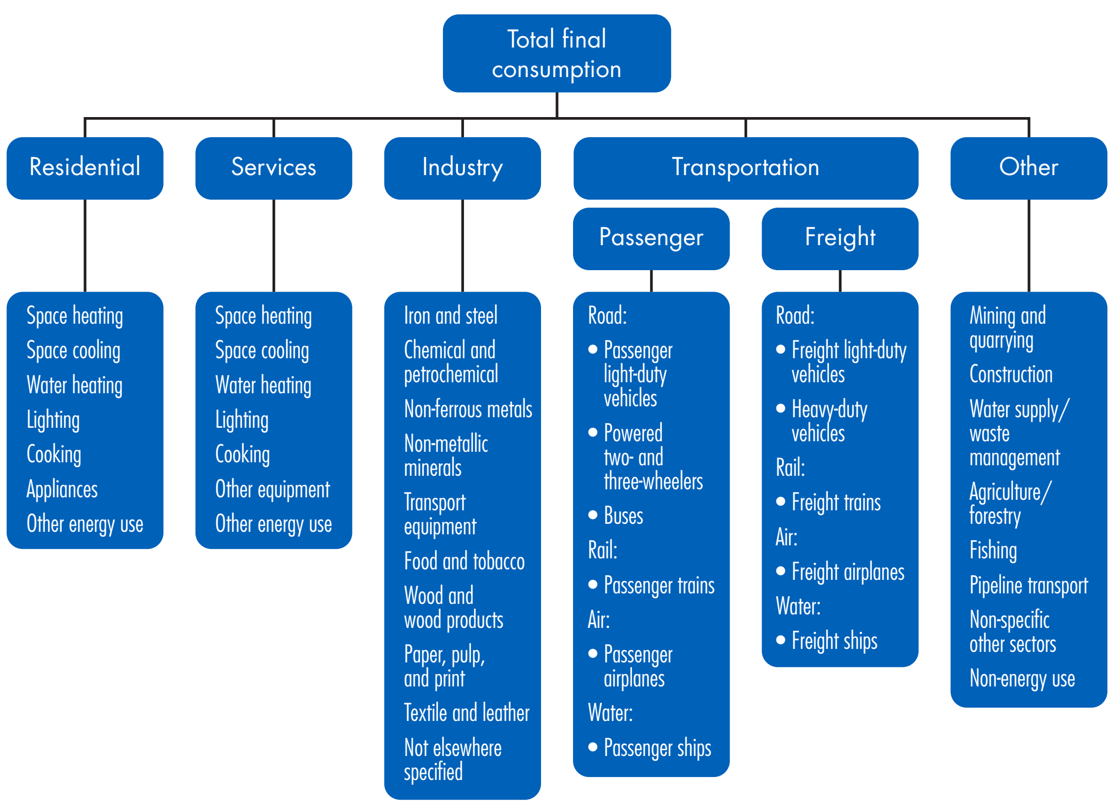
Decomposition analysis, if done at sectoral level with finely disaggregated indicators, can be very informative. Results of such analysis follows for countries with consistent time series data on final energy demand and appropriate activities for the industry, household (residential), services, and transport sectors (IEA 2014b). A logarithmic mean Divisia index decomposition method was employed.

Industry

Industry is the largest energy-consuming sector and crucial to raising energy efficiency globally, but is also heterogeneous, complex, and not always clearly differentiated from other sectors.[4] At aggregate level, industry is the sector where the most information is available. In many countries, energy balances are disaggregated at International Standard Industrial Classification (ISIC) two-digit level (UNSD 2008). This classification system can be used to assess the role of industry in the economy as a whole, but is insufficient to evaluate trends within the sector. For example, in China, energy per unit of value added decreased by 65 percent over 1990–2000 and 15 percent over 2000–10—yet subsectoral data indicate that energy-intensive industries have increased their share of total industrial production and so had an upward impact on energy intensity despite the improvement in overall energy efficiency.

The relations between energy and output and its variations among countries are influenced by several factors, such as the average age of plants (since newer plants are usually more efficient than older ones); maintenance practices; mix and quality of energy (such as fuel heat value or reliability of power supply); the quality and specifications of raw materials and products; processes and technologies used; and structure of the sector.

Figure 5.11. **Disaggregation of sectors, subsectors, and end uses in IEA energy indicators approach**



Source: IEA 2014a.

Note: Services include the commercial and public service sectors.

Indicators by industrial subsector help illuminate where and how energy is used and where the greatest potential for reducing energy consumption may lie. In-depth indicators should be developed to help policies to reduce consumption to target this potential, given the importance of the industrial subsector, potential savings from the subsector (assessable by analysis of best available technologies or benchmarking), and data availability (or potential to obtain data).

Industry has more potential sources of information on indicators than any other sector. Not only do industrial facilities, particularly large ones, tend to measure and to keep records related to their energy-using activities, but multiple official, commercial (industry-association), and unofficial channels exist for reporting and sharing such information and for tracking transactions with other entities.

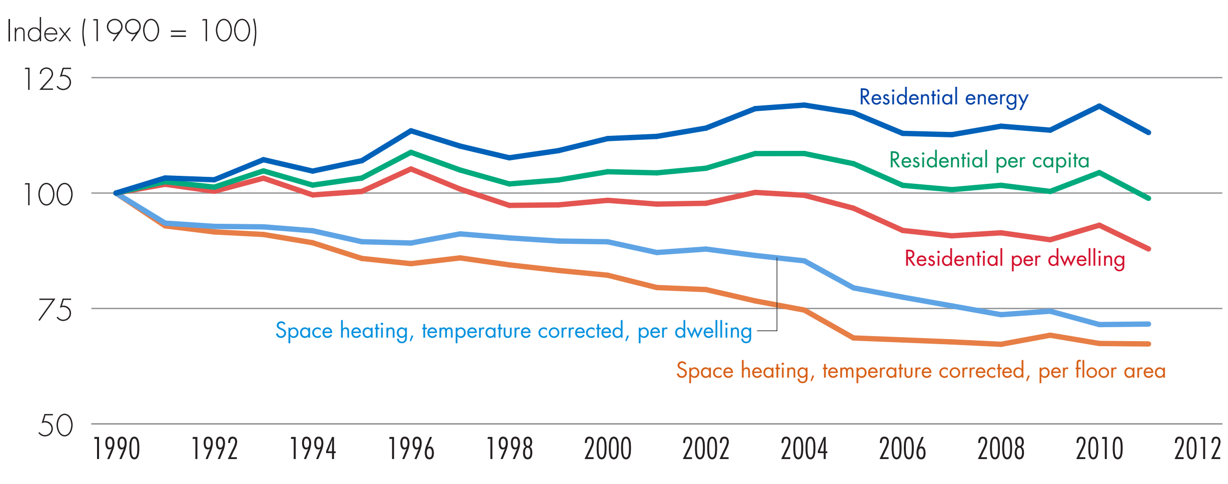
Households

Energy consumption trends in the residential sector are driven by a wide range of factors, including overall energy efficiency improvements, changes in population, energy mix, urbanization, number of occupied dwellings, dwelling size, dwelling type, building characteristics (including age profile), inhabitants per household, income level and growth, consumer preferences and behavior, energy availability, climatic conditions, appliances and equipment penetration rate, and standards.

Two main activity variables explain trends in residential energy consumption: floor area (for space heating and space cooling) and number of occupied dwellings (for water heating, lighting, and appliances). Underlying gradually rising energy consumption are a flat trend in energy per capita and falling trends in energy per dwelling, space heating energy consumption per dwelling, and space heating energy consumption per unit floor area—all implying a rise in demand due to an increasing population and shrinking household size (figure 5.12).

The analytical framework to develop energy efficiency indicators in the residential sector may be defined in numerous ways. The expected level of detail depends greatly on the information available and on the country or regional situation. In countries where most of the building stock is one type of building, a breakdown between different dwelling types may not be a priority. But this distinction is important for countries like Canada, where single-family dwellings account for 55 percent of the total and multi-family dwellings 30 percent—and single-family dwellings use twice as much energy as do apartments. Similarly, a distinction between rural and urban households may be essential if there are notable differences in fuel supply and equipment. Where enough data are available, the decomposition of space heating per capita can reveal important information on the drivers of change in energy consumption. For instance, in most Organisation for Economic Co-operation and Development (OECD) countries, increasingly fewer occupants and larger homes tend to drive up energy demand, but this is frequently offset by falling end-use conversion losses and rising efficiency of space heating systems.

Figure 5.12. **Residential energy indicators**



Source: IEA database (2015).

Except for information collected by energy utilities, data on household energy use and corresponding activities can be hard to obtain. Household surveys and administrative sources can fill this gap, but models need to adapt to accommodate this often noncomparable data. Internet sources offer an opportunity to bring down the cost of gathering data in some categories (box 5.2).

Services

End uses in public and commercial services include a huge variety of activities, including space heating, cooling and ventilation, water heating, indoor and outdoor lighting, commercial appliances, and medical and office equipment. The main activity indicator is value added, as higher levels of economic activity lead to increases in employment and stocks of buildings and equipment, both of which raise demand for energy services. Additional influences are climate, floor area, building type and age, maturity of an economy, building energy management, and technical energy efficiency.

Services are less energy-intensive than industry and transport but demand is growing, and the sector has the lowest information availability of the four. In many countries' energy balances, it is a residual. Better indicators require countries to more accurately measure energy consumption and to collect and estimate data on key indicators, like total floor area, with surveys and models.

Given the difficulty in obtaining information at even the most aggregate level, a first step may be to develop indicators on end use. Understanding which end use is most important may reveal the largest potential for energy reduction. For example, if 60 percent of energy is used for space heating, policies to improve the efficiency of building envelopes and heating equipment would be a priority.

The driving forces of services energy consumption are very much a function of the development status of commercial activities. In developing countries, services may be less mature than industry. Indeed, without a good-quality

Box 5.2. **Addressing the data challenge: Appliance sector**

Deficiencies in data-collection capacity are perennial obstacles to developing and maintaining the accurate and current data sets needed to derive energy efficiency indicators, but information and communications technologies are opening up new possibilities.

One approach with strong near-term potential is web crawling to create product databases for the growing number of countries where online shopping for consumer appliances and other energy-consuming equipment is common. In countries where appliances are also tested and labeled, such real- time market statistics can be compared with energy consumption and product class information to build single-product indicators. Combined with other information, such as sales and retirement of equipment, sectorwide indicators can be developed for higher-level tracking.

Such techniques could be applied in developing countries that have robust appliance markets and thriving e-commerce channels, including China, India, Mexico, South Africa, and Brazil. According to IEA data, these five countries accounted for 32 percent of global electricity consumption in 2012 and 61 percent of electricity use among non-OECD countries, from where virtually all future net increases in energy demand are expected to come. Appliance energy databases in just these few countries would greatly improve the collective ability to measure progress in boosting appliance efficiency by estimating average energy consumption per appliance—the IEA's recommended indicator (IEA 2014a).

Harvesting information from the Internet is the core of the "Appliance Data Access" approach developed by CLASP (Center for Law and Social Policy), Lawrence Berkeley National Laboratory, and the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative and demonstrated in concept in 2013 (Katzman et al. 2013). The method is now being tested in SEAD-funded pilot projects in Mexico and South Africa to establish its applicability in developing country markets.

Source: Lawrence Berkeley National Laboratory.

supply it is difficult for the sector to develop, given its reliance on electricity.

Transport

Efforts are required to produce indicators in more countries and to build toward global scale. Data collection is costly, so countries should consider their needs and prioritize activities before undertaking the multiyear process of building and sustaining the expertise and institutions it needs.

The transport sector includes the movement of people and goods by the transport modes of road, rail, water, and air.[5] Energy consumption in the passenger and freight transport segments is driven by different factors that should be (but rarely are) treated separately. Passenger transport by road, for example, can be subdivided by vehicle size into two- and three-wheelers, passenger light duty vehicles, and buses. Trends in passenger transport energy are influenced by population and density, land-use patterns, transport infrastructure, travel patterns, income, vehicle ownership, vehicle occupancy, consumer preferences and behavior, and average fuel economy. The main activity variables are passenger-kilometers (pkm) and vehicle-kilometers (vkm).

Because national energy balances seldom separate transport consumption into passenger and freight segments, their shares must be estimated top down (such as through energy consumption questionnaires) and bottom up (such as from vehicle stock, mileage, and fuel

Table 5.6. **Transport sector indicators**

Indicator	Coverage	Energy data	Activity data
Passenger transport			
Passenger transport energy consumption per GDP/capita	Overall	Total passenger transport energy consumption	GDP, population
Passenger transport energy consumption per vehicle-kilometer	Overall	Total passenger transport energy consumption	Total passenger vkm
	Mode/vehicle type	Energy consumption by mode/vehicle type	Vkm by mode/vehicle type
Passenger transport energy consumption per passenger -kilometer	Overall	Total passenger transport energy consumption	Total pkm
	Mode/vehicle type	Energy consumption by mode/vehicle type	Pkm by mode/vehicle type
Freight transport			
Freight transport energy consumption per GDP	Overall	Total freight transport energy consumption	GDP
Freight transport energy consumption per vehicle-kilometer	Overall	Total freight transport energy consumption	Total freight vkm
	Mode/vehicle type	Energy consumption by mode/vehicle type	Vkm by mode/vehicle type
Freight transport energy consumption per ton-kilometer	Overall	Total freight transport energy consumption	Total tkm
	Mode/vehicle type	Energy consumption by mode/vehicle type	Tkm by mode/vehicle type

Source: IEA 2014a.

economy). But producing a consistent analysis usually requires modeling, drawing inputs from a range of sources—each of which may cover only part of the picture—to produce a uniform output. For most countries, gathering better data on road transport is a priority, given its high share of passenger and freight transport and the dependence of most countries on oil imports. The level of disaggregation varies among countries: in Asia, for instance, two- and three-wheelers are very common modes of transport, while they represent a marginal share in Nordic countries. Table 5.6 lists common indicators for passenger and freight transport and table 5.7 gives examples of sources and methods.

None of this improvement will come easily or free of cost. Great effort and expense went into setting up the IEA's Mobility Model (see chapter 3), and much the same can be said of similar systems established by national and international industry associations for industrial energy efficiency. For efficiency indicators in the transport and other sectors to be tracked globally over the long term, there must be a concerted effort sustainably financed by organizations and countries (see box 5.1).

The purpose of pursuing energy efficiency is, of course, not to raise efficiency for its own sake but to contribute toward a wide range of welfare-enhancing outcomes. Capturing these outcomes also requires indicators, some of them closely aligned with the data described above and some in other areas entirely (box 5.3). Tracking these is important for quantifying the impacts of efficiency changes and for attracting resources.

Table 5.7. **Examples of sources and methods for better transport sector energy efficiency indicators**

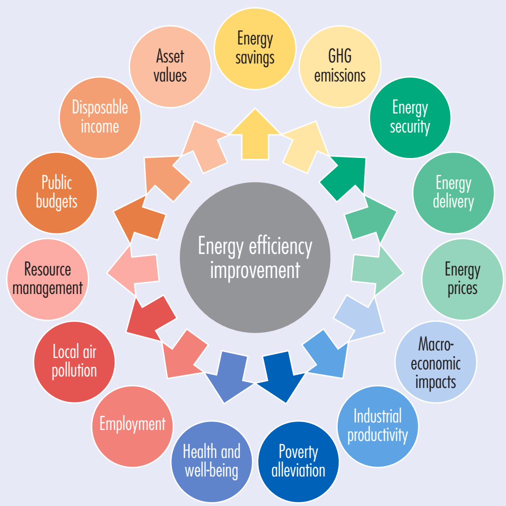
Data	Source	Methodology
Energy consumption data		
Total transport	National energy balance National energy statistics	Administrative sources Modeling
By subsector	National energy balance National energy statistics	Administrative sources Mobility surveys modeling
By segment		Mobility surveys modeling
By vehicle type		Mobility surveys modeling
Activity data		
GDP, population	National statistics offices	Administrative sources
Vehicle-km (vkm)	Vehicle registers/roadworthiness testing services Inspecting organizations Municipalities/transport authorities National and international databases Transport ministries	Measurements: odometer readings Measurements: road traffic count Administrative sources Mobility surveys modeling
Passenger-km (pkm)	National and international databases Transport ministries	Administrative sources mobility surveys
Ton-km (tkm)	National and international databases Transport ministries	Administrative sources Mobility surveys, freight surveys
Vehicle stocks	Statistics offices Manufacturers National and international databases Vehicle registers	Administrative sources Administrative sources/measurements
Fuel economy	Manufacturers	Administrative source modeling

Source: IEA 2014a.

Box 5.3. Multiple benefits of energy efficiency: Contributions to productivity, growth, and access

Energy efficiency contributes to sustainability of energy systems, prosperity across income levels, social development, gender equality, and environmental sustainability. For developing countries, reducing energy demand is neither a priority nor the primary role of efficiency. Rather, efficiency cost-effectively enhances the development impact, through multiple benefits, of every unit of energy consumed in pursuing the well-being of their citizens (figure).

Multiple benefits of energy efficiency



Source: IEA 2014c.

One set of these multiple benefits—interactions between energy and water consumption—is discussed in chapter 6. Another is expanding energy access, enabling countries to supply more energy services through existing or proposed energy infrastructure by allowing newly connected customers to do more with the little power they often receive. Investments in sectors producing energy-efficient goods and services can, with enhanced productivity, boost economic output and drive up employment. For energy-consuming countries, reduced energy demand can lower spending on imports and exposure to price volatility, while raising economic competitiveness and improving trade balances.

Furthermore, efficiency can increase affordability of energy services (such as lighting, heating, and refrigeration) by reducing per-unit costs. Energy efficiency measures on the supply side can cut local pollution from energy supply processes and allow developing countries to pursue economic growth while limiting carbon emissions, especially coupled with increases in low- or zero-carbon energy supplies. Finally, by reducing infrastructure needs, efficiency reduces energy assets exposed to extreme weather events, boosting the resilience of energy systems.

Source: IEA 2014c; authors.

Methodological improvements in tracking renewable energy share

Methodological challenges

GTF 2013 proposed a methodology for measuring and tracking global progress against the SE4All objective in RE. It also provided a tracking framework encompassing the immediate and medium term and global/country levels (table 5.8). The *GTF 2013* methodology was to measure the contribution of renewables on the basis of final energy consumption excluding non-energy uses of fossil fuels (such as for producing plastics and chemicals), or total final energy consumption (TFEC). (Annex 3A details the methodology and steps to calculate the RE share indicator.)

During the preparation of GTF 2013, participant organizations discussed the advantages and disadvantages of measuring and tracking the objective at the primary or at the final energy level. Ultimately, the group selected measurement of final energy, a decision that reached widespread consensus during a formal international peer review and consultation process. Measurement at the level of primary energy underrepresents the contribution of renewables due to arbitrary assumptions regarding conversion efficiencies applied to fossil-fuel, nuclear, and RE options. The share of RE is higher when measured at the level of final consumption despite the fact that transmission and distribution losses need to be considered (box 5.4).

Table 5.8. **Tracking framework for SE4All RE objective**

Tracking level	Immediate	Medium term
Global	• Total final energy consumption (petajoules) • Electricity (megawatts and gigawatt-hours) • 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 cost • Investment level	• Improved definitions and data associated with bioenergy • RE in distributed generation, RE in off-grid (including micro-grids) • Harmonized approach to target setting
Country	None.	• Development of consistent targets expressed as RE share of TFEC by 2030 • Support and implementation of revised information-gathering systems aimed at improving coverage of the full range of RE technologies and uses in selected countries • Piloting of application of sustainability criteria in bioenergy in selected countries • Development of sustainability criteria for other RE technologies and piloting their application in selected countries

Source: *GTF 2013.*

GTF 2013 recommended that, given the need to develop a comprehensive and comparable analysis at a global level, IEA energy statistics—complemented with UN data for the smaller non-OECD countries—be used as the basis for tracking progress toward the objective.

GTF 2013 also identified actions to take in response to data gaps and methodological problems to track more accurately the SE4All objective, including the following:

- Improve inadequate definitions and data collection in bioenergy
- Better distinguish between modern and traditional uses of solid biofuels[6]
- Improve inadequate definitions and data collection in distributed RE power generation for grid-connected and off-grid systems
- Implement or promote a harmonized approach to target setting

Sustainability in bioenergy—complexity and a pragmatic measuring approach

GTF 2013 noted the complexity and difficulty of integrating sustainability into RE tracking.

The most common sustainability concept contains three dimensions: environmental, economic, and social. This concept originated in the work of the World Commission of Environment and Development (commonly known as the Brundtland Commission), which published the politically influential report *Our Common Future* in 1987. This three-dimensional model is commonly referred to as the "triple bottom line." The concept was further refined with the Triangle of Sustainable Development (Munasinghe and Cruz 1995). This version not only stylizes the equal weight of the sustainability dimensions but also underscores the complexity of balancing the three and managing potential trade-offs in policy and investment decisions (figure 5.13).

When the three SE4All objectives are examined through an integrated perspective that considers such trade-offs

Box 5.4. **Measuring and tracking renewable energy at the final level of the energy balance**

Noncombustible RE sources sometimes require a conversion to their primary energy equivalent to express their energy content at supply level. This conversion is often based on a set of assumptions unique to the energy balance methodology chosen (physical content, direct equivalent, substation, and so on). Monitoring at final energy consumption level removes the influence of such assumptions and allows a comparison of sources used to meet final energy demand.

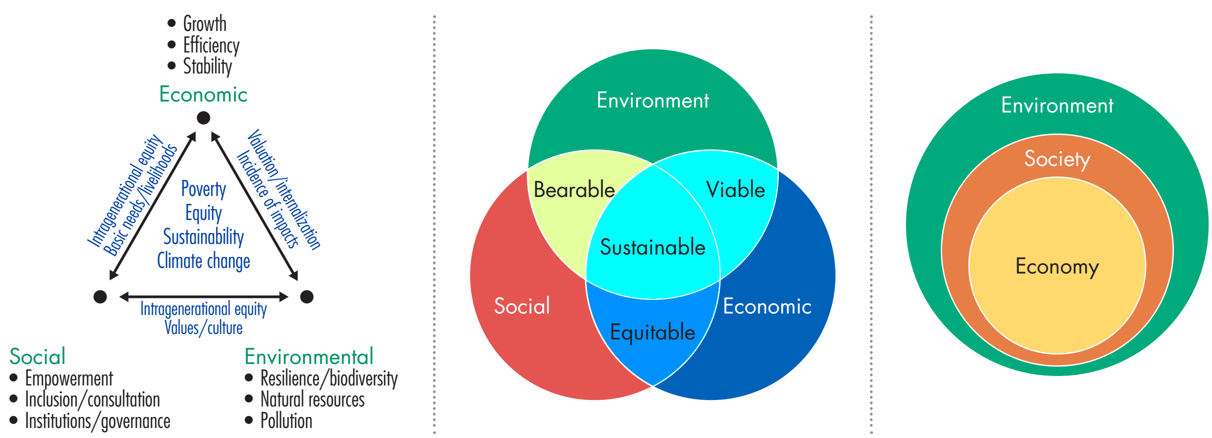
Within the TFEC figures, heat and electricity are reported directly in the form ready for consumption. Although other primary energy sources (such as fossil fuels and bioenergy used for heating in the residential sector) are still reported by fuel content, "final energy" best represents the energy in the forms familiar to end users.

Comparison of primary and final energy consumption methodologies

	RE contribution to global energy supply or consumption in exajoules (%)			
	Primary energy supply			Final energy consumption
Percentage renewables in global energy mix	Physical content method	Direct equivalent method	Substitution method	
2010	69 (13)	68 (13)	91 (17)	61 (18)

Source: *GTF 2013.*

Figure 5.13. **Conceptualization of "sustainability" and "sustainable development"**



Sources: Triangle, Munasinghe 1992; variations prepared by authors.

and synergies, sustainability concerns become obvious. These synergies can occur among the SE4All objectives, as well as between them and other development sectors (chapter 6). But it is not just for making decisions about trade-offs or promoting synergies and co-benefits that good governance and institutional capacity are increasingly regarded as important factors for giving sustainability concrete form. Without good governance and institutional capacity, the prerequisite stakeholder dialogue and decision making are hardly achievable at all.

Measuring—let alone tracking—sustainability in any development sector is undoubtedly difficult, and energy is not different, particularly if one limits measurement to quantifiable metrics. Yet monitoring progress in sustainable energy development can be eased when semiquantitative and qualitative indicators are used, including proxies such as the degree of implementation of good practices and stakeholders' opinions. We now illustrate a possible pathway to sustainability for bioenergy before moving on to the specific issue of how to quantify traditional use of solid biofuels. Because bioenergy is probably the most complicated type of RE for measuring sustainability, the following steps could be applied to other types of RE.

Measuring sustainability of bioenergy

Given the complex and multifaceted character of bioenergy, its sustainability is context specific. Experience has shown that it is useful to start from a broadly agreed-upon framework for action, which for bioenergy exists in the shape of, first, the sustainability principles of the Roundtable on Sustainable Biomaterials (to which promoters of sustainable bioenergy must commit); and second, the indicators for sustainable bioenergy developed by the Global Bioenergy Partnership (GBEP). These indicators list the aspects that must be considered in assessing the sustainability of bioenergy development. (Box 5.5 describes GBEP; annex 3B lists the indicators and provides lessons learned from preliminary testing of these indicators.)

The issues surrounding quantifiable indicators often relate to the lack of adequate and reliable data, and, when they exist, the frequently inadequate capacity of national, regional, or institutional decision makers to analyze them when they concern complex topics such as bioenergy.

The Food and Agriculture Organization of the United Nations (FAO) has begun work on energy efficiency and the use of wood energy in agrifood chains, but much more work and support is needed.

For example, measuring greenhouse gas (GHG) emissions has received much attention in recent years as a proxy indicator for energy sustainability. This is primarily carried out through life cycle assessments of energy resources, and there is now sufficient knowledge, agreement on protocols, and standardization regarding how to undertake life cycle assessments on RE, including bioenergy, to consider tracking energy systems' GHG emissions.[7] But consensus is yet to be reached on important issues such as the impacts of indirect land use change on the GHG balance of bioenergy and the overall GHG impact of using forest-based bioenergy. For sustainability assessments and tracking that include more than GHG emissions alone, systematic and reliable quantitative data are needed. The scarcity of these data remains a key bottleneck.

Because not all sustainability aspects can be readily assessed with the numerical data to hand, a pragmatic approach for regularly assessing progress of the sustainable development of bioenergy—a precondition for tracking—could rely on a mix of proxy, country-level, semiquantitative, and qualitative measurements.

Percentage of land use following established good practice (semiquantitative). Good practices that reduce the risks of unsustainable use and that harness opportunities in bioenergy are known—see, for instance, FAO 2013a and 2013b. Examples include outgrower programs, sustainable agriculture intensification, or integrated food energy systems. These quantitative assessments should be combined with a rapid assessment of the quality of implementation. The definition of good practice could be translated into performance indicators, which are often easier and cheaper to measure than quantifiable indicators. The FAO has proposed including the assessment of good practice performance in measuring GBEP indicators as part of the current discussions on lessons learned (see annex 3B).

The amount of land used under certification schemes (semiquantitative). One should bear in mind the large differences in the quality of sustainable bioenergy certification programs. Most are weak in assessing the impact of bioenergy on food security, which is why this measurement can only be seen as a proxy for sustainability. Moreover, the forestry sector offers two lessons. First, a balanced approach to objectives needs to be sought, because if the bar is too high this could create a disincentive for even attempting to reach it, while a bar too low might see companies that already perform well being certified, thus failing to provide a meaningful impact of certification. Second, there is interest in combining "pass/fail" indicators with those indicators monitoring progress. The latter could be applied to good practice implementation.

This pathway could be discussed within the SE4All high impact opportunity (HIO) activities on Sustainable Bioenergy, which has partners from nongovernmental organizations, the private sector, and international organizations. HIOs serve as a collective forum for stakeholders working

Box 5.5. **Global Bioenergy Partnership: Working together for sustainable development**

In 2005, the G8 group of countries agreed to support wider, cost effective biomass and biofuels deployment through the establishment of the GBEP, launched at the 14th session of the Commission on Sustainable Development in May 2006. Since then GBEP has received support and a renewed mandate from the G8 and the G20, and a growing number of developed and developing countries have joined. As of January 2015, GBEP partners and observers numbered 50 governments and 26 international organizations.

In 2011, GBEP members agreed on 24 indicators for assessing and monitoring national bioenergy sustainability. This agreement marked the first global, government-level consensus on a set of voluntary, science-based indicators whose main purpose is to inform policymakers about the sustainability of the bioenergy sector in their countries and to guide them to policies fostering sustainable development.

Measured over time, the indicators will show progress against a nationally defined sustainable development path. The GBEP indicators address the environmental, social, and economic pillars of this path and cover the production and use of all solid, liquid, and gaseous biofuels for heating and cooking, power generation, and transport.

Each indicator has its own multipage methodology sheet providing all the information needed to evaluate it (FAO 2011, 2014a, 2014b). By January 2015, the indicators for bioenergy were either being implemented or had been implemented in around a dozen countries.

Pillars		
Environmental	*Social*	*Economic*
Themes		
GBEP considers the following themes relevant, and these guided the development of indicators under this pillar:		
Greenhouse gas emissions, productive capacity of the land and ecosystems, air quality, water availability, use efficiency and quality, biological diversity, land-use change, including indirect effects	Price and supply of a national food basket, access to land, water and other natural resources, labor conditions, rural and social development, access to energy, human health and safety	Resource availability and use efficiencies in bioenergy production, conversion, distribution and end-use, economic development, economic viability and competitiveness of bioenergy, access to technology and technological capabilities, energy security/diversification of sources and supply, energy security/infrastructure and logistics for distribution and use
Indicators		
1. Life-cycle GHG emissions	9. Allocation and tenure of land for new bioenergy production	17. Productivity
2. Soil quality	10. Price and supply of a national food basket	18. Net energy balance
3. Harvest levels of wood resources	11. Change in income	19. Gross value added
4. Emissions of non-GHG air pollutants, including air toxics	12. Jobs in the bioenergy sector	20. Change in consumption of fossil fuels and traditional use of biomass
5. Water use and efficiency	13. Change in unpaid time spent by women and children collecting biomass	21. Training and re-qualification of the workforce
6. Water quality	14. Bioenergy used to expand access to modern energy services	22. Energy diversity
7. Biological diversity in the landscape	15. Change in mortality and burden of disease attributable to indoor smoke	23. Infrastructure and logistics for distribution of bioenergy
8. Land use and land-use change related to bioenergy feedstock production	16. Incidence of occupational injury, illness and fatalities	24. Capacity and flexibility of use of bioenergy

Source: FAO 2011, 2014a, 2014b.

on various high impact initiatives to advance the SE4All objectives.

Qualitative data. Most data would be sourced through primary stakeholders' opinions, for example through questionnaires recording opinions on how the bioenergy sector has performed as a whole. One aspect of qualitative indicators is that they require a comparison with previous periods to record change, rather than making absolute assessments. An optimal assessment would require involvement of all stakeholders through multi-stakeholder consultations.

Labor conditions (qualitative). Labor is commonly part of a bioenergy production system, as in agricultural or forestry production. In forest certification systems, labor conditions are generally part of the sustainability assessment (such as whether certain minimum labor standards have been met, relative to benefits provided).

Defining traditional use of solid biofuels

Bioenergy suffers from definitional problems, especially what constitutes "traditional" use of biomass, and the extent to which such use meets sustainability criteria.

The 2010 *World Energy Outlook (WEO)* defines traditional use of solid biofuel as the consumption of wood, charcoal, agricultural residues, and animal dung for cooking and heating (IEA 2014a). This definition is also used by the 2014 *Medium Term Renewable Energy Market Report* (IEA 2014d): "Traditional biomass use refers to the use of fuelwood, animal dung, and agricultural residues in simple stoves with very low combustion efficiencies. Traditional biomass use is estimated here—in line with the methodology used in the IEA *WEO 2010*—as the use of solid biomass in the residential sector of non-OECD countries, excluding countries in non-OECD Europe and Eurasia." But this assumption does not take into account either the traditional use of solid biofuel that continues in OECD countries (such as for heating in rural homes in open fireplaces) or the efficient use of solid biofuels in non-OECD countries (as in well-designed cookstoves or other appliances).

It is unclear to what extent solid biofuels used traditionally are produced or used unsustainably, due to lack of data. One recent attempt to quantify the proportion of wood fuel (that is, firewood and charcoal) that is used in a nonrenewable or unsustainable way, based on a spatially explicit assessment and using a sample of 90 pan-tropical countries (all developing economies; box 5.6), suggests that the share of solid biofuels used in an unsustainable way is 4–5 percent of global TFEC (Bailis et al. 2015). This estimate is much lower than the 9.7 percent estimated in this report for year 2012, based on the assumption that all solid biofuels consumed by the residential sector of developing economies go toward traditional use and that this use is unsustainable (see figure 4.2). Bailis et al. show that not all wood fuel used in the 90 studied countries is harvested and used unsustainably.

The Bailis (2015) approach provides a practical methodology to assess the fraction of woodfuel consumption harvested unsustainably and could eventually be adopted by SE4All measurement efforts. Given the often unclear and changing use of the term "traditional"—and in some cases the use of the term "modern"—it is important to develop and introduce better definitions for these two modes of biomass use and to improve measurements to better qualify and quantify the contribution of solid biofuels to TFEC.

Feasibility of measuring and tracking sustainability in bioenergy

Assessing and measuring sustainability are highly complex, and the periodic assessments required to track it will be even more so. With current knowledge and tools—and the capacity and funding limitations to be overcome in less developed economies—it is not yet possible to recommend periodic and global tracking. But many countries and stakeholders already use current tools and manage RE development sustainably.

In the case of bioenergy, there is broad consensus on the merits of a reference sustainability framework (that is, the principles of the Roundtable on Sustainable Biomaterials and the GBEP indicators). Sufficient knowledge and tools exist to guide decision makers and practitioners toward achieving a certain degree of sustainability on the most critical of the three sustainability dimensions. For instance, the FAO has developed a sustainable bioenergy support package providing tools for governments and operators/investors to carry out situational analysis, practices and policies to promote a better understanding of sustainability, and ways to monitor and evaluate performance at territorial and operations levels (FAO 2013c).

Existing methods and tools should be used in situations that merit sustainability analysis, especially those requiring a better understanding of trade-offs and synergies. Eventually, it is expected that global and country experiences

Box 5.6. **Assessing the fraction of nonrenewable biomass**

In their analysis of the fraction of nonrenewable biomass (fNRB), Bailis et al. (2015) present a spatially explicit snapshot of woodfuel supply and demand in the tropical regions where traditional woodfuel consumption is concentrated. They treat woodfuel demand as an exogenous factor derived from a mix of national and subnational studies supplemented by data from the FAO, IEA, and UN.

Woodfuel demand has subsistence and commercial components. Subsistence demand occurs primarily in rural areas, where people collect their own fuel within a few hours' nonmotorized travel of their homes. Commercial demand originates in urban and some densely populated rural areas and is typically supplied by motorized transport over much longer distances.

On the supply side, the analysis assumes that nearly all landscapes produce a measurable increment of woody biomass either as new growth or as regrowth from previous disturbances. If an area is harvested for woodfuel below the annual growth rate, woody biomass stocks are not depleted and harvesting is sustainable. But if annual harvesting exceeds incremental growth, it is unsustainable, leading to a decline of woody biomass, forest degradation, and net carbon emissions. One key question is whether by-products from land-use change are actually used as woodfuel, which is rarely known. The authors therefore explore two scenarios: one assuming they are, and one that they are not.

The study develops a map of supply–demand balance by estimating harvesting pressure, first from subsistence and then commercial harvesters. By combining woodshed (that is, woodfuel supply zone) mapping of commercial demand with localized supply–demand balances, the minimum quantity of nonrenewable biomass required to meet existing demand is defined. In this approach, it is assumed that woodfuel consumers manage their resources sustainably to the extent possible, so that unsustainable harvesting arises only after the sustainable supply in a given location has been fully exploited. Thus, minimum nonrenewable biomass indicates the degree to which a given region can sustainably meet woodfuel demand under ideal management.

But ideal management is unlikely, and so, to simulate suboptimal harvesting, it is assumed that harvesting sometimes exceeds sustainable levels in some areas even if the sustainable supply in an adjacent accessible area has not been fully exploited. To estimate the extent of this deviation, a proxy defined by the fraction of each country's forested area under formal management is used. From this an "expected" quantity of nonrenewable biomass, also expressed as a fraction of the total harvest (fNRB) is derived. Both minimum and expected nonrenewable biomass are expressed in absolute terms and as a fraction of the total harvest for a given region.

Source: Bailis et al. 2015.

Note: See http://www.wisdomprojects.net/global/index.asp for a description of woodshed mapping.

will lead to better measurements and a more practical tracking of the factors driving the most critical impacts on the environment, economy, or society.

Renewable energy power generation in grid-connected and off-grid systems

GTF 2013 emphasized the need to improve collection of data on distributed renewable power generation technologies in both grid-connected and off-grid (including mini-grid) systems. While data gaps in these segments do not appear to significantly affect the overall proportion of renewables within the current global energy mix, renewable generation technologies are expected to become more prominent.

The definitions of RE in grid-connected and off-grid configurations adopted by the IEA's Photovoltaic Power Systems Implementing Agreement (PVPS) are presented in box 5.7. (Note that these definitions are not consistent across all agencies and national entities that collect energy data.)

Box 5.7. **IEA PVPS definitions**

Off-grid systems

Off-grid systems provide electricity to households, villages, and commercial users not connected to the grid. In domestic applications, they provide electricity for lighting, refrigeration, and other low power load uses. They have been installed worldwide and are often the most appropriate technology to meet the energy demands of off-grid communities. In nondomestic uses, they provide power for a wide range of applications, such as telecommunication, water pumping, vaccine refrigeration, and navigational aids. In these applications, small amounts of electricity have a high value, making off-grid systems commercially cost competitive.

Mini-grids

A mini-grid is a stand-alone grid not connected to the main grid. Local energy producers can use mini-grids to provide electricity using distributed or centralized energy resources to manage local electricity supply and demand.

Grid-connected centralized systems

These systems fulfill the functions of centralized power stations. The power they deliver is not tied to a particular customer, and the system is not located specifically to perform functions on the electricity network other than supplying bulk power.

Grid-connected decentralized systems (distributed generation)

These systems provide power to a grid-connected customer or directly to the electricity network (at distribution voltage). Such systems may be on or integrated with the customer's premises, often on the demand side of the electricity meter. Unlike other forms of distributed generation, size is not a determining feature of these systems.

Source: IEA PVPS 2014.

Existing data on renewable energy

Global RE trends in off-grid configurations are only reported by the IEA for OECD and larger developing economies. Other sources provide data on the use of RE in mini-grids by country, but no organization consolidates these data globally.

Few agencies collect data on distributed generation, and most of that information is on photovoltaic (PV) installations. The IEA reports trends on decentralized PV applications from 1992 by type of system (on-grid versus off-grid, and centralized versus decentralized for on-grid systems). Bloomberg New Energy Finance reports annual growth of residential PV from 2000, tabulating data by system size. Only a few countries publish official disaggregated data on distributed generation.

Nor do consolidated global statistics exist on the number of installations or energy delivered by RE in off-grid configurations, including mini-grids. Some countries report data on mini-grid and off-grid markets, including Australia, Bangladesh, China, India, Indonesia, Morocco, and the United States (International Renewable Energy Agency [IRENA] 2014; 2015), and some international agencies report trends on some of the sources, technologies, or segments of rural and distributed generation markets (IEA PVPS 2014; IRENA 2014; World Bank 2012; IFC 2012).

Similarly, consolidated data of PV in off-grid systems for developing countries cover only a few countries, and there are no global data on RE in pico, micro, or mini-grids. (Annex 3C presents an analysis of trends in these areas based on existing data.)

The key constraint underlying this situation is that the survey tools used to collect national energy statistics rarely include modules or questions on the off-grid and distributed categories of RE use. Even when they do, definitions differ widely across agencies and in the literature, making global comparison and aggregation difficult.

Moving forward

Renewable grid-connected (centralized and decentralized) systems are relative straightforward to define, but renewable off-grid systems are less so due to the range of technologies and applications they incorporate. Indeed, there is no consistent categorization of renewable off-grid systems across agencies and data collection systems. Nor are there consistent indicators to differentiate, evaluate, compare, and aggregate data on renewable off-grid systems, including hybrid systems (IRENA 2015).

Renewable off-grid systems need to be characterized in a systematic way to allow comparing and aggregating applications and to provide a global perspective on scale of deployment. Categories of renewable off-grid systems should be consistent across application areas and resources. This will allow coherent assessment of what off-grid systems should be included in surveys and how they relate to each other. Questionnaires and surveys to collect statistics on energy balances should be modified to include modules on off-grid systems—particularly in countries with low access to electricity, where off-grid systems are more feasible and reliable.

IRENA has proposed a systematic categorization of off-grid applications (table 5.9) and developed a survey questionnaire to improve RE data collection for off-grid systems.[8]

A review of data collection and reporting methodologies for the above RE sources is needed to ensure that their share of energy consumption is accurately represented as their importance grows. But only a substantial and coordinated effort will resolve these issues and subsequently incorporate improved methodologies and conventions within the UN International Recommendations for Energy Statistics (IRES). Funding, as always, will be critical.

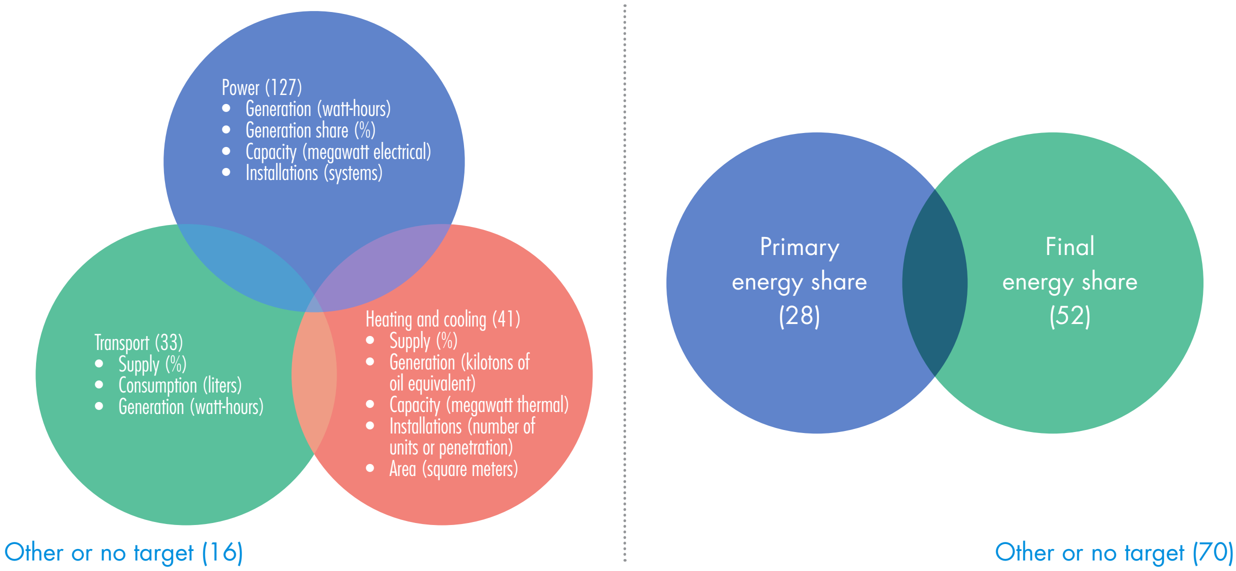
Target setting—principles for a harmonized approach

By early 2013, 144 countries had policy targets to promote RE deployment, up from 109 in 2010 (REN21 2014). But the different targets these countries introduced are difficult to aggregate for global-level tracking. RE targets include those focused on sectors (power generation, transport, and heating and cooling) and those based on primary or final energy (figure 5.14).

Table 5.9. **Proposed categorization of off-grid applications**

System	Stand-alone			Grids		
	DC		AC	AC/DC		AC
	Solar lighting kits	DC solar home systems	AC solar home systems; single-facility AC systems	Nano-grid, pico-grid	Micro-grid, mini-grid	Full-grid
Off-grid						
Application	Lighting	Lighting and appliances	Lighting and appliances	Lighting, appliances, emergency power	All uses	All uses
User	Residential, community	Residential, community	Community, commercial	Community, commercial	Community, commercial, industrial	—
Key component	Generation, storage, lighting, cell charger	Generation, storage, DC special appliances	Generation, storage, lighting, regular AC appliances; building wiring included but no distribution system	Generation + single-phase distribution	Generation + three-phase distribution + controller	Generation + three-phase distribution + transmission

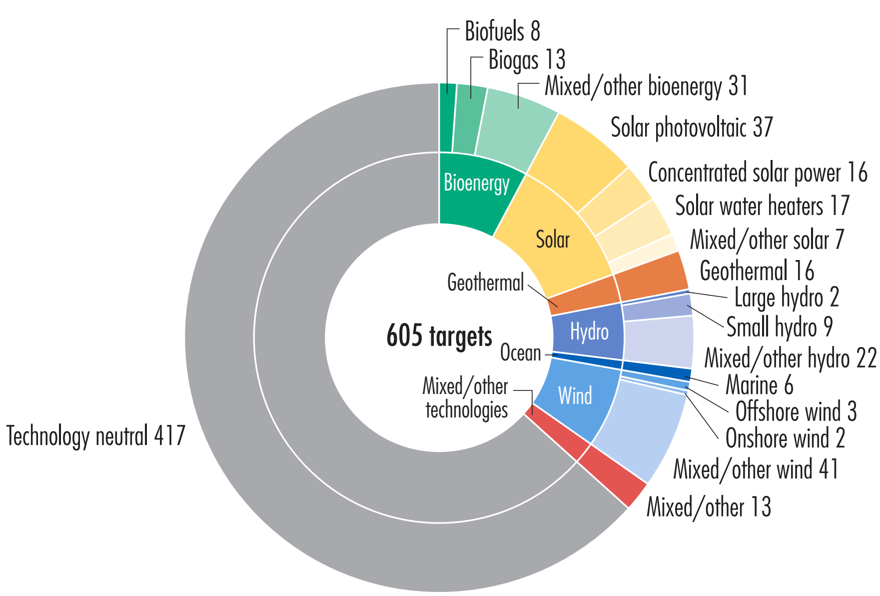
Figure 5.14. **Number of countries subscribed to different types of targets, 2013**



Source: Analysis based on data from REN21 2014.

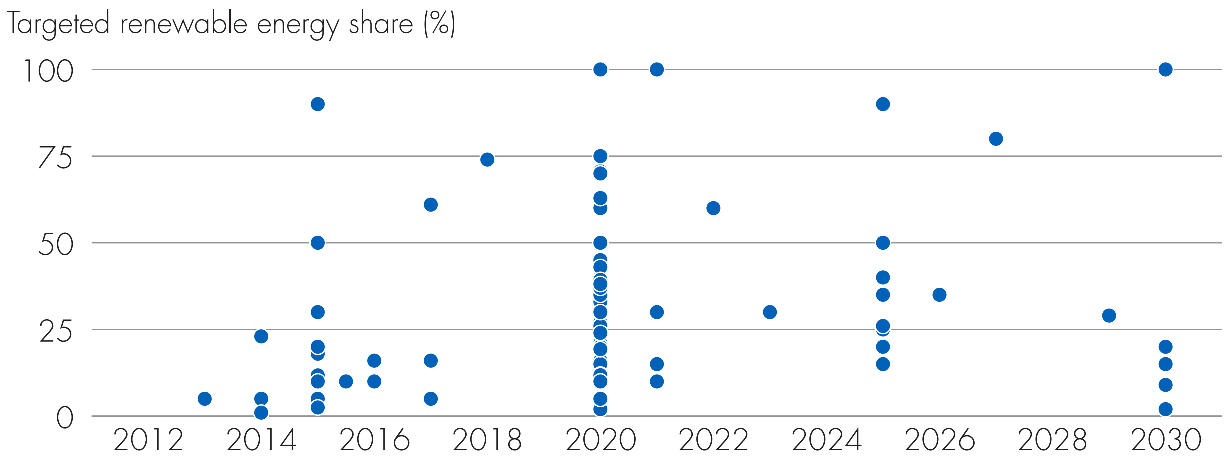
Note: Chart is based on a compilation of about 600 targets. Numbers in parentheses are numbers of countries. Targets that do not specify a sector but are measured in units relevant to that sector are allocated to that sector (such as MW_e to power generation and MW_{th} to heat generation).

Figure 5.15. **RE targets by technology**



Source: Data from REN21 (2014).

Figure 5.16. **Frequency of target year in electricity generation RE share targets**



Source: Data from REN21 (2014).

Targets related to the power sector, whether to actual generation, capacity, number of generation units, and so on, are most common and are in place in 127 countries (about 88 percent of countries with an RE target). Many countries have more than one type of target; for instance, 28 countries have a RE target in each of the transport, power, and heating/cooling sectors.

In total, there are about 605 RE targets. Most are technology neutral, although about 243 targets (40 percent) support a specific resource or technology (figure 5.15). More than 50 percent of targets are set for 2020, although other common target years are the half decade and decade—2015, 2025, and 2030 (figure 5.16). Targeted shares range widely, depending on countries' circumstances and commitment.

Global tracking requires converting this range of RE targets to a common metric, allowing an aggregate global target. Also desirable is promoting certain principles and design attributes for improving the robustness of the targets themselves. For the *GTF,* targets should be credible (balancing aspiration and realism, and mandatory); certain or stable (with no retroactive decisions to change the target); measurable and time-bound (that is, data allow tracking and a target year is set);[9] transparent (linked to policy, disclosed publicly); and actionable (accompanied by an action plan or strategy).

For better tracking progress toward the SE4All objectives, member states should complement their domestic targets with targets aligned with the SE4All objective in RE—percentage of RE in TFEC and the share of RE in electricity generation.

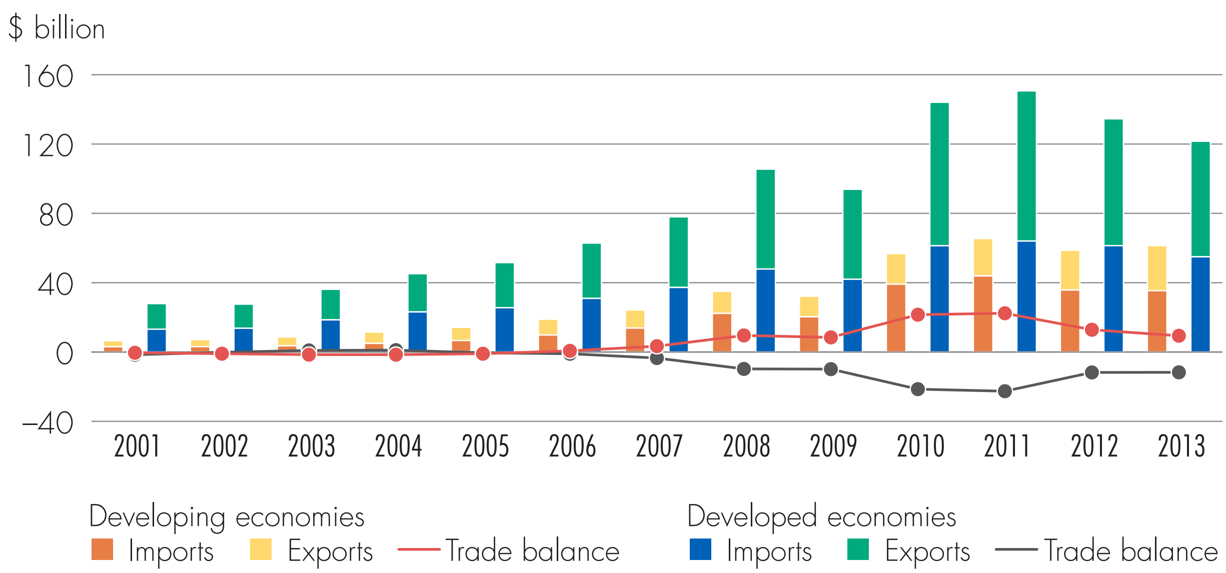
Access to technology and knowledge in sustainable energy

Achieving the SE4All objectives will require countries to adopt cutting-edge technologies in sustainable energy. Several indicators for which data are available can provide some perspective on their success: international trade in products used in sustainable energy; tariff and nontariff barriers to trade; and the number of engineering qualifications and scientific journal citations, which give a sense of capacity to absorb and apply technology. Other indicators are patenting and investment in research, development, and innovation, though both are concentrated in HICs and UMICs (see figures A4.2 and A4.3 in annex 4).

Trade in sustainable-energy products

A World Bank trade analysis considered a basket of 12 products used in sustainable energy (figure 5.17). Developing economies' trade in this product basket grew steeply in absolute terms in the decade 2001–11, though it has stabilized since. In 2013, trade in developing countries reached about half the trade volume in developed countries. China is responsible for 19 percent of the total global

Figure 5.17. **Balance of trade in 12 sustainable energy products, 2001–13**



Source: World International Trade Solutions database (World Bank 2014).

Note: The 12 products are solar PV, light emitting diodes (LEDs), small hydro turbines (capacity below 1 MW and 1–10 MW), wind turbines, biodiesel, insulation materials, fluorescent lamps, heat pumps, reversible heat pumps for air conditioning, electric vehicles, portable electric lamps, and parts of portable electric lamps. The product *photosensitive semiconductor device* (HS Code 854140) aggregates PV cells (whether or not assembled in modules or made up into panels) and LEDs.

trade for these products and for 56 percent of the trade among developing economies, mainly due to its large volume of solar PV exports. Developing economies became net exporters and developed economies net importers of these 12 products after 2007.

Though the value of trade registered for the selected basket of products in developing economies remains smaller than that of developed economies, a growing number of countries trade some of these products (tables 5.10–5.12). For instance, although low-income countries (LICs) and lower middle-income countries (LMICs) accounted for only about four percent of the global value of trade in solar PV/LEDs in 2013, 70–74 percent of countries in these income categories registered trade in this technology. Access to PV in LICs increased from two to 25 countries in 2001–13. But the proportions of LICs with trade activity in wind turbines and small hydro turbines (1–10 MW) in 2013 were very small, around nine percent and three percent respectively, and no LIC registered trade in biodiesel that year.

In energy efficiency, access to fluorescent discharge lamps (CFLs), insulation materials, and electric- and gas-powered vehicles was acceptable across income levels in 2013, with 85, 53, and 71 percent of LICs trading these products; again their contribution to the global value of trade was smaller than for high-income countries (HICs). The number of low-income countries trading heat pumps has increased gradually: in 2013, 38 percent of LICs and 58 percent of LMICs traded these technologies.

Portable electric lamps with their own source of energy serve as a good proxy for access to technology, as they are a direct substitute for kerosene lamps and other forms of traditional lighting. In 2013, 81 percent of all countries had access to this technology. From 2001 to 2013, 29 LICs and LMICs gained access to this type of lamp, while the number of such countries in the high-income group remained stable. But trade in parts for portable electric lamps tells a very different story, as in 2013 there were just 10 LICs and LMICs trading this product. This suggests that maintenance and repair of these lamps is constrained in low-income countries, which implies higher household energy expenditures.

The trade of small hydropower turbines is low across income groups, notably in LICs. They are a well-developed RE technology that can improve electricity access in rural areas, lower the unsustainable harvesting of solid biofuels,

Table 5.10. **Trade in products relevant to renewable energy by income group: Access and value, 2013**

Income group (number of countries)	Solar photovoltaic and LEDs HS Code 854140		Wind turbines HS Code 850231		Biodiesel HS Code 382600		Hydro turbines (1–10 MW) HS Code 841012	
	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)
Low income (34)	74	0.18	9	0.47	0	0.00	3	1.82
Lower middle income (50)	70	3.81	18	2.99	2	7.35	14	12.55
Upper middle income (55)	75	33.22	27	18.70	20	10.05	13	49.94
High income (75)	76	62.79	37	77.84	43	82.60	15	35.69
All (214)	74		26		21		12	
Total global trade value ($ billion)		**103.00**		**14.09**		**19.41**		**0.18**

Source: World Integrated Trade Solutions database (World Bank 2015b).

Note: The estimation of the percentage of countries with access to the technology considers only countries with a trade value above US$100,000. The percentage contribution to the total value of trade is based on total amount traded; a similar estimation based on trade as a percentage of GDP is provided in annex 3.

Table 5.11. **Trade in products relevant to energy efficiency by income group: Access and value, 2013**

(%, unless otherwise specified)

Income group (number of countries)	Reversible heat pumps for air conditioning HS Code 841581		Heat pumps HS Code 841861		Fluorescent discharge lamps (CFLs) HS Code 853931		Insulation HS Code 701939, 680610 & 680690		Electric- and gas-powered vehicles HS Code 870390	
	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)
Low income (34)	18	0.47	38	0.22	85	0.69	53	0.23	71	0.93
Lower middle income (50)	36	2.98	58	1.32	82	6.61	65	3.91	66	6.73
Upper middle income (55)	65	36.86	78	10.29	85	48.07	79	18.5	75	6.21
High income (75)	63	59.69	71	88.17	79	44.63	76	77.36	73	86.13
All (214)	50		64		82		70		71	
Total global trade value ($ billion)		**4.98**		**4.31**		**11.64**		**11.26**		**6.80**

Source: World Integrated Trade Solutions database (World Bank 2015b).

Note: The estimation of the percentage of countries with access to the technology considers only countries with a trade value above US$100,000. The percentage contribution to the total value of trade is based on total amount traded; a similar estimation based on trade as a percentage of GDP is provided in annex 3.

Table 5.12. **Trade in products relevant to energy access by income group: Access and value, 2013**

Income group (number of countries)	Portable electric lamps with their own source of energy HS Code 851310		Parts of portable electric lamps with their own source of energy HS Code 851390		Hydro turbines (<1 MW) HS Code 841011	
	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)	Access (% of countries)	Trade value (% of global total)
Low income (34)	88	0.18	12	0.92	0	1.16
Lower middle income (50)	82	3.81	12	6.01	12	8.20
Upper middle income (55)	84	33.22	29	30.04	13	26.28
High income (75)	75	62.79	43	63.03	15	64.35
All (214)	81		27		11	
Total global trade value ($ billion)		**6.99**		**0.15**		**0.18**

Source: World Integrated Trade Solutions database (World Bank 2015b).

Note: The estimation of the percentage of countries with access to the technology considers only countries with a trade value above US$100,000. The percentage contribution to the total value of trade is based on total amount traded; a similar estimation based on trade as a percentage of GDP is provided in annex 3.

and contribute to scaling up sustainable energy for all. But no more than three LICs and nine LMICs imported this key technology in 2013 (in both the 0–1 and 1–10 MW capacity ranges).[10]

Access to sustainable energy technology is the result of many factors—not just trade, but also energy demand, resource potential, market-formation policies, industrial policy (including manufacturing and local-content rules), customs and trade regulations, cost relative to other options, and access to affordable finance. Therefore, although trade data provide a good proxy for how the most sophisticated or needed products are crossing boundaries and reaching beneficiaries, the broader question of access to technologies requires all these factors to be considered in the analysis of access to technology, too.

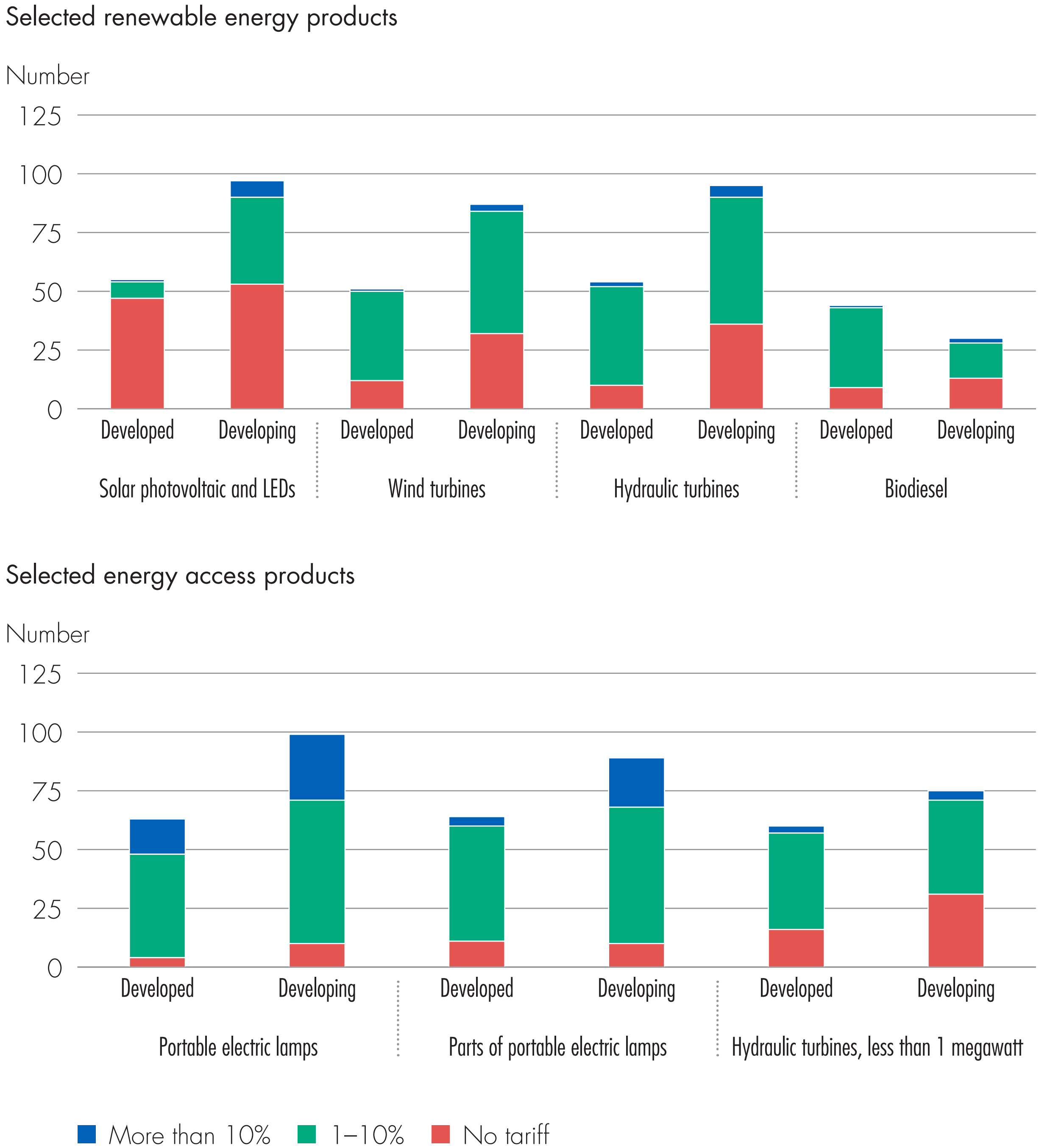
Tariff and nontariff barriers to trade

Access to sustainable energy technology is constrained by import taxes and other barriers to trade. For instance, 68 percent of LICs and 53 percent of LMICs apply an import tariff on small hydropower turbines, against only 20 percent of HICs (figure 5.18, top panel). Also, while only 15 percent of HICs impose import tariffs on solar PV, 48 percent of upper middle-income countries (UMICs), 40 percent of LMICs, and 50 percent of LICs apply them.[11] Notably, 45 percent of Sub-Saharan African countries and 50 percent of South Asian countries apply an import tariff on the technology, versus none in North America.

Among the 12 products relevant to sustainable energy selected for the analysis, 89 percent of developing countries apply import tariffs on portable electric lamps and about 73 percent on small turbines (figure 5.18, bottom panel).

Other nontariff measures are applied to imports that affect the trade of sustainable energy products. Most developed countries impose financial measures and contingent trade protective measures.[12] But developing economies use multiple measures, including licenses or permits to import, quality requirements, inspections, price controls, and others. Procedural obstacles in developing economies may also make it difficult for businesses to comply with nontariff measures. Reducing tariff and nontariff barriers requires special attention from policymakers in developing economies.

Figure 5.18. **Number of countries with import tariffs on selected technologies**



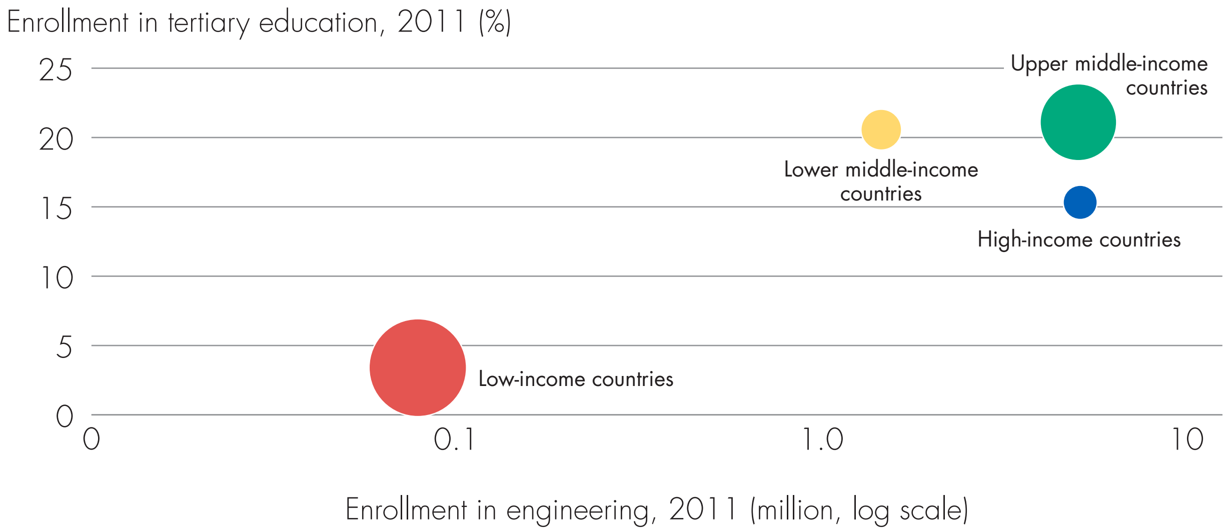
Source: World International Trade Solutions database (World Bank 2014).

Absorbing and applying technology

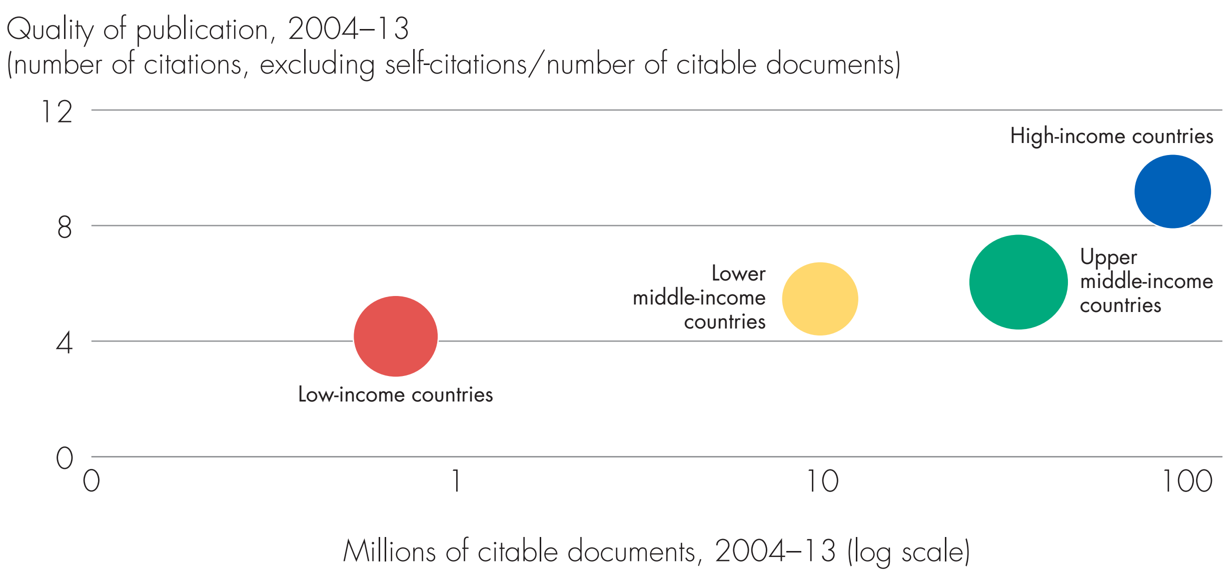
The transfer, absorption, and adaptation of technology by a country is constrained by the technical and commercial capacity of its institutions and companies, as well as the skills held by its white- and blue-collar workers. The enrollment rate in engineering, manufacturing, and construction programs in tertiary education is much lower in LICs than in UMICs, LMICs, and HICs. Similarly, the volume and quality of publications is lower in less developed economies (figure 5.19).[13] A review of the value

Figure 5.19. **Technical knowledge in clean energy**

Enrollment in engineering, manufacturing, and construction programs



Volume and quality (citations) of publications in renewable energy



Source: UNESCO Institute for Statistics (upper figure); SCImago Journal and Country Rank (lower figure).

Note: Size of bubble reflects compound annual growth rate (CAGR) of enrollment in engineering, 2007–11 (upper figure) and CAGR of number of citable documents, 2004–13 (lower figure).

chain for RE products reveals that local services play a key role during the various phases of project development, including in engineer-procure-construct, balance of system, and operation and maintenance (see table A4.2 in annex 4). Workforce development is therefore critical to the scale-up of sustainable energy in developing economies.

Promisingly, trade of RE products among developing economies, including core products of solar, wind, hydropower, and solid biofuel technologies, grew at 26.7 percent over 2004–11, against 9.7 percent globally (UNEP 2014). This growth has been largely driven by China and other countries in East and Southeast Asia. But developing countries, in particular LICs, will need support to access the key sustainable energy technologies. They also need to strengthen their science and technology infrastructures; create laboratory facilities, including prototyping and other innovation infrastructure; and build capacity.

Many measures can be introduced to accelerate adoption of clean and RE technologies, including market formation policies and trade and customs regulation; international cooperation for sharing technologies and knowledge (for example, biregional collaboration in research and innovation); deployment of the Technology Bank and the Science, Technology, and Innovation Capacity Building Mechanism for less developed countries; and establishing global intellectual property regimes and the flexibilities under the Agreement on Trade-Related Aspects of Intellectual Property Rights fully consistent with the SE4All objectives.

Conclusions

Existing data and tools are sufficient to track, in very broad terms, progress toward the SE4All objectives at global and country levels, but do not yet provide enough detail to guide the steps to those goals. Still, the outlines of a data revolution may be emerging. This sea-change will require resources and will rely on new approaches and technologies, but even more it will demand greater commitment from—and better communication and cooperation among—the countries, organizations, firms, and individuals responsible for gathering, processing, and reporting energy information.

For energy access, a way forward—the *GTF* multitier framework—has already been designed, measuring access to electricity and modern fuels and cookstoves. It has been widely agreed on, and implementation is under way. A global survey, administered every few years by a qualified survey agency, could cover the great majority of households facing energy access deficits by working with only 30–40 countries. The longer-term plan to incorporate selected elements of the multitier framework into global and national household surveys would enable finer-grained and more-timely tracking of access trends in all the countries where access remains a significant challenge.

Reaching the global objectives for energy efficiency and RE also relies on a relatively few countries, but in some ways tracking this progress is even more challenging than for access. Multiple sectors, activities, and technologies are involved, each with different channels and types of data, and few agencies are concerned with more than a small subset of these. For these reasons, progress in tracking efficiency and RE lags that for access.

To better track global efficiency trends, the selection of target sectors and activities should precede planning and organization. Although decomposition analysis can disaggregate macro statistics, more-detailed sectoral data are needed. The stakeholders most concerned with tracking—international organizations handling global and regional energy statistics and national statistical agencies from the top energy consumers—must collectively agree on which sectors and energy-using activities to track, and in which (top energy-consuming) countries. These decisions would in turn determine the sector-specific bodies, including industry and other associations, to be included in the next stage—proposing indicators, identifying data sources, and outlining means for collecting current and new types of data. The principle should be applied of building on existing data collection, as it has been done with access.

The key missing pieces for RE have been identified—improved measures of bioenergy, more consistent definitions of grid-connected and off-grid electricity generation, and harmonized approaches to RE targets. Measuring sustainability of bioenergy is an intractable issue, but the advent of SE4All offers a framework to bring together efforts by organizations and to move, over the next few years, to building better national and global indicators. A range of methods has been proposed for measuring off-grid electricity that are comparable to those for grid-connected generation. Selecting and piloting one or more of these methods will require a multi-stakeholder process with strong leadership and adequate funding. By comparison, the effort needed to develop methods for translating national RE targets into a common, comparable basis for incorporation into the SE4All monitoring framework would be much smaller and more easily undertaken by a single, lead organization.

None of this work will be accomplished without cost. A new funding stream to support the data revolution for sustainable development should therefore be endorsed. For this, an assessment will be needed of the scale of investments, capacity development, and technology transfer required, especially for LICs, and proposals developed for mechanisms to leverage the creativity and resources of the private sector. Funding will also be needed to implement an education program aimed at improving people's, intermediaries', and public servants' capacity and data literacy to break down the barriers between people and data.

These programs to improve the SE4All tracking indicators have implications well beyond this *GTF 2015.* This initiative will advance adoption of practices and norms that will enable countries to more accurately assess their own performance and to initiate and adjust their own improvement efforts. New methods tested in those countries most important to SE4All's global objectives with become quickly available for use by scores of other countries, for which the pursuit of similar goals will have profound benefits for development. These programs also have implications for other regional and global initiatives: We hope, for instance, that the foreseen improvements in SE4All tracking indicators help build the capacity needed to monitor progress toward the Sustainable Development Goals.

Annex 1. Multitier frameworks for energy access

Multitier frameworks have been devised for energy access at household level (including electricity, cooking, and heating), and for productive and community uses. All frameworks are technology neutral and allow an assessment of all energy sources—from solar lanterns to grids and from improved cookstoves to natural gas stoves—while keeping energy applications, meaningful to end users, at the core of the approach. While a summary of various multitier frameworks is presented in this report, details about how these frameworks have been conceptualized will be provided in the forthcoming World Bank and ESMAP report, *Beyond Connections: Energy Access Redefined.*

Frameworks for access to household electricity

Access to household electricity supply is measured through seven energy attributes for which successive thresholds have been established (see table 5.3). A gradually improving electricity supply enables enhanced feasibility of electricity services through use of electrical appliances.

Distinct from the tiers of electricity supply, tiers of access to electricity services are defined based on the appliances used (table A1.1). A third multitier framework—again distinct from the frameworks for supply and services—may be defined in terms of tiers of electricity consumption. An estimated annual consumption for each tier has been derived by multiplying an indicative number of hours of use for a range of appliances by their typical power load in watts (table A1.2).

Measuring access to household lighting and phone charging solutions

Within the overarching framework for household access to electricity, an approach for more detailed measurement of access to household lighting solutions has been devised. Modern lighting and phone charging are important first steps toward improved household electricity access and are captured in tier 1. To reflect the benefit of small lighting devices that may not meet tier 1 standards, continuous measurement is used between tier 0 and tier 1.

The unit of measurement for access to lighting is lumen-hours per day, whereas for communication devices it is watt-hours of charging. Studies by Lighting Global[14] reveal that over 90 percent of focus groups examined across Africa and India are satisfied with brightness levels of around 25 lumens and with using about four hours of power each evening. This sets a minimum threshold of 100 lumen-hours per day—though this threshold is far below the tier 1 standard of 1,000 lumen-hours per day for a family of five. A nonlinear mathematical function based on (1) the lumen-hours of lighting available from a single device and (2) the number of people whose lighting needs it can satisfy is used to determine this threshold (figure A1.1).

Variables for calculating the communication tier score are defined in the box below. Energy for phone charging is defined in watt-hours of electricity. Full credit (a score of 1) is given for charging capabilities if systems can charge approximately one phone every day; partial (2/3) credit is given if one phone can be charged every three days. If a neighborhood phone recharging service is used, one-third (1/3) credit is given.

$$T_{c_{pub}} = \textit{if } [\textit{neighborhood access}] \rightarrow 0.33, \textit{ else } 0$$

$$T_{c_{hh}} = \textit{if } [\textit{household access} > 1 \text{ Wh/day}] \rightarrow 0.66$$

$$T_{c_{hh}} = \textit{if } [\textit{household access} > 3 \text{ Wh/day}] \rightarrow 1.00$$

$$T_c = \max(T_{c_{pub}}, T_{c_{hh}})$$

where $T_{c_{pub}}$ is the communication tier score through neighborhood access, $T_{c_{hh}}$ is the communication tier score through household system-level access, and T_c is the communication tier score.

A weighted average tier score is calculated across lighting (70 percent weight) and phone charging (30 percent weight). This tier score is used as the tier rating of households that do not have access to any higher level electricity supply solutions.

Measuring access to household cooking solutions

Access to household cooking solutions is evaluated based on the combination of seven energy attributes, starting

Table A1.1. **Multitier matrix for measuring access to household electricity services**

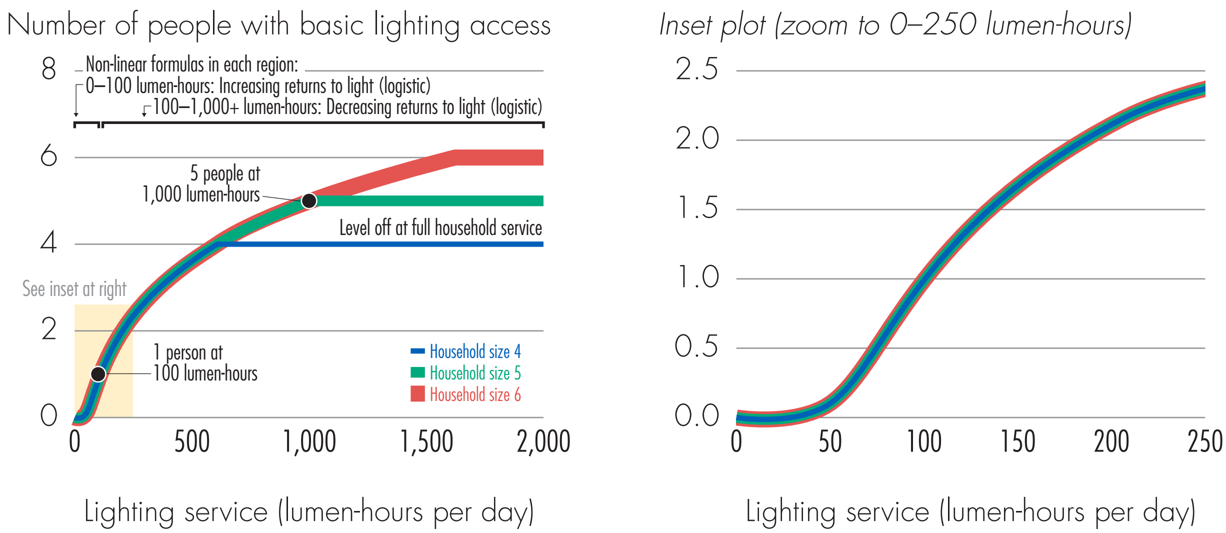
		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Tiers	Tier criteria	—	Task lighting *and* Phone charging	General lighting *and* Television *and* Fan (if needed)	Tier 2 *and* Any medium power appliances	Tier 3 *and* Any high power appliances	Tier 2 *and* Any very high power appliances
Appliances	**Indicative list of appliances**		**Very low power appliances**	**Low power appliances**	**Medium power appliances**	**High power appliances**	**Very high power appliances**
	Lighting	—	Task lighting	Multi-point general lighting			
	Entertainment and communication	—	Phone charging, radio	Television, computer	Printer		
	Space cooling and heating	—		Fan	Air cooler		Air conditioner,[a] space heater[a]
	Refrigeration	—			Refrigerator,[a] freezer[a]		
	Mechanical loads	—			Food processor, washing machine, water pump		
	Product heating	—				Iron, hair dryer	Water heater
	Cooking	—			Rice cooker	Toaster, microwave	Electric cooking

a. Intermittent loads.

Table A1.2. **Multitier matrix for measuring access to household electricity consumption**

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Annual consumption levels (kilowatt-hours)	< 4.5	≥ 4.5	≥ 73	≥ 365	≥ 1,250	≥ 3,000
Daily consumption levels (watt-hours)	< 12	≥ 12	≥ 200	≥ 1,000	≥ 3,425	≥ 8,219

Figure A1.1. **Implications of the tier 1 framework for a household of five using a single light source with a range of performance characteristics and different levels of access to mobile charging**



Source: World International Trade Solutions database (World Bank 2014).

with access to rudimentary solutions and increasing gradually to modern cooking solutions that deliver the highest results for all attributes (see table 5.4).

Measuring access to household heating solutions

Household heating is a major energy requirement in many countries with cold seasons or high altitude areas. Household access to heating (where needed) is measured through eight attributes (table A1.3).

Table A1.3. **Multitier matrix for measuring access to household heating solutions**

			Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Attributes	1. Capacity			Personal space around individuals is heated	At least one room has heating		All rooms in the household have heating	
	2. Duration					At least half the time when needed (> 50 percent of the time)	Most hours when needed (> 75 percent of the time)	Almost all hours when needed (> 95 percent of the time)
	3. Quality					Comfortable temperature at least 50 percent of the time	Comfortable temperature at least 75 percent of the time	Comfortable temperature all the time
	4. Convenience (fuel collection time)				Maximum 7 hours/week	Maximum 3 hours/week	Maximum 1.5 hours/ week	Maximum 0.5 hours/ week
	5. Affordability					Maximum 2 times grid tariff		Maximum grid tariff
	6. Reliability					Maximum 3 disruptions per day	Maximum 7 disruptions per week	Maximum 3 disruptions per week of total duration < 2 hours
	7. Indoor air quality (health)	$PM_{2.5}$ ($\mu g/m^3$)		[To be specified by a competent agency such as WHO based on health risks]	[To be specified by a competent agency such as WHO based on health risks]		< 35 (WHO IT-1)	< 10 (WHO guideline)
		CO (mg/m^3)			< 7 (WHO guideline)			< 7 (WHO guideline)
	8. Safety						No accidents (burns or unintended fires) over the past year that required professional medical attention.	

Note: WHO is the World Health Organization.

Table A1.4. **Multitier matrix for measuring energy access by productive engagements**

			Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
1. Capacity	Electricity	Power		Minimum 3 W	Minimum 50 W	Minimum 200 W	Minimum 800 W	Minimum 2 kW
		Daily supply capacity		Minimum 12 Wh	Minimum 200 Wh	Minimum 1.0 kWh	Minimum 3.4 kWh	Minimum 8.2 kWh
		Typical source		Solar lanterns	Solar home systems	Generator or grid	Generator or grid	Grid
	Non-electric					Available non-electric energy partially meets requirements	Available non-electric energy largely meets requirements	Available non-electric energy fully meets all re-quirements
	Both					No relevant application is absent solely due to energy supply constraints		
2. Duration of daily supply	Electricity			Minimum 2 hrs	Minimum 4 hrs	Minimum 50 percent of working hours	Most of working hours (minimum 75 percent of working hours)	Almost all of work-ing hours (minimum 95 percent of working hours)
	Non-electric					Available non-electric energy partially meets requirements	Available non-electric energy largely meets requirements	Available non-electric energy fully meets all re-quirements
	Both					Longer working hours are not prevented solely by lack of adequate energy (capacity or duration)		
3. Reliability							No reliability issues that have severe impact	No reliability issues or little impact
4. Quality							No quality issues that have severe impact	No quality issues or little impact
5. Affordability							Variable cost of energy is less than two times the grid tariff	Variable cost of energy is less than grid tariff
6. Legality							Energy bill is paid to the utility, pre-paid card seller, authorized representative, or legal market operator	

(continued)

Table A1.4. **Multitier matrix for measuring energy access by productive engagements** *(continued)*

			Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
7. Convenience							Time and effort in securing and preparing energy does not cause severe impact	No convenience issues or little impact
8. Health (Indoor air quality from use of fuels)	$PM_{2.5}$ ($\mu g/m^3$)			[To be specified by competent agency such as WHO]	[To be specified by competent agency such as WHO]	[To be specified by competent agency such as WHO]	< 35 (WHO IT-1)	< 10 (WHO guideline)
	CO (mg/m^3)						< 7 (WHO guideline)	< 7 (WHO guideline)
	or Use of fuels (BLEENS)				Use of non-BLEENS solutions (if any) for heating in the open or with smoke extraction		Use of BLEENS or equivalent solutions only (if any)	
9. Safety							Energy supply solutions have not caused any accidents over the last one year that required professional medical assistance.	Energy supply solutions have not caused any accidents over the last one year

Note: BLEENS is biogas, LPG (liquefied petroleum gas), ethanol, electricity, natural gas, and solar; CO is carbon monoxide; kW is kilowatts; kWh is kilowatt-hours; PM is particulate matter; W is watts; Wh is watt-hours; WHO is the World Health Organization.

Measuring access to energy for productive engagements

The wide diversity of productive activities and enterprises makes it extremely difficult to devise a one-size-fits-all metric for energy access. There are hundreds of different types of productive engagements varying in scale of operations as well as degree of mechanization. Furthermore, productive engagements involve a wide range of energy applications and energy sources. The energy applications used by productive engagements can be broadly classified as lighting, information and communication, motor power, space heating, product heating, and water heating.

The proposed multitier framework for productive engagements is based on the energy access experienced by a single working individual (the respondent) rather than by the enterprise as a whole. It captures eight energy attributes of energy access that determine the usefulness of the supply for each productive application (table A1.4). Access to energy is first assessed for each application separately. Relevant energy applications are identified by their significant impact on productivity, sales, cost, or quality. The primary energy source for each application is identified and its attributes evaluated. The energy access rating for the productive engagement as a whole is the lowest tier among all applications.

Table A1.5. **Multitier matrix for measuring energy access by community facilities**

			Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
1. Capacity	Electricity	Power		Min 3 W	Min 50 W	Min 200 W	Min 800 W (min 2 kW for institutions)	Min 2 k (min 10 kW for institutions)
		Daily supply capacity		Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
		Typical source		Solar lanterns	Solar home systems	Generator or mini- grid	Generator or grid	Grid
	Non-electric					Available non-electric energy partially meets requirements	Available non-electric energy largely meets requirements	Available non-electric energy fully meets all requirements
	Both					No relevant application is absent solely due to energy supply constraints		
2. Duration of daily supply	Electricity			Min 2 hrs	Min 4 hrs	Min 50 percent of working hours	Most of working hours (min 75 percent of working hours)	Almost all of working hours (min 95 percent of working hours)
	Non-electric					Available non-electric energy partially meets requirements	Available non-electric energy largely meets requirements	Available non-electric energy fully meets all requirements
	Both					Longer working hours are not prevented solely by lack of adequate energy (capacity or duration)		
3. Reliability							No reliability issues that have severe impact	No reliability issues or little impact
4. Quality							No quality issues that have severe impact	No quality issues or little impact
5. Affordability							Variable cost of energy is less than two times the grid tariff	Variable cost of energy is less than grid tariff
6. Legality							Energy bill is paid to the utility, pre-paid card seller, authorized representative, or legal market operator	

(continued)

Table A1.5. **Multitier matrix for measuring energy access by community facilities** *(continued)*

			Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
7. Convenience							Time and effort in securing and preparing energy does not cause major inconvenience	No convenience issues or little impact
8. Health and safety	Health: use of fuels (BLEENS)				Use of non-BLEENS solutions (if any) for heating in the open or with smoke extraction		Use of BLEENS or equivalent solutions only (if any)	
	Safety						Energy supply solutions have not caused any accidents over the last one year that required professional medical assistance.	Energy supply solutions have not caused any accidents over the last one year

Note: BLEENS is biogas, LPG (liquefied petroleum gas), ethanol, electricity, natural gas, and solar; kW is kilowatts; kWh is kilowatt-hours; W is watts; Wh is watt-hours.

Measuring access to energy for community facilities

Energy for community facilities is fundamental for socio-economic development, as it drives improvements in human capital. Five different sub-locales of energy for community facilities are considered: schools, health clinics, government buildings, and community halls (table A1.5), and street lighting (table A1.6). While fuels may also be used for cooking or space heating in some cases, electricity is the most important source of energy for most applications in community facilities. The proposed framework examines only electricity in all community facilities. Fuels for cooking or space heating are examined only in country contexts where they may be relevant.

Table A1.6. **Multitier matrix for access to street lighting**

Street lighting		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Attributes	Capacity		At least one functional street lamp in the neighborhood	At least 25 percent of the neighborhood is covered by functional street lamps	At least 50 percent of the neighborhood is covered by functional street lamps	At least 75 percent of the neighborhood is covered by functional street lamps	At least 95 percent of the neighborhood is covered by functional street lamps
	Duration		Street lighting functions for at least 2 hours each day	Street lighting functions for at least 4 hours each day	Street lighting functions for at least 50 percent of night hours each day	Street lighting functions for at least 75 percent of night hours each day	Street lighting functions for at least 95 percent of night hours each day
	Reliability					No reliability issues perceived by users	
	Quality					No brightness issues perceived by users	
	Health and safety					No perceived risk of electrocution due to poor installation or maintenance.	

Annex 2. Data and methods for analyzing energy intensity and energy efficiency

Data sources

Data on primary and final energy consumption by country and sector are primarily from energy statistics and balances compiled by the IEA. Sectoral energy statistics follow the International Standard Industrial Classification ISIC 3. Where figures are missing from IEA databases, they are supplemented by UNSD statistical databases.

Total primary energy supply, as defined by the IEA, is the sum of indigenous production + imports – exports – international marine and aviation bunkers ± stock changes. It is equivalent to inland total primary energy demand, excluding international marine and aviation bunkers, which are included in only world energy consumption. Energy statistics used to calculate indicators in this chapter come primarily from the IEA, whose terminology and definitions are generally used for these variables.

Total final energy consumption is used for decomposition analysis of energy intensity.

National GDP and sector value added (VA) data are from the World Bank's WDIs. In the first edition of the *GTF* (2013), energy intensity values were presented in both market exchange rate terms and in 2005 purchasing power parity (PPP) terms. PPP factors are updated at intervals of several years, and this volume uses the recently released 2011 PPP figures. Time series statistics for national energy and economic accounts are subject to constant modifications as data are updated to reflect newer and more accurate information. Thus, some of the figures and numbers in *GTF 2015* may not precisely match corresponding ones in *GTF 2013*.

For industry and agriculture, VA figures are used as reported by WDI. For services (sometimes also termed "other services," "commercial and public services," or "the tertiary sector"), VA data are calculated by subtracting transport VA from the services category in the WDI database, which includes transport. Gaps in VA time series were filled by estimating missing values based on growth rates calculated from surrounding years.

Transport VA is derived from UNSD's national accounts aggregate database and from WDI figures. First, the transportation VA in 2011 local currency units, sourced from the UN national accounts database, is converted to 2011 PPP dollars, and the growth rate is calculated with the constant local currency unit data from the UN. The time series data are then derived by multiplying the baseline year data (2011) with the growth rate. For those countries for which sectoral VA data are missing in the WDI database, the same method was applied to calculate VA based on the UN database.

VA is, however, a poor activity indicator for the transport sector. More appropriate indicators are provided by the IEA's proprietary Mobility Model, from which aggregate indicators were drawn. The information for 2000 to 2010 result from collection and aggregation of national-level data on vehicle stocks, mileages, loads, and fuel economies. Sources for these data include national and regional statistical offices (such as Eurostat for European member states), vehicle manufacturers associations (such as the International Organization of Motor Vehicle Manufacturers and its members for road vehicle stocks and registrations), other industry associations (such as the International Union of Railways for rail data), thematic reports (such as the Review of Maritime Transport of the United Nations Conference on Trade and Development), and international organizations (such as the International Civil Aviation Organization). Data for 2000–10 are based on extracts of historical information in five-year time steps. Data for 2011 and 2012 result from extrapolations of historical data for 2010 and modeling results for 2015.

For the residential (or household) sector, population and household data are from WDI.

Methods

Primary energy intensity is calculated at the national and higher levels as primary energy consumed per 2011 GDP dollars in PPP terms.

Final energy intensity for production sectors other than transport (agriculture, industry, and services), is calculated as the amount of final energy consumed per 2011 VA dollars in PPP terms. For the household sector, energy use per household is used where appropriate. Energy intensities for the transport sector were calculated as follows:

- Annual data on energy consumption in road, rail, aviation (including domestic aviation and international bunkers) and shipping (including domestic navigation and international bunkers) were extracted from IEA energy balance data.
- The IEA's Mobility Model was used to allocate energy consumption to passenger and freight services in each mode and submodes (such as two- and three-wheelers, light-duty vehicles, buses, and minibuses) based on shares of fuel use by service and submode.
- Transport activity data (passenger-kilometers [pkm] and freight ton-kilometers [tkm]) were taken from the IEA Mobility Model to evaluate energy intensities at submodal level, then aggregated.

Logarithmic mean Divisia index (LMDI) decomposition analysis

As in *GTF 2013,* a logarithmic mean Divisia index (LMDI) decomposition method was employed to analyze the contributions to changes in energy consumption of activity level, economic structure, and sectoral energy intensity (Ang 2006; Ang and Liu 2001; Ang and Liu 2006). Because the energy consumption decomposition analysis covers only final energy consumption, trends in energy extraction, conversion, transmission, and distribution are not covered. Upstream energy activity is an area requiring considerable further data acquisition before analysis can proceed at a global level.

The energy intensity indicator for the agriculture, services, and industry sectors are constructed as the energy consumed in each sector divided by the sector VA,[15] while in the residential and transportation sectors the efficiency indicators are "residential energy consumption per household" and transport energy use per unit of passenger/freight activities, respectively.

The LMDI with multiplicative chaining decomposition analysis is adopted in *GTF 2015,* as follows:

$$D_{tot} = E^T/E^0 = D_{act}\, D_{str}\, D_{in} \qquad (1)$$

where the ratio change of energy consumption from year 0 to year T, E^T/E^0, is decomposed to give the activity, structure, and intensity indexes, D_{act}, D_{str}, and D_{int}, respectively.

Assume that total energy consumption in a specific sector is the sum of consumption in n different subsectors and define the following variables for a certain period:

E = total energy consumption in the sector

E_i = energy consumption in subsector i

Q = total activity level of the sector

Q_i = activity level of subsector i

S_i = activity share of subsector i ($= Q_i/Q$)

I = aggregate energy intensity ($= E/Q$)

I_i = energy intensity of subsector i ($= E_i/Q_i$)

Based on the data for year t–1 and year t, the decomposition formulae are given by:

$$D_{act} = \exp\left(\sum_i \widetilde{w}_i \ln\left(\frac{Q^t}{Q^{t-1}}\right)\right) \qquad (2)$$

$$D_{str} = \exp\left(\sum_i \widetilde{w}_i \ln\left(\frac{S_i^t}{S_i^{t-1}}\right)\right) \qquad (3)$$

$$D_{int} = \exp\left(\sum_i \widetilde{w}_i \ln\left(\frac{I_i^t}{I_i^{t-1}}\right)\right) \qquad (4)$$

$$\widetilde{w}_i = \sum_i \frac{(E_i^t - E_i^{t-1})/(\ln E_i^t - \ln E_i^{t-1})}{(E^t - E^{t-1})/(\ln E^t - \ln E^{t-1})} \qquad (5)$$

The activity, structure and intensity decomposition index, setting a certain year as the baseline year (for example, 1990), is derived by calculating the product of the index of each category in previous years as of 1990.

Composite economy-wide decomposition index

The LMDI chaining analysis was carried out by decomposing by factor then aggregating by sector. Two independent index decomposition analysis results for the residential sector, the transportation sector, and other sectors (agriculture, industry, services) were then aggregated to derive the economywide decomposition index:

$$(D_{int})_{e-w} = \exp\left(\sum_i \widetilde{w}_j \ln(D_{int})_j\right) \qquad (6)$$

where subscript j denotes the sectors to be aggregated, and D_{int} results from formula (4).

Calculation of avoided energy demand

The decomposition analysis is the basis for estimating avoided energy demand. The energy demand avoided (that is, energy saved), assuming energy efficiency remains the same as the baseline year, was calculated as:

$$\Delta E_{int} = \sum_i \overline{w}_i \ln\left(\frac{I_i^T}{I_i^0}\right) \quad (7)$$

in which

$$\overline{w}_i = \frac{(E_i^T - E_i^0)}{(\ln E_i^T - \ln E_i^0)} \quad (8)$$

A negative value means reduced energy use due to energy efficiency improvement. Sectoral and regional avoided energy demand is calculated by summing up the avoided energy demands for each year in the specified period.

Calculate avoided energy demand in year *t* based on the logarithmic means of energy consumption in year *t* and year *t*–1 and the differences between the natural logs of energy intensities in years *t* and *t*–1:

Energy avoided in year *t* =
$(E^t - E^{t-1})/(\ln E^t - \ln E^{t-1}) * [\ln(I^t) - \ln(I^{t-1})]$

where *I* signifies economic energy intensity. The calculation thus establishes a moving baseline, wherein changes in energy intensity are accounted year-to-year, rather than according to a fixed base year. The globally aggregated avoided energy consumption presented earlier in this chapter was calculated assuming a fixed base year of 1990 in order to capture the ongoing benefits of energy efficiency investments and operational changes:

Energy avoided in year *t* =
$(E^t - E^{1990})/(\ln E^t - \ln E^{1990}) * [\ln(I^t) - \ln(I^{1990})]$

Annex 3. Methodological aspects in renewable energy

A. Methodology for the renewable energy tracking indicator

Renewable energy accounting approach

RE accounting is a complex task arising from a series of assumptions and decisions made throughout the monitoring process. A number of choices are possible starting at the early stages of data collection all the way through the development of indicators (IRENA 2013). As a result, various methodologies have been developed to quantify the role of renewables relative to the overall energy system. Describing them in detail are beyond the scope of this annex, but two main assumptions with a noticeable effect on RE accounting should be highlighted: the boundary of the energy system at which the monitoring occurs; and the convention used to define the energy system. In practice, this requires decisions about whether or not to monitor at the level of primary energy supply or final energy consumption and in the case of the former, which convention to use in constructing an energy balance.

These issues were explored in the first *GTF,* and it was decided to monitor RE as close as possible to the final energy use to remove the influence of the assumptions about the primary energy equivalent for non-combustible sources *(GTF 2013)*. This corresponds to accounting for RE at the final energy consumption level of the energy balance. The indicator chosen and the methodology developed to calculate it are described below. It was also decided that the IEA Energy Balances data would serve as the underlying data used to calculate the indicator. The basic energy statistics definitions and methodological assumptions adopted by the IEA follow the internationally agreed UNSD International Recommendations for Energy Statistics (UNSD 2011).

While the indicator used in this report is derived from the historical data published in the IEA World Energy Statistics and Balances database, it does not directly correspond to any of the published indicators due to differences with existing harmonized definitions for international energy statistics.

Calculating the RE share indicator

The indicator used in this report to track RE within an energy system is the share of RE in total final energy consumption,[16] and is expressed as a percentage ($\%REN_{TFEC}$).

This share is calculated as the ratio of final energy consumption of renewables after allocation ($AFEC_{REN}$) to total final energy consumption (TFEC) and is given by:

$$\%REN_{TFEC} = \frac{AFEC_{REN}}{TFEC} = \frac{TFC^{*}_{REN} + (TFC^{2}_{ELE} \times \%REN_{ELE}) + (TFC^{2}_{H} \times \%REN_{H})}{TFC^{2}_{TOTAL}}$$

where the variables in the equation are defined in table A3.1 and are calculated from the flows in the IEA energy balance, which are defined in IEA 2014f.

The denominator (TFEC) is calculated as the sum of total final consumption minus non-energy use for all energy sources, or equally, the sum of the energy consumed in the industry, transport, and other sectors. The numerator ($AFEC_{REN}$), on the other hand, is not a direct summation of the underlying raw data but a series of calculations reflecting the fact that monitoring occurs at the final energy level. At this level in the energy balance, electricity and heat are secondary energy obtained by different primary energy sources, of which some are renewable. Assumptions need to be made in order to fully account for the renewable component of such secondary sources. It was decided to allocate the final consumption of electricity and heat to renewables based on the share of renewables in gross production.

Limitations and scope for improvement

The advantages and disadvantages of final versus primary energy accounting can be reviewed in *GTF 2013* and IRENA (2013). One of the important advantages of final energy accounting is that non-energy use can be excluded, a convention more appropriate for assessing how renewables are contributing to meeting actual energy

* Total final consumption after removing the non-energy use of fuels. The remaining quantity corresponds to the final energy consumption in the end-use sectors (industry, transport, and other). This adjustment is necessary for total and fossil fuels but does not apply to RE, electricity, or heat.

Table A3.1. **Explanation of variables**

Symbol	Name	Definition
TFEC	Total final energy consumption	The sum of final energy consumption in the end-use sectors (transport + industry + other sectors) for all energy sources; alternatively, total final consumption (TFC) – non-energy use across all energy sources (by definition, TFEC = TFC_{TOTAL} after the non-energy use is removed)
$AFEC_{REN}$	Final energy consumption of renewables after allocation (REN = total RE sources[a])	The final energy consumption of renewables + the allocated final energy consumption of renewable electricity and renewable heat
$\%REN_{ELE}$	Share of renewables in gross electricity production (ELE = electricity)	Ratio of gross electricity production from renewable sources to total gross electricity production: $$\%REN_{ELE} = \frac{ELE_{REN}}{ELE_{TOTAL}}$$
$\%REN_{H}$	Share of renewables in gross heat production[b] (H = heat)	Ratio of gross heat production from renewable sources to total gross heat production (TOTAL = all fuels): $$\%REN_{H} = \frac{H_{REN}}{H_{TOTAL}}$$

a. Total RE sources includes hydro, wind, solar photovoltaic, solar thermal, geothermal, and marine power; renewable municipal waste; solid biofuels; liquid biofuels; and biogases.

b. Gross heat production for the purposes of energy statistics is defined as the total heat produced by the installation (combined heat and power plants and heat plants) and includes the heat used by the installation's auxiliaries, which use a hot fluid (such as space heating or liquid fuel heating) and losses in the installation/network heat exchanges, as well as heat from chemical processes used as a primary energy form. For autoproducers, heat used by the undertaking for its own processes is not included here; only heat sold to third parties should be reported. Since only heat sold to third parties is reported, gross heat production for autoproducers equals net heat production.

needs. Another advantage is that monitoring at the final energy level excludes the influences of any assumptions made during the primary energy equivalent calculation (physical content versus direct equivalent versus substitution; see UNSD 2011). But there are caveats to be aware of with this particular methodology:

1. The allocation of heat and electricity consumption based on shares of production assumes that proportionate shares of the fuels exist in the flows between the primary and final levels of the energy balance. As a consequence, the implicit assumption is that transmission and distribution losses, the energy industry's own use, and statistical differences are equally distributed among the fuels. In addition, in the case of combustible fuels, this allocation also implies adding "apples and oranges" at the final energy level because conversion losses have already occurred during the transformation of primary to secondary energy.

2. For countries with electricity trade, it is impossible to know how much of the electricity demand is truly met by RE sources within national borders. Thus the allocation of the electricity consumption based on shares of production is merely an assumption that does not attempt to account for trade, and may over- or understate the contribution of renewables.

3. The inclusion of international bunkers of renewable origin would need to be taken into account at the global level, although it currently is very marginal.

Finally, any methodology strongly relies on the quality of underlying data. In this case, problems exist for several countries and globally, as for example in the accounting of solid biofuels, for which sound data collection systems are not in place everywhere. Improving the quality of these data is one of the priorities of the SE4All initiative.

Despite these limitations, this simplified methodology was chosen to ensure comparability across countries at the global level based on the best available comprehensive data. But the $\%REN_{TFEC}$ indicator used in this report was designed only for global tracking: It is not detailed enough to support legally binding commitments and should be used with caution in target setting until the limitations are better understood and addressed.

Target setting not only requires expertise in RE accounting methodologies but also a robust energy statistical framework that yields repeatable and reliable data. One example of such an accounting methodology is the framework outlined in the EU Directive 2009/28/ED, which sets out the legal basis for monitoring RE share in the European Union. Although conceptually similar to that presented here, the calculation is complex and requires dozens of raw data points collected from joint questionnaires based on a set of internationally agreed upon definitions. Such extensive accounting systems are necessary when quantitative information is translated into binding targets. However, for countries with the motivation to track RE share but lacking resources to do so comprehensively, a balance must be struck between imposing reporting burdens early on and having an initial proxy for a target that may be inadequate.

In the near term, the SE4All methodology may be used as an intermediate step to achieve such a balance, bearing in mind that on a country level, efforts should be focused on ensuring a sound statistical monitoring framework and developing expertise in RE accounting. Definitions must be harmonized internationally to facilitate a comparison of targets across countries. But in the long term, a unified approach to target setting with a harmonized indicator will require international agreement on accounting methodologies.

B. Global Bioenergy Partnership sustainability indicators

Lessons learned with GBEP indicators

FAO, which is among the founding members of GBEP, ran pilot testing of the 24 GBEP sustainability indicators in Colombia and Indonesia as a project supported by the International Climate Initiative of the German Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. Implementation of the GBEP indicators in the various countries has led to a number of important lessons learned (tables A3.2–A3.4). In particular, the work carried out in Colombia and Indonesia showed the relevance of the environmental, social, and economic issues addressed by the GBEP sustainability indicators for bioenergy. This FAO project confirmed the value of the indicators as tools to inform and support sustainable bioenergy development decision making. For instance, they showed that renewable biofuels production and use have not caused significant impacts on the domestic supply and price of the main food items in either country. This might change if more ambitious national biofuel targets are imposed, such as those currently under consideration in Indonesia. However, FAO recommended more attention be paid in both countries to the land-use changes associated with expanding key bioenergy feedstocks (such as oil palm), which may have negative repercussions on environmental and social sustainability. If conversion of land with high carbon stocks is avoided, the displacement of fossil fuels with bioenergy can lead to GHG emission reductions. FAO also emphasized the potential for significant expansion in electricity generation, with resulting environmental and socioeconomic benefits, from sugarcane and palm oil residues through the removal of fossil fuel subsidies.

The GBEP indicators cover a broad range of complex environmental, social, and economic issues. They are data and skill intensive and some of the indicator methodologies are particularly sophisticated. For this reason, a multidisciplinary team of experts with an in-depth knowledge of both a particular national context and a domestic bioenergy sector is needed to measure the indicators. At the same time, as shown by the experience in Colombia and Indonesia, it is important to strengthen the capacity of developing countries to monitor the sustainability of bioenergy, especially with regard to complex issues such as greenhouse gas emissions and food security. This was done as part of the FAO project through a series of trainings and workshops. Furthermore, in both Colombia and Indonesia the project stimulated and facilitated dialogue across ministries and other stakeholders, such as producers' organizations. Stakeholder engagement and ownership of the process is critical to getting access to the necessary data, receive inputs and feedback, discuss and interpret results, and ultimately inform policy discussions and decisions. To this end, regional workshops were organized to foster the exchange of information and experiences among countries in the respective regions.

As emerged during this project, there is room to further enhance the practicality of the indicators and to provide additional guidance on both methodological and practical issues related to their application. GBEP members are committed to strengthening the indicators' relevance and practicality as tools to inform decision making leading to modern, sustainable bioenergy development.

Table A3.2. **GBEP indicators: Environmental pillar**

THEMES

GBEP considers the following themes relevant to development of indicators under this pillar:

GHG emissions, productive capacity of the land and ecosystems, air quality, water availability, use efficiency and quality, biological diversity, and land-use change (including indirect effects).

Indicator name	Indicator description
1. Lifecycle GHG emissions	Lifecycle GHG emissions from bioenergy production and use, as per the methodology chosen nationally or at community level, and reported using the GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy 'Version One'
2. Soil quality	Percentage of land for which soil quality, in particular in terms of soil organic carbon, is maintained or improved out of total land on which bioenergy feedstock is cultivated or harvested
3. Harvest levels of wood resources	Annual harvest of wood resources by volume and as a percentage of net growth or sustained yield, and the percentage of the annual harvest used for bioenergy
4. Emissions of non-GHG air pollutants, including air toxics	Emissions of non-GHG air pollutants, including air toxics, from bioenergy feedstock production, processing, transport of feedstocks, intermediate products and end products, and use; and in comparison with other energy sources
5. Water use and efficiency	• Water withdrawn from nationally determined watershed(s) for the production and processing of bioenergy feedstocks, expressed as the percentage of total actual renewable water resources (TARWR) and as the percentage of total annual water withdrawals (TAWW), disaggregated into renewable and nonrenewable water sources • Volume of water withdrawn from nationally determined watershed(s) used for the production and processing of bioenergy feedstocks per unit of bioenergy output, disaggregated into renewable and nonrenewable water sources
6. Water quality	• Pollutant loadings to waterways and bodies of water attributable to fertilizer and pesticide application for bioenergy feedstock cultivation, and expressed as a percentage of pollutant loadings from total agricultural production in the watershed • Pollutant loadings to waterways and bodies of water attributable to bioenergy processing effluents, and expressed as a percentage of pollutant loadings from total agricultural processing effluents in the watershed
7. Biological diversity in the landscape	• Area and percentage of nationally recognized areas of high biodiversity value or critical ecosystems converted to bioenergy production • Area and percentage of the land used for bioenergy production where nationally recognized invasive species, by risk category, are cultivated • Area and percentage of the land used for bioenergy production where nationally recognized conservation methods are used

8. Land use and land-use change related to bioenergy feedstock production	• Total area of land for bioenergy feedstock production, and as compared to total national surface and agricultural and managed forest land area
	• Percentages of bioenergy from yield increases, residues, wastes and degraded or contaminated land
	• Net annual rates of conversion between land-use types caused directly by bioenergy feedstock production, including the following:
	  • arable land and permanent crops, permanent meadows and pastures, and managed forests;
	  • natural forests and grasslands (including savannah, excluding natural permanent meadows and pastures), peatlands, and wetlands

Table A3.3. **GBEP indicators: Social pillar**

THEMES

GBEP considers the following themes relevant to development of indicators under this pillar:

Price and supply of a national food basket (nationally defined collection of representative foodstuffs, including main stable crops, measured at the national, regional, or household level); access to land, water, and other natural resources; labor conditions; rural and social development; access to energy; human health; and safety.

Indicator name	Indicator description
9. Allocation and tenure of land for new bioenergy production	Percentage of land—total and by land-use type—used for new bioenergy production where: • a legal instrument or domestic authority establishes title and procedures for change of title • the current domestic legal system or socially accepted practices provide due process and the established procedures are followed for determining legal title
10. Price and supply of a national food basket	Effects of bioenergy use and domestic production on the price and supply of a food basket, which is a nationally defined collection of representative foodstuffs, including main staple crops, measured at the national, regional, or household level, taking into consideration: • changes in demand for foodstuffs for food, feed and fiber • changes in the import and export of foodstuffs • changes in agricultural production due to weather conditions • changes in agricultural costs from petroleum and other energy prices • the impact of price volatility and price inflation of foodstuffs on the national, regional, or household welfare level, as nationally determined
11. Change in income	Contribution of the following to change in income due to bioenergy production: • wages paid for employment in the bioenergy sector in relation to comparable sectors • net income from the sale, barter or own consumption of bioenergy products, including feedstocks, by self-employed households/individuals

12. Jobs in the bioenergy sector	• Net job creation as a result of bioenergy production and use, total and disaggregated (if possible) as follows:
	  • skilled/unskilled
	  • temporary/indefinite
	• Total number of jobs in the bioenergy sector and percentage adhering to nationally recognized labor standards consistent with the principles enumerated in the ILO Declaration on Fundamental Principles and Rights at Work, in relation to comparable sectors

13. Change in unpaid time spent by women and children collecting biomass	Change in average unpaid time spent by women and children collecting biomass as a result of switching from traditional use of biomass to modern bioenergy services
14. Bioenergy used to expand access to modern energy services	Total amount and percentage of increased access to modern energy services gained through modern bioenergy (disaggregated by bioenergy type), measured in terms of energy and numbers of households and businesses Total number and percentage of households and businesses using bioenergy, disaggregated into modern bioenergy and traditional use of biomass

(continued)

Table A3.3. **GBEP indicators: Social pillar** *(continued)*

15. Change in mortality and burden of disease attributable to indoor smoke	Change in mortality and burden of disease attributable to indoor smoke from solid fuel use, and changes in these as a result of the increased deployment of modern bioenergy services, including improved biomass-based cookstoves
16. Incidence of occupational injury, illness, and fatalities	Incidences of occupational injury, illness and fatalities in the production of bioenergy in relation to comparable sectors

Table A3.4. **GBEP indicators: Economic pillar**

THEMES

GBEP considers the following themes relevant to development of indicators under this pillar:

Resource availability and use efficiencies in bioenergy production, conversion, distribution, and end-use; economic development; economic viability and competitiveness of bioenergy; access to technology and technological capabilities; energy security/diversification of sources and supply; energy security/infrastructure and logistics for distribution and use.

Indicator name	Indicator description
17. Productivity	• Productivity of bioenergy feedstocks by feedstock or by farm/plantation • Processing efficiencies by technology and feedstock • Amount of bioenergy end product by mass, volume or energy content per hectare per year • Production cost per unit of bioenergy
18. Net energy balance	Energy ratio of the bioenergy value chain and comparison with other energy sources, including energy ratios of feedstock production, processing of feedstock into bioenergy, bioenergy use, and lifecycle analysis
19. Gross value added	Gross value added per unit of bioenergy produced and as a percentage of gross domestic product
20. Change in the consumption of fossil fuels and traditional use of biomass	• Substitution of fossil fuels with domestic bioenergy measured by energy content and in annual savings of convertible currency from reduced purchases of fossil fuels • Substitution of traditional use of biomass with modern domestic bioenergy measured by energy content
21. Training and re-qualification of the workforce	Percentage of trained workers in the bioenergy sector out of total bioenergy workforce, and percentage of re-qualified workers out of the total number of jobs lost in the bioenergy sector
22. Energy diversity	Change in diversity of total primary energy supply due to bioenergy
23. Infrastructure and logistics for distribution of bioenergy	Number and capacity of routes for critical distribution systems, along with an assessment of the proportion of the bioenergy associated with each
24. Capacity and flexibility of use of bioenergy	• Ratio of capacity for using bioenergy compared with actual use for each significant utilization route • Ratio of flexible capacity which can use either bioenergy or other fuel sources to total capacity

C. Renewable energy in distributed and rural markets

Global trends of RE in off-grid configurations are only reported by the IEA for a few countries (OECD and other larger economies), and there are no global data on the evolution of RE in mini-grids. Other sources provide data on a per-country basis, but no organization consolidates data globally. In distributed generation, few agencies collect data, and data are predominantly only on photovoltaic (PV) installations. The IEA reports trends on decentralized PV applications from 1992, and Bloomberg New Energy Finance (BNEF) reports annual growth of residential PV from 2000 (BNEF 2014b). But where BNEF tabulates data by system size, the IEA collects data by type of system (on-grid versus off-grid, and centralized versus decentralized for the case of on-grid systems). In addition, only a few countries report official disaggregated data on distributed generation. The key constraint is that survey tools designed to collect national energy statistics do not generally include modules or questions on these categories. In addition, definitions differ widely across different agencies and the literature, so it is difficult to compare and aggregate data globally.

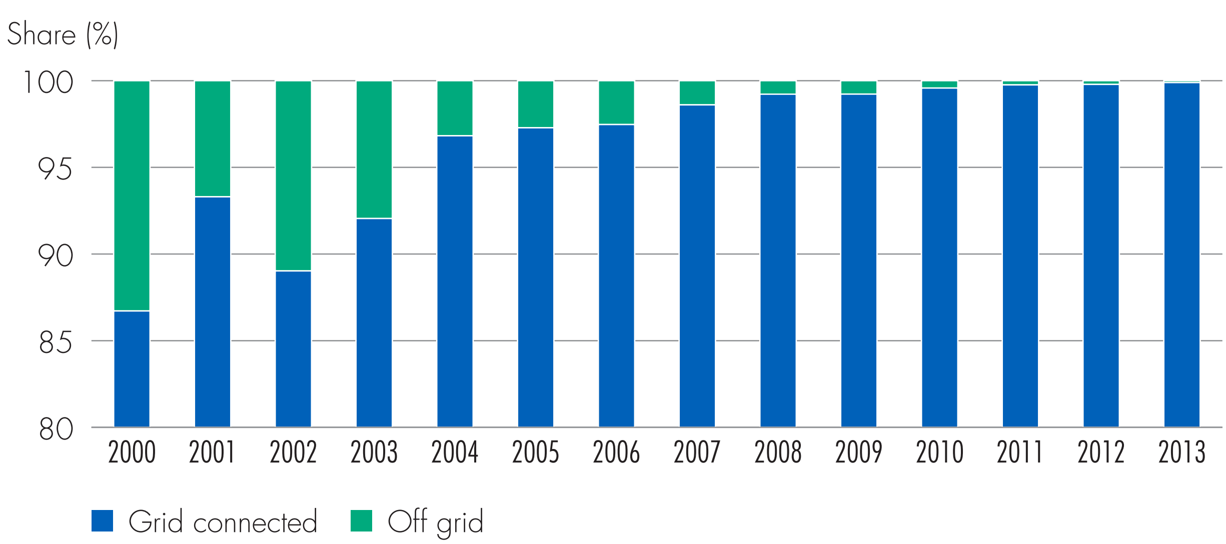
Renewable energy in off-grid markets

Consolidated statistics at global level on the number of installations or energy delivered by RE in off-grid configurations—including mini-grids—do not exist. Some countries, however, report data on mini-grid and off-grid markets (United States, Australia, China, India, Indonesia, Bangladesh, and Morocco, among others; IRENA 2015). In addition, international agencies report trends on some of the sources, technologies, or segments of the rural and distributed generation markets (IEA PVPS 2014,IFC 2012).

For instance, the IEA's Photovoltaic Power Systems Programme (PVPS) reports that the rapid deployment of grid-connected solar PV has dwarfed the off-grid market in the countries it covers (figure A3.1). However, this might not be the case in countries like Bangladesh, India, or Indonesia, where energy access rates are low and rural electrification programs with RE have been large.

According to IEA (2014d), the capacity of PV in off-grid configurations reached 705 MW, including installations for domestic and nondomestic uses, but this number only includes PVPS countries (figure A3.2).

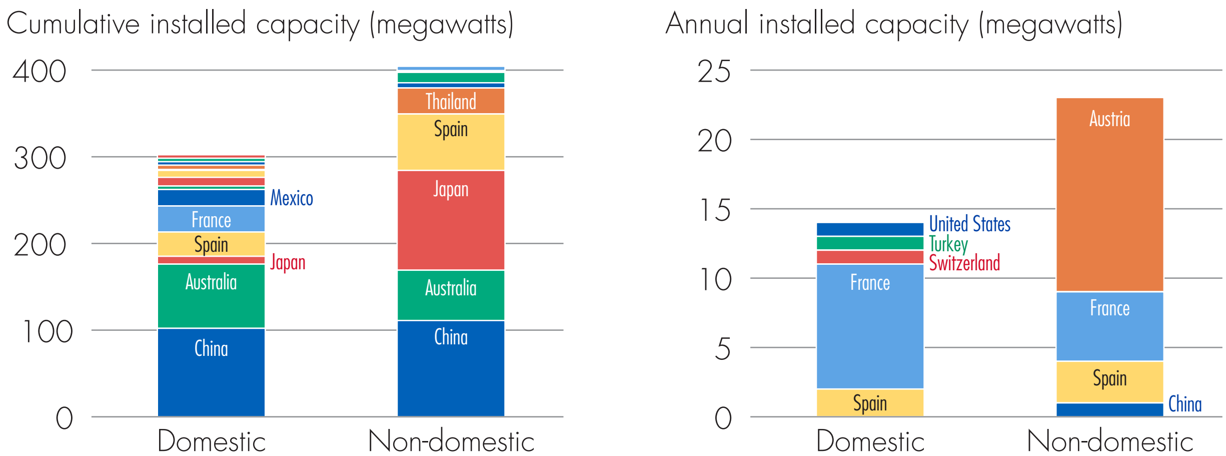
Figure A3.1. **Solar photovoltaic share of grid-connected and off-grid installations: PVPS countries, 2013**



Source: IEA PVPS 2014.

Note: PVPS reporting countries include all Organisation for Economic Co-operation and Development (OECD) countries and 29 non-OECD countries.

Figure A3.2. **Capacity of photovoltaic in off-grid systems: PVPS countries, 2013**



Source: IEA PVPS 2014.

Note: Off-grid systems provide electricity to households, villages, and other commercial users that are not connected to the grid. In domestic applications, they provide electricity for lighting, refrigeration, and other low power loads. They have been installed worldwide and are often the most appropriate technology to meet the energy demands of off-grid communities. In non-domestic uses, they provide power for a wide range of applications, such as telecommunications, water pumping, vaccine refrigeration, and navigational aids. These are applications where small amounts of electricity have a high value, thus making off-grid systems commercially cost competitive. Bangladesh is outside the IEA PVPS network.

Similarly, consolidated data of PV in off-grid schemes for developing countries only covers a few countries (table A3.1). Global data of RE in pico, micro, or mini-grids does not exist either. But IRENA has made an attempt to collect and consolidate existing data (box A3.1).

Renewable energy in grid-connected centralized and decentralized markets

The evolution of grid-connected PV in centralized and decentralized PV schemes is illustrated in figure A3.3. Centralized PV grew at a fast rate from 2006 in spite of several countries' decision to discontinue support for utility-scale PV in Europe.[17] In 2013, centralized PV represented more than 50 percent of the grid-connected PV market at the global level. The grid-connected PV market has expanded at a 54 percent CAGR.

RE trends in decentralized schemes are better illustrated by small-scale solar PV systems, because data on such systems are available on an annual basis.[18,19] BNEF data show that residential-scale PV reached about 38.6 GW in 2013, with 7.3 GW added in 2013 (figure A3.4). Most of this addition came in the EU, Asia, Oceania, and North America and the Caribbean. From a sharp rise since 2008, residential PV actually saw a decline in 2013, largely in the EU.

Table A3.1. **Number of solar home systems, selected countries**

Country	Year	Number
Bangladesh	2013 (December)	About 2,600,000
India	2012 (March)	861,654
China	2008	> 400,000
Kenya	2010	320,000
Indonesia	2010	264,000
Nepal	2012	229,000
South Africa	Estimate	150,000
Sri Lanka	2011	132,000
Morocco	Estimate	128,000
Zimbabwe	Estimate	113,000
Mexico	Estimate	80,000
Tanzania	Estimate	65,000
Total		5,100,000

Source: IRENA 2013.

Box A3.1. **Trends in mini-grids with renewable energy**

IRENA estimates an aggregated global capacity of 22.5 GW in isolated diesel-based power systems—75 percent of it in developing economies, of which only 2–3 percent includes RE (hybrids). This indicates huge potential for incorporating RE in mini-grids globally.

- India is a leading country in the area of mini-grids. Schnitzer et al. (2014) identified around 750 mini-grid systems in India, including 135 rice husk gasification systems and 599 solar PV mini-grids, with a total capacity of 8.2 MW and typically 10–400 customers each.
- Morocco is a leader in electrification through development of village-scale mini-grids. Approximately one out of ten villages electrified by 2010 had been reached with a renewable mini-grid solution (about 366 villages or 5,200 households) (Benkhadra 2011).
- Most Sub-Saharan African countries are still at the pilot stage with renewable mini-grids; only Mali, Senegal, and Kenya have been identified as having more than a dozen green mini-grids implemented and ready for scale-up (IED 2013).

Brazil has ambitious plans to connect more than 250,000 households in rural regions through RE-based mini-grids and provides an 85 percent capital subsidy. By 2010, only 15 small hydro-based mini-grids and one solar PV–based mini-grid had been established in Brazil (Deshmukh 2013).

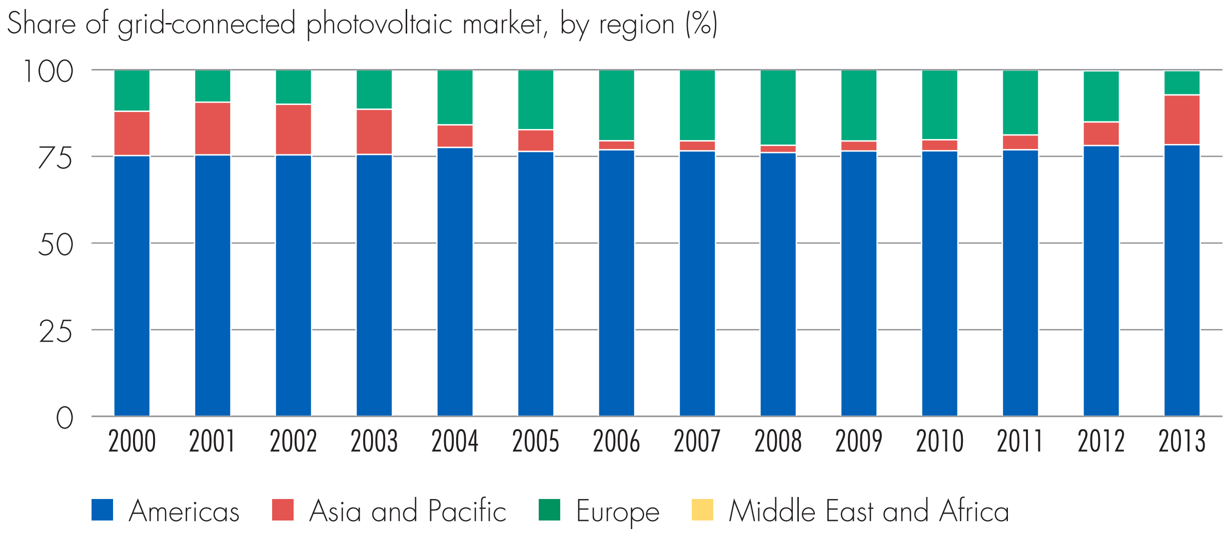
Werner and Breyer (2012) estimate that at least 42 countries and regions have mini-grid systems in operation.

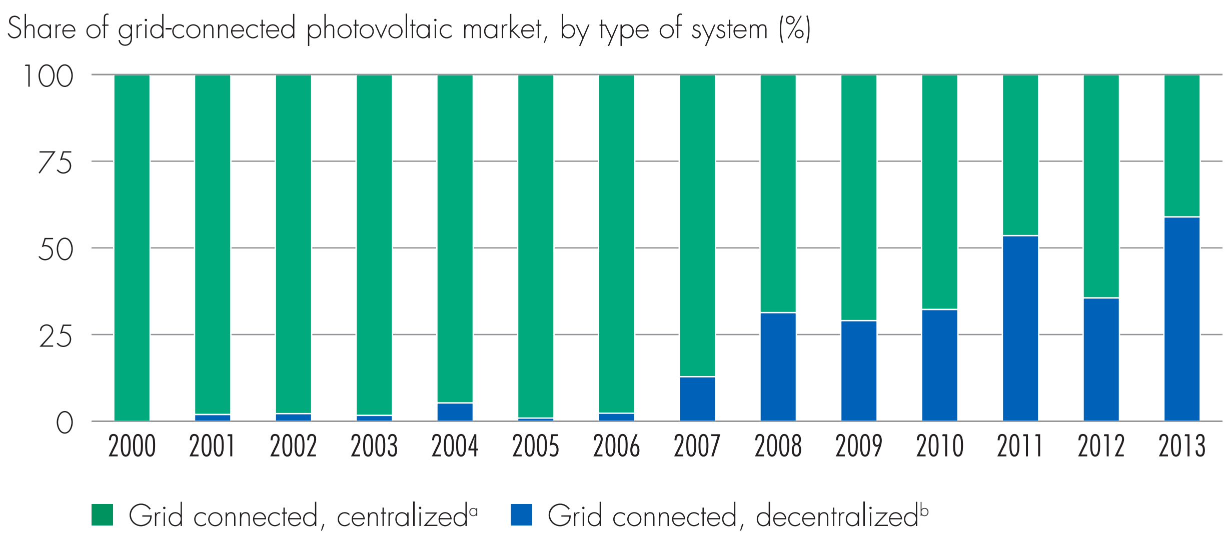
Source: IRENA 2015.

Europe's continued strong PV market development until 2012 was the result of a few countries driving the market, mainly Germany and Italy, which added 64 percent of total European capacity in 2012. In 2013, decline in both these PV markets slowed growth in Europe generally. Decreased political support for PV incentives in the two countries and stabilization of the market were the main factors. In 2012, Germany set a capacity threshold, sharply cut feed-in tariffs (FITs), and adopted a monthly decrease of FiTs. In 2012, Italy put in place a revised solar PV incentive policy that lowered FITs greatly, and set an annual financial cap for solar PV FITs and premiums, which was reached in June 2013, causing all solar PV installations to cease for the rest of the year.

IEA data show that decentralized grid-connected PV has seen the most support, cumulatively, in Germany, Japan, Italy, United States, and France (figure A3.5). In 2013, however, the biggest driver by far was Japan, followed by Germany. For off-grid distributed generation, IEA data show that China, Australia, and Japan have the largest capacities.

Figure A3.3. **Global evolution of grid-connected photovoltaic markets, 2000–13**



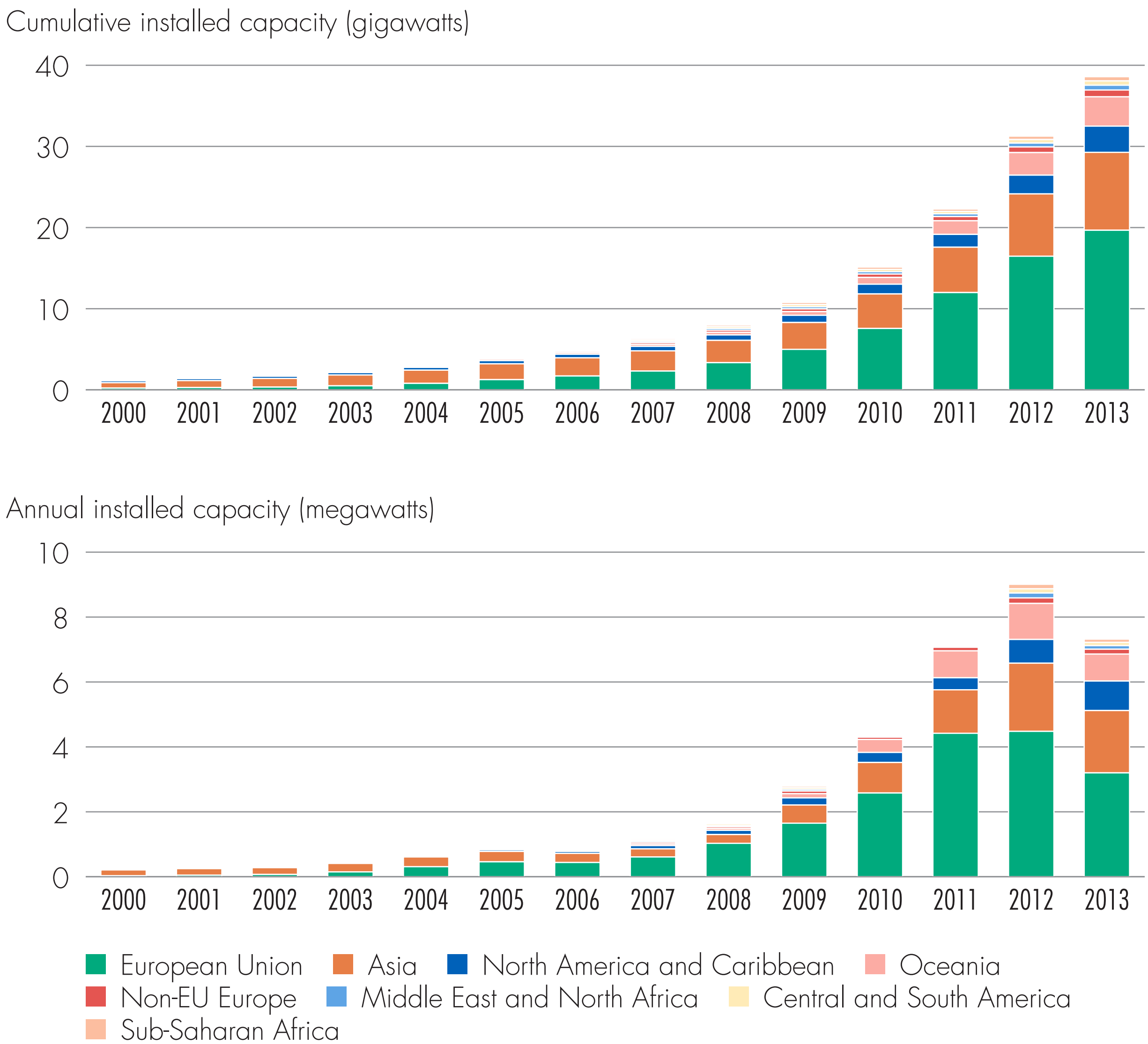


Source: IEA PVPS 2014.

a. Such systems fulfill the functions of centralized power stations. The power delivered by such a system is not associated with a particular electricity customer, and the system is not located to specifically perform functions on the electricity network other than the supply of bulk power.

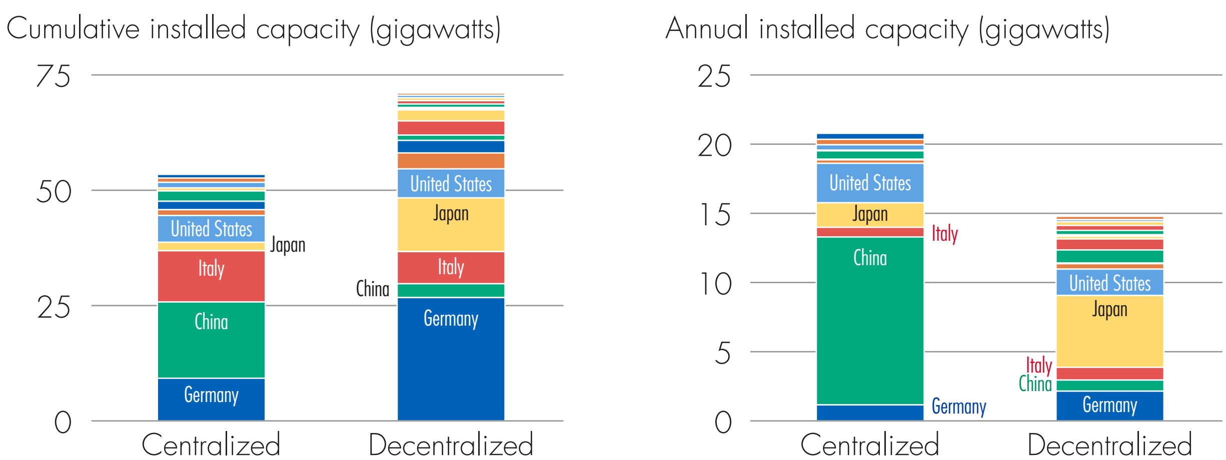
b. Such systems are installed to provide power to a grid-connected customer or directly to the electricity network (specifically at the distribution voltage level). Such systems may be on or integrated into the customer's premises, often on the demand side of the electricity meter.

Figure A3.4. **Global evolution of solar photovoltaic (≤ 20 kW), 2000–13**



Source: BNEF 2014c.

Figure A3.5. **Global capacity of grid-connected solar photovoltaic, 2013**



Source: IEA PVPS 2014.

Annex 4. Access to technology

The tables below present data on trade in the basket of 12 products relevant to sustainable energy as a percentage of GDP, by income group.

Table A4.1. **Trade in relevant products as a share of GDP by income group, 2013 (%)**

Renewable energy

Income group (number of countries)	**Solar photovoltaic and LEDs** HS Code 854140	**Wind turbines** HS Code 850231	**Biodiesel** HS Code 382600	**Hydro turbines (1–10 MW)** HS Code 841012
Low income (34)	0.031	0.011	0.000	0.001
Lower middle income (50)	0.075	0.008	0.027	0.001
Upper middle income (55)	0.183	0.014	0.010	0.001
High income (75)	0.127	0.021	0.031	0.000

Energy efficiency

Income group (number of countries)	**Reversible heat pumps for air conditioning** HS Code 841581	**Heat pumps** HS Code 841861	**Fluorescent discharge lamps (CFLs)** HS Code 853931	**Insulation** HS Code 701939, 680610 & 680690	**Electric- and gas-powered vehicles** HS Code 870390
Low income (34)	0.004	0.002	0.013	0.004	0.010
Lower middle income (50)	0.003	0.001	0.015	0.008	0.009
Upper middle income (55)	0.010	0.002	0.030	0.011	0.002
High income (75)	0.006	0.007	0.010	0.017	0.011

Energy access

Income group (number of countries)	**Portable electric lamps with their own source of energy** HS Code 851310	**Parts of portable electric lamps with their own source of energy** HS Code 851390	**Hydro turbines (< 1 MW)** HS Code 841011
Low income (34)	0.028	0.000	0.0003
Lower middle income (50)	0.009	0.000	0.0003
Upper middle income (55)	0.017	0.000	0.0003
High income (75)	0.006	0.000	0.0002

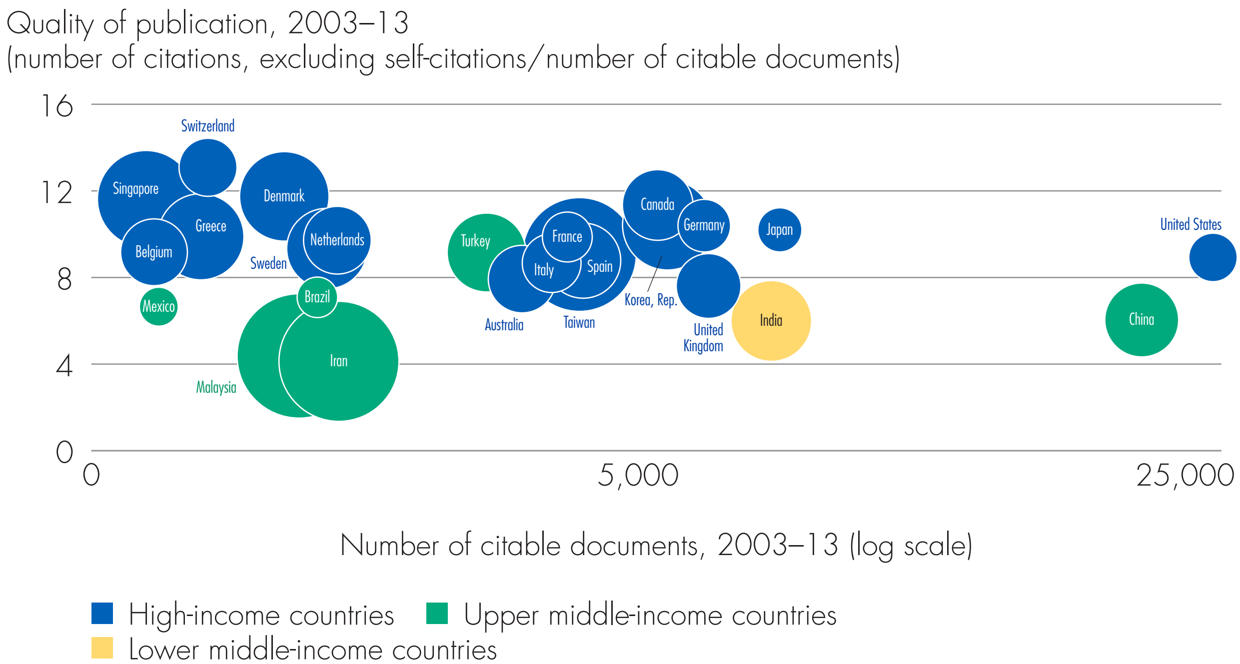
Source: World International Trade Solutions database (World Bank 2014).

Table A4.2. **Activities in the value chain of selected renewable energy technologies and distribution of value (%)**

Technology	Major equipment	Engineering, procurement and construction/balance of system	Operations and maintenance
Onshore wind	57	22	21
	Turbine	Civil works 44 Balance of system 31 Other costs 25	Insurance Routine component and equipment maintenance Replacement parts and materials
Solar thermal	45	37	19
	Solar collector	Civil works Balance of system Other costs	Routine inspection Maintenance of absorption and adsorption chillers
Solar photovoltaic	54 (> 1 MW) 45 (< 1MW)	36 (> 1 MW) 46 (< 1MW)	10 (> 1 MW) 9 (< 1MW)
	PV module	Civil works 57 Balance of system 29 Other costs 14	Routine inspection Preventative maintenance Corrective maintenance
Concentrated solar power	36	55	9
	Solar field 80 Thermal storage system 20	Civil works 35 Balance of system 30 Other costs 35	Routine inspection Preventive maintenance Corrective maintenance
Small hydro	23	57	20
	Electromechanical equipment	Civil works 65 Balance of system 25 Other costs 10	Fixed costs Variable costs
Geothermal	32	45	23
	Power plant	Civil works 40 Balance of system 30 Other costs 30	Fixed costs Variable costs
Bioenergy	42	27	32
	Feedstock conversion system 80 Prime mover 20	Civil works 30 Balance of system 50 Other costs 20	Fixed costs Variable costs
Biofuels	46	27	27
	Major equipment	Civil works Balance of system Other costs	Fixed costs Variable costs

Source: World Bank 2014.

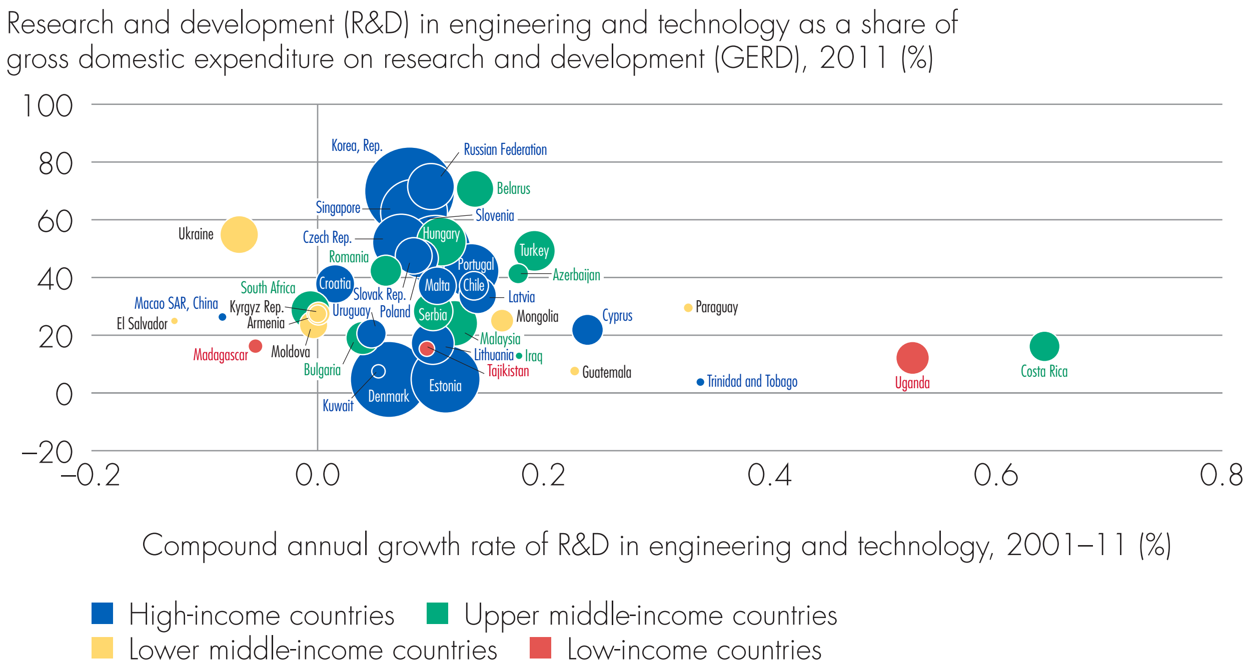
Figure A4.1 **Publications and citations in renewable energy: Top 25 countries**

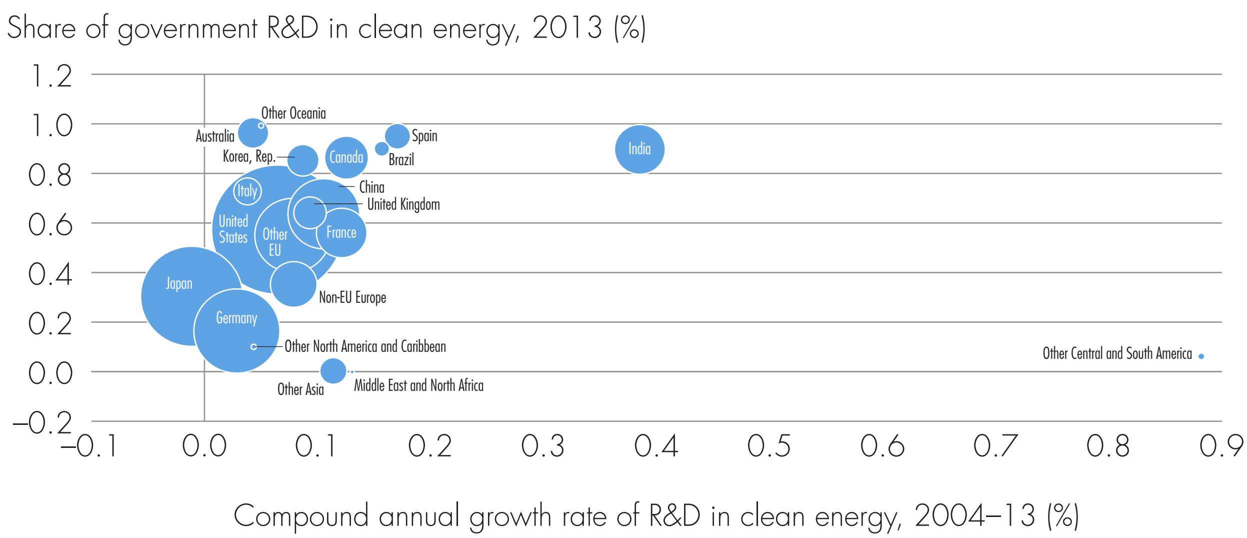


Source: SCImago Journal and Country Rank database (Subject area: Energy; subcategory: Renewable energy, sustainability and the environment).

Note: Size of bubble reflects number of citable documents per unit of GDP by country.

Figure A4.2 **Research and development as a percentage of GDP**



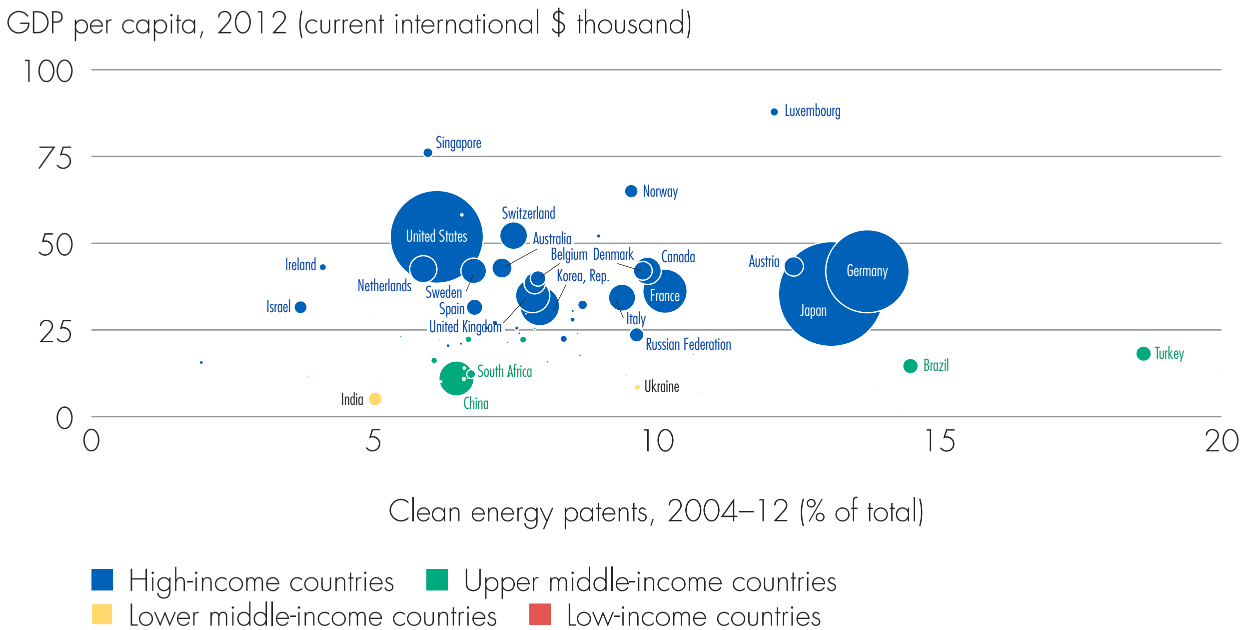


Engineering and technology Clean energy

Source: UNESCO Institute for Statistics; BNEF 2014a.

Note: Size of bubble reflects GERD (upper figure) or government R&D in clean energy (lower figure) as a share of GDP by country. Other Central and South America not depicted here (CAGR of 0.9; government share of 0.06). Clean energy includes RE technologies, energy smart technologies, low carbon services, and support.

Figure A4.3: **Patent publications in clean energy, 2004–12[a]**



Source: WIPO IP Statistics Data Center (WIPO 2014).

a. Based on the IPC Green Inventory developed by the International Patent Classification Committee of Experts to facilitate searches for patent information relating to so-called "environmentally sound technologies" as listed by the United Nations Framework Convention on Climate Change.

Note: Size of bubble reflects number of patents in clean energy by country.

Notes

1. Data and figures presented are meant only to demonstrate the advantages of the multitier approach over binary measurement; the authors are not responsible for the quality of the data or the accuracy of the results.
2. In GTF 2013, energy intensity values were presented at market exchange rates as well as in 2005 PPP terms. PPP factors are updated at intervals of several years, and this volume uses the recently released 2011 PPP figures.
3. This section draws on the IEA's recent publications on constructing energy efficiency indicators based on analysis of energy consumption in more than 20 residential, services, industry, and transport end uses (IEA 2014a, 2014b, and 2014e).
4. Industry covers the manufacture of finished goods and products, mining and quarrying of raw materials, and construction. Power and heat generation, refineries, and the distribution of electricity, gas, and water are excluded in the results throughout this chapter.
5. Pipelines and international air and marine transport are excluded here.
6. With the data available in energy balances, the current distinction assumes that all solid biofuels are used in the residential sector, and that in developing economies solid biofuels are entirely devoted to traditional purposes, which implies unsustainable or nonrenewable harvesting.
7. Except, perhaps, in the natural gas, shale gas, and shale oil industries.
8. The questionnaire defines off-grid electricity as "electricity generated in plants that are off the main grid, that is to say in stand-alone systems and mini-grids. Off-grid capacity refers to the capacity of these stand-alone systems and mini-grids."
9. Target setting requires expertise in RE accounting methodologies. It also requires a robust energy statistical framework yielding repeatable and reliable data.
10. There is growing consolidation of companies manufacturing hydropower turbines globally: in 2013 just five countries accounted for 65 percent of exports of small hydro turbines (China, Germany, Austria, the

United States, and Italy). Very few developing countries have developed value chains for manufacturing small turbines, and those that have generally have little production capacity and a narrow range of capacity scales. Only one LIC and two LMICs export small hydropower turbines (India, Democratic Republic of Congo, and Sri Lanka).

11. There are three types of import tariffs: most-favored nation (MFN), preferential, and bound tariffs. In general, the bound rate is the highest tariff, the preferential the lowest, and the MFN is somewhere in between. For our analysis we have used the effective or lowest available tariff. If a preferential tariff exists, it is used as the effective tariff, otherwise the MFN is used. Tariffs can also take several forms; this analysis uses the most common form, the ad valorem tariff, which means that the customs duty is calculated as a percentage of the product's value.
12. Financial measures are intended to regulate the access and cost of foreign exchange for imports and define the terms of payment. Contingent trade protective measures include anti-dumping, countervailing, and offsetting measures.
13. Figure A4.1 presents the top 25 countries in number and quality of publications in renewable energy.
14. https://www.lightingglobal.org.
15. Value-added data are from WDI and UNSD's National Account Main aggregate database.
16. Total final energy consumption (TFEC) is a variable defined solely for the purposes of this report and does not directly correspond to any of the flows published in the IEA World Energy Statistics and Balances (2014). The word "Total" refers to the sum across fuels rather than sectors. The quantity corresponds to the sum of the final energy consumption in the end use sectors (industry, transport, and other) across all fuels.
17. Various factors seem to have influenced this policy decision, including social and environmental concerns, grid-connection issues, and projects' incremental costs.
18. Grid-connected RE in decentralized schemes can also be referred to as RE in distributed generation. Distributed generation can be defined as electricity generation from small-scale dispersed systems that are typically close to the point of consumption and are connected at distribution voltage.
19. Data used for tracking PV in distributed generation come from BNEF and IEA, which gather this data very differently. BNEF tabulates data by system size, while the IEA collects data by system type. The IEA broadly classifies data on PV as on-grid and off-grid. It further disaggregates on-grid systems according to centralized and decentralized systems. In the same way, off-grid systems are disaggregated by the type of use: domestic and nondomestic.

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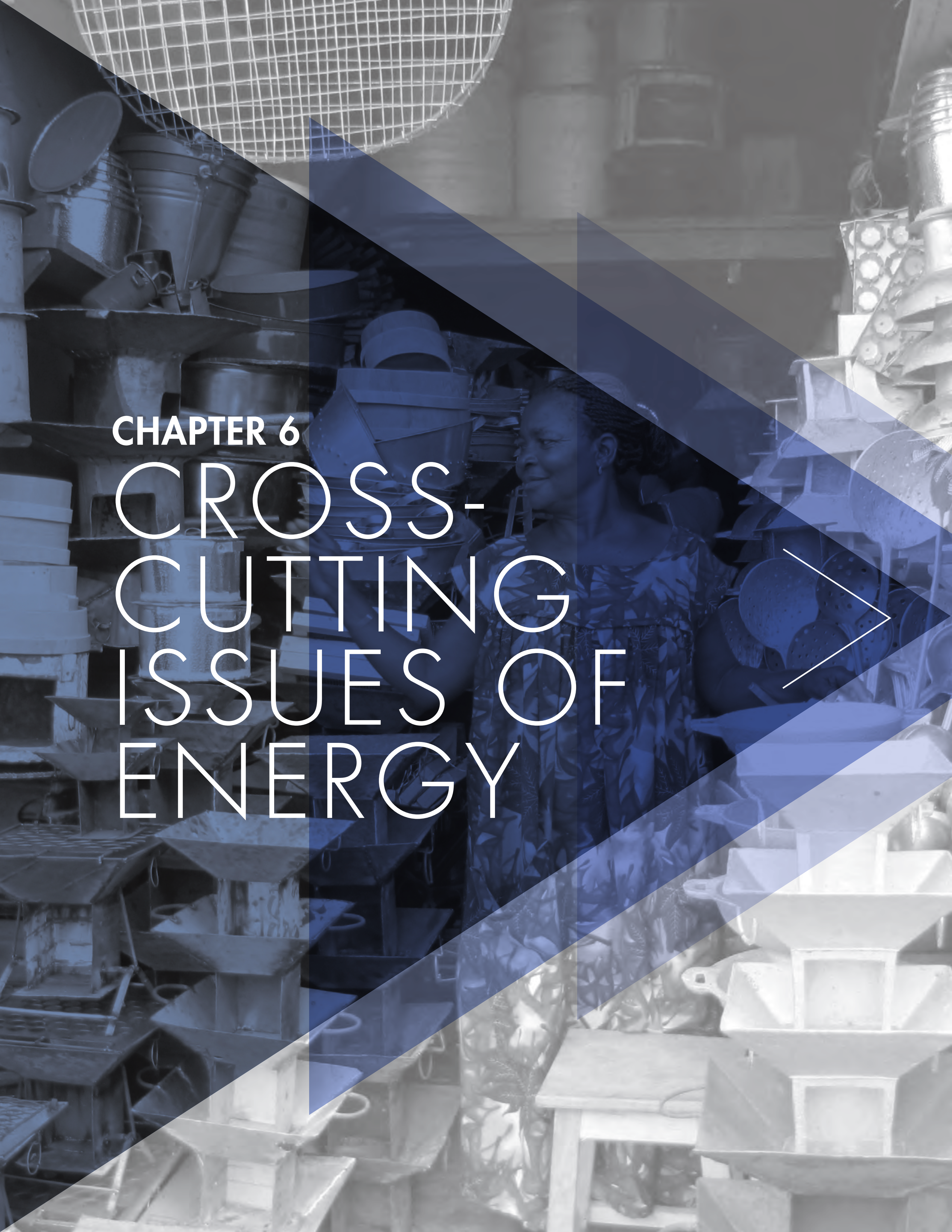


CHAPTER 6
CROSS-CUTTING ISSUES OF ENERGY

Cross-cutting issues of energy: Exploring the nexus of water, food, health, and gender

Highlights

- The energy sector is intertwined with water, food, public health, and gender matters. Hence a nexus perspective increases understanding of these interdependencies, enhancing efficiency, balancing trade-offs, building synergies, and improving governance. Energy helps to achieve secure and equal access to productive resources and inputs, helps to sustain food production systems, and helps to boost investment in rural infrastructure and technology. It also facilitates access to safe drinking water and sanitation, improvement of water quality, and expansion of wastewater treatment. Energy can help reduce death and illness from air, water, and soil pollution and contamination. It can also support women's equal rights to economic and natural resources, enhance use of enabling technology, and help prevent violence against women and girls in public and private places.

- The three objectives of Sustainable Energy for All (SE4All) are closely interwoven into the four nexus areas—water, food, health, and gender. Providing universal access to modern energy services, increasing the share of renewable energy (RE), and improving energy efficiency will greatly influence them.

- The SE4All objectives generate multiple nexus opportunities and challenges. Water security may be increased if water-related risks are managed well and contamination risks minimized. Similarly, food security may improve, and RE sources may help decouple food prices from energy prices, while managing production of energy crops. Global health may improve further as efforts focus on reducing air pollution and strengthening health services delivery. Finally, gender equality can be enhanced as time poverty decreases through better energy services and as women participate more actively in the energy value chain.

- Although existing data capture part of the nexus approach, improvements are needed in all four sectors to accurately monitor intersectoral impacts, supporting policymakers in developing integrated policies.

Introduction

The energy sector's interactions with water, food, public health, and gender are tightly linked to energy services and energy systems. They are also fundamental to meeting the objectives of Sustainable Energy for All (SE4All). Numerous opportunities will arise from more holistic decision making in energy if a wider set of cross-sectoral perspectives can be generated.

This chapter, part of the SE4All *Global Tracking Framework (GTF)* for the first time (in this 2015 edition), is different from the other three main, quantitative chapters (2, 3, and 4) that track the direct objectives of SE4All. Rather, this chapter is conceptual and introduces nexus concepts addressing four areas and their links to energy: water, food, health, and gender. While energy has links to and influences many other areas (such as education), these four form the initial foray for the GTF. The chapter also considers existing data and indicators, and gaps in them.

What is a nexus?

The interlinked nature of the development challenge is often known by the term "nexus." It simply means that two or more elements, or sectors, are inextricably intermeshed and that actions in one area have impacts on one or more of the others. The literature has highlighted multiple links between environmental, social, and economic development factors: development objectives such as poverty reduction, shared prosperity, and environmental sustainability cannot be addressed in isolation: they require an integrated approach.

The Sustainable Development Goals (SDGs) for energy seem to be interleaved with other goals such as water and sanitation, food security and nutrition, health, and gender. Energy facilitates, for example, access to safe drinking water and sanitation, improvement of water quality, and expansion of wastewater treatment. It also helps achieve secure and equal access to productive resources and inputs, sustainable food production, and increased investment in rural infrastructure and technology development. Energy can contribute to reducing death and illness from air, water, and soil pollution and contamination. It can also support women's equal rights to economic and natural resources, enhance use of enabling technology, and help curtail violence against women and girls in public and private places.

The term *nexus* has in particular been used to describe interdependencies in managing resources. The *energy-water-food nexus* refers to the synergies and trade-offs between the use of energy and water and the production of food. Attaining the SDGs hinges on availability of these resources, and on responsible and efficient resource use that limits humanity's impact on the climate and on ecosystems. Hence the need to analyze how all these systems interact and overlap.

The *energy-health* nexus encapsulates the positive and negative effects of energy on global health. Reduced energy poverty offers huge benefits for human health, but energy systems can also have negative impacts due to air pollution from incomplete combustion of fossil fuels and solid biofuels. As energy demand is expected to grow, particularly in emerging economies, the impact of energy systems on the global burden of disease may rise unless health-sensitive energy policy interventions are introduced.

Finally, the *energy-gender* nexus focuses on the role of energy in gender equality and in women's empowerment. Links between energy and gender have garnered greater attention, as evidence shows that improving gender equality and social inclusion is critical to maximizing the development impacts of energy programs. As emphasized by the *World Development Report 2012: Gender Equality and Development* (World Bank 2012a), greater gender equality can enhance productivity, make institutions more representative, and improve development outcomes for the next generation.

Why the nexus approach?

Despite growing awareness of the interconnectedness of the SDGs, the global community has so far addressed nexus challenges in isolation. It has neglected intersectoral links, often leading to incoherent and inconsistent strategies that fail to leverage synergies and balance trade-offs. Per the *World Water Development Report 2014*, "at the country level, fragmented sectoral responsibilities, lack of coordination, and inconsistencies between laws and regulatory frameworks may lead to misaligned incentives" (WWAP 2014, p. 61). There is, however, an emerging consensus that systemic problems should be addressed in a holistic manner focusing on inherently interlinked aspects to obtain sustainable outcomes. The World Economic Forum argues in its 2011 report that "any strategy that focuses on one part of the water-food-energy nexus without considering its interconnections risks serious unintended consequences" (van der Elst 2011). Any responsible development pathway therefore needs to account for these interdependencies in order to be coherent. Decision makers—even those responsible for only one sector—need to consider cross-sectoral impacts if energy, water, and food security are to be simultaneously achieved, global health improved, and gender equality promoted.

A nexus perspective increases the understanding of the interdependencies across sectors, enhancing efficiency, balancing trade-offs, building synergies, and improving governance across sectors. It builds the informed and transparent frameworks necessary to meet the world's increasing energy, water, and food demand, without compromising sustainability, and ensuring optimum health impacts and gender equality. Conventional policy and decision making in silos should therefore give way to an integrated approach.

Decision makers should develop strategies and investments to explore and exploit synergies, and to identify and optimize trade-offs among the intersecting objectives. The recognition has been growing that a more integrated approach to policy and practice of sustainable development is needed in the post-2015 world to break down the silo approach and to focus instead on the coherence of the SDGs and their targets. The preamble to the Open Working Group's final document of late 2014 states that the proposed SDGs constitute "an integrated, indivisible set of global priorities for sustainable development."

Although the theory of coordinated strategies and actions sounds wonderful, the reality is a different matter. Governance is first and foremost sectoral and emanates from discrete, institutional entities. Coordination between, for example, ministries—as well as between levels of government (national and local)—has often failed to reach expectations. Such failures may be driven by power rivalries among ministries, whether political or personal, further exacerbated by unclear or overlapping responsibilities and jurisdictions. Frequently the capacity (human, skills, funding, and infrastructure) may not be enough: short of resources, institutions' priorities will often be core duties, leaving cross-cutting efforts to suffer.

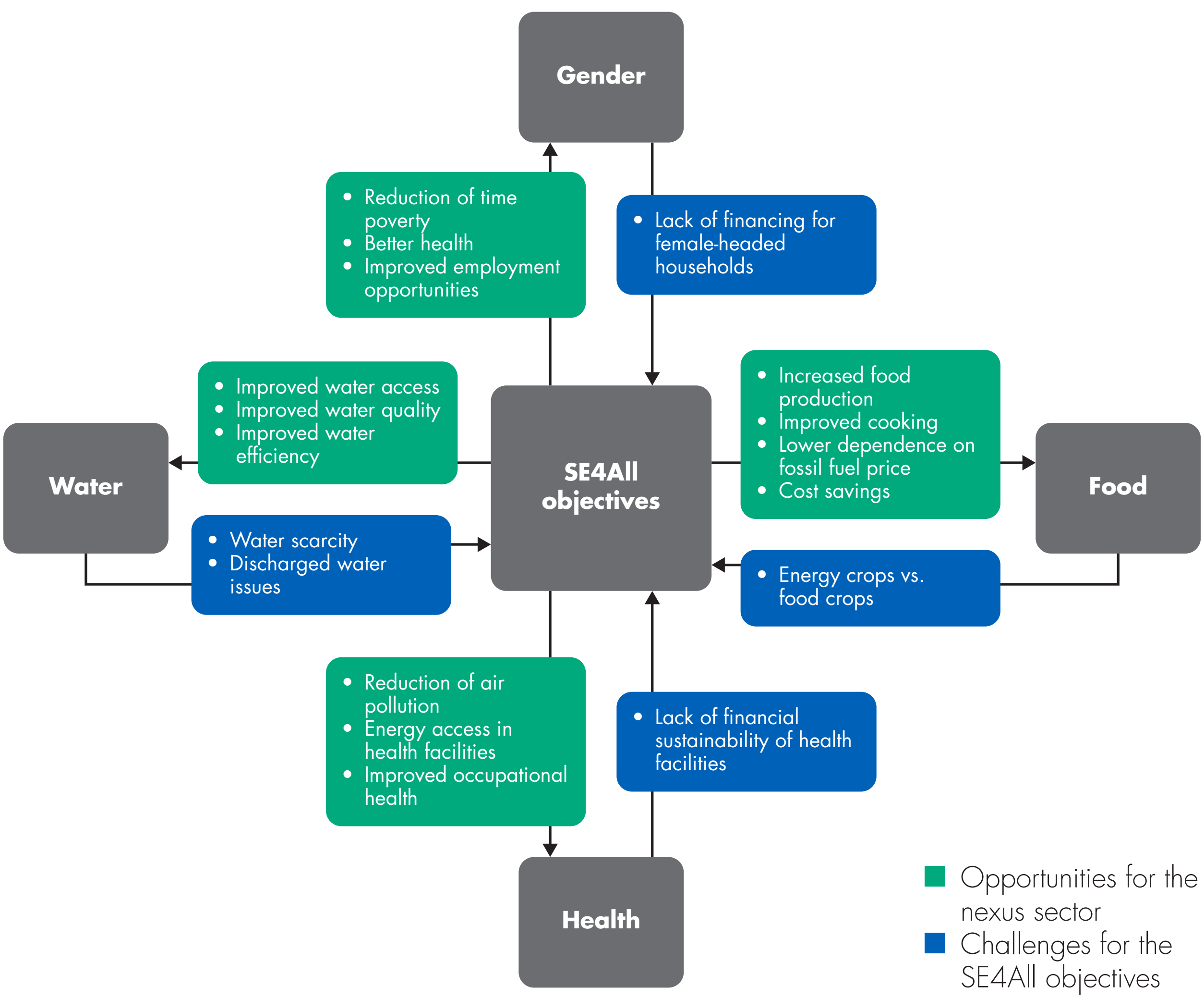
Adopting and realizing a nexus approach require robust incentives and frameworks that stimulate stakeholders to take part. This is because—despite a broad consensus on the potential of the nexus perspective—implementation faces many hurdles. Policies, incentives, and empowering frameworks to avoid unintended consequences are all necessary, bringing in government agencies, the private sector, and civil society. An evaluation system completes the loop.

Indicators that track the contribution of one sector to others inform decision makers, encourage coordination, and guide progress, offsetting data gaps and asymmetric access to information that can block cohesive governance. If information is missing or not available to all departments or levels, this can hamper productive dialogue and action. Thus arises the need for information and measurement systems on nexus indicators that enhance coordination and provide guidance on achieving tangible outcomes.

The nexus and SE4All

Achieving the SE4All objectives has implications for water and food security, global health, and gender equality. The three SE4All objectives are closely interwoven into the four nexus areas analyzed in this chapter, and so providing universal access to modern energy services, increasing the share of RE, and improving energy efficiency will affect them all. These implications may entail opportunities or challenges (figure 6.1). Thus identifying the intersectoral

Figure 6.1. **Implications of SE4All objectives for the four nexus sectors**



Source: Authors.

relationships early on is of great importance in targeting synergies and forestalling potential tensions. The means by which the SE4All objectives are pursued (policies, regulations, technology, and institutions) will determine the positive and negative impacts on nexus areas.

Water requirements will depend on the amount of energy produced and on the technology mix. Improved energy access will raise the energy available for extracting and treating water, but will add pressure on water resources. A higher share of RE in the energy mix may help reduce water intensity in energy, as photovoltaic (PV) panels and wind energy gain share, but global energy supply from water-intensive thermal plants is also expected to grow. Water efficiency should increase as old, inefficient power plants are replaced.

Food security will benefit. Access to modern energy services in agriculture helps raise food production, often improving farm income, while the uptake of RE in agrifood systems helps in decoupling agricultural production from the fossil fuels market. Energy efficiency in agriculture and agrifood systems usually has a positive effect on economic returns of food production in the long run through savings on energy costs.

Access to modern energy services cuts air pollution, particularly electric lighting and clean cooking and heating solutions, while reliable access to energy in often-remote health facilities should also improve access to health services. Such facilities could become anchor customers, committing to off-take electricity, and incentivizing energy providers to enter remote markets, although their financial ability to do this should be scrutinized. RE, too, can reduce outdoor air pollution and improve occupational health in that it replaces polluters of air, water, and soil. Energy efficiency may improve indoor and outdoor air pollution, and modern appliances should enable off-grid health facilities to provide a wider range of health services.

Women and men will be affected differently as the world moves toward the SE4All objectives. Improved access reduces time poverty and drudgery, particularly for women, and improves indoor air pollution (which disproportionately affects women and children). Dissemination of RE off-grid solutions to the base of the economic pyramid may be boosted by women entrepreneurs, if empowered.

The next four sections explore the links between energy, on the one hand; and water security, food security, global health, and gender equality, on the other. Each section first analyzes the indicators needed for monitoring progress toward the SE4All objectives and second proposes tentative nexus indicators—summarized in tables 6.1, 6.2, 6.3, and 6.4—to enable better monitoring.

Energy and water

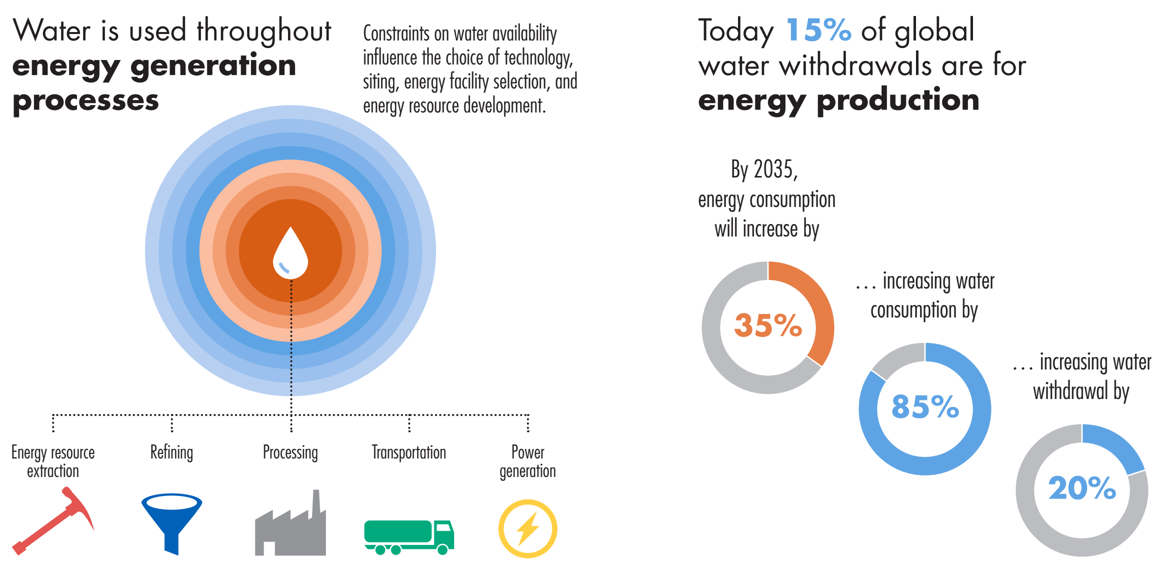
Introduction

The trade-offs between energy and water have been gaining international attention in recent years as demand for resources mount and as governments continue their struggles to ensure reliable supply to meet sectoral needs. About 748 million people still lack access to improved sources of drinking water. Nearly half of those people are in Sub-Saharan Africa. And more than one-third of the global population—around 2.5 billion people—remains without access to improved sanitation (WHO-UNICEF 2014). Water scarcity already affects every continent. Some 1.2 billion people live in areas of physical scarcity,[1] and 500 million are approaching this situation, while another 1.6 billion people face economic water shortage,[2] as countries lack the infrastructure to take water from rivers and aquifers (FAO 2007).

Energy and water resources are inextricably tied together. Huge amounts of water are needed, in almost all energy generation, including fossil fuel extraction and processing (figure 6.2). Conversely, the water sector needs energy to extract, treat, and transport water. Energy and water are used in producing crops, including those generating energy through biofuels. This relationship is what is known as the energy-water nexus (sometimes the energy-water-food nexus) (U.S. DOE 2014; WWAP 2014; Bazilian et al. 2011; Stillwell et al. 2014). These interdependencies could complicate solutions and make a compelling case to improve integrated water and energy planning to forestall unintended outcomes.

While the energy-water challenge is increasingly recognized, energy planners and governments often plan without considering existing and future water constraints. Planners in both sectors are frequently ill-informed about the drivers of these challenges, how to address them, and the merits of technical, political, management, and governance options, which themselves are poorly tracked. Hence it is vital to develop indicators (integrated where possible) and tools that tackle energy and water challenges on a country basis. Integrated planning will become crucial to ensure a sustainable strategy for many

Figure 6.2. **Water needs in the energy sector**



Source: Rodriguez, Delgado, and Sohns 2014.

Note: For example, in 2012, the *World Energy Outlook* of the International Energy Agency (IEA) concluded that water constraints could challenge the reliability of existing energy operations, require costly adaptive measures, and threaten the viability of proposed projects. Expansion plans for coal power plants in China and India, for instance, could become unfeasible due to water scarcity (Adelman 2012). In water-scarce regions like the Middle East and North Africa, desalination of water, which is very energy intensive, is increasing energy demand substantially, pushing water utilities to explore ways to reduce their energy demand, produce energy on site, or both (World Bank 2012b; Siddiqi and Anadon 2011). In the United Arab Emirates in 2010, for example, desalination absorbed an estimated 24 percent of total energy needs (World Bank 2012b).

countries, especially where climate change, urbanization, and population and economic growth are going to exacerbate water scarcity (Rodriguez et al. 2013; Hadian and Madani 2013).

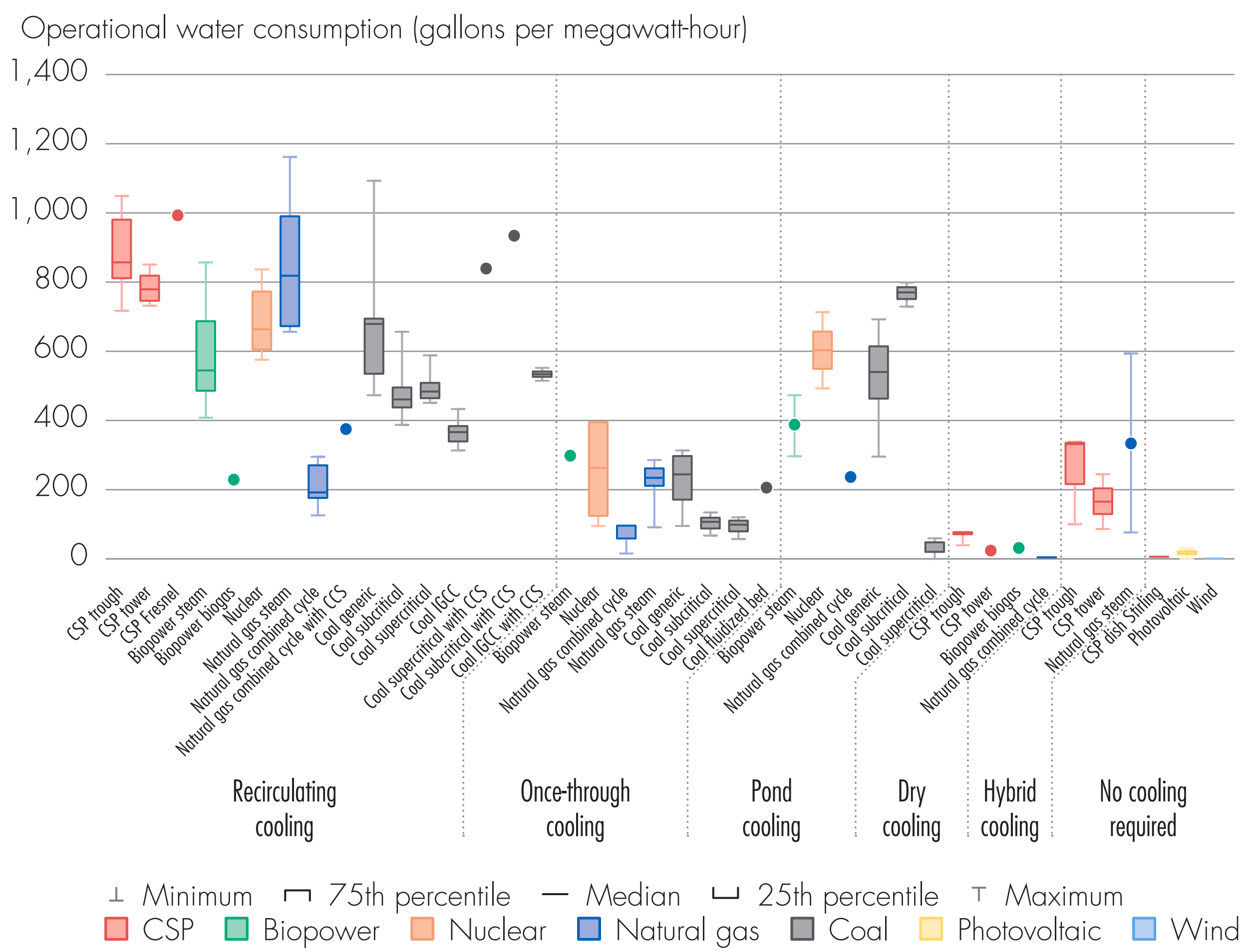
Energy-water nexus and the SE4All objectives

Energy can affect water security[3] elements such as access, safety, and affordability. Access to water can be jeopardized by insufficient or intermittent supply of electricity (or liquid fuel) for pumping, treating, and distributing water. Reliable and affordable access to energy can ensure continuous supply of the required quantities of safe water as well as wastewater treatment services. Improved energy access can also support the use of energy-intensive technologies, such as desalination or more powerful groundwater pumps, which are expected to expand rapidly as easily accessible freshwater resources are depleted (IRENA 2015).

In 2030, almost half of the world population will be living in areas of high water stress if no new policies are introduced (WWAP 2012) and the increased demand for energy could put additional pressure on already constrained water resources. With extraction of energy resources, such as oil, gas and coal, and unconventional sources such as shale and tar sands, water is required for acquiring, transporting, processing, and refining (Mauter et al. 2014; IEA 2012; Fry et al. 2012). Thermal power plants,[4] such as fossil fuel, nuclear, and concentrated solar power plants, require large amounts of water, mainly for cooling, depending on the type of cooling system (Rodriguez et al. 2013; NETL 2009; figure 6.3)[5]. So they are often placed near a water source (river, lake, or ocean). Solar power also requires water for washing collectors and panels. Hydropower can be generated only if water is available in reservoirs or rivers. Finally, feedstock production for biofuels may depend on irrigation (Stone et al 2010).

The energy sector not only withdraws and consumes water (box 6.1), altering water flow patterns and water quantities, but also generates substantial wastewater. Energy operations can greatly undermine water resources through post-production water discharge and possible contamination of aquifers during drilling (IRENA 2015). Water used during

Figure 6.3. **Operational water consumption factors for electricity-generating technologies**



Source: Macknick et al. 2011.

Note: CSP is concentrating solar power. CCS is carbon capture and sequestration; IGCC is integrated gasification combined cycle.

extraction and wastewater generated from energy production must be managed carefully to protect the environment and water resources in the long term. But under stringent regulations, wastewater treatment may add heavy costs.

Changing water supply patterns—due to unanticipated weather activity, reallocation of water resources into other sectors or new regulations—may constrain opportunities for power generation or energy extraction (IRENA 2015). Climate change is intensifying energy insecurity through changing rainfall and surface runoff averages, increased water temperatures, and greater probability of extreme weather conditions (US DOE 2013, van Vliet 2012). Water scarcity, variability, and quality can constrain or raise the cost of thermal power generation and energy extraction (although in most cases the cost of accessing water is small compared with the revenue generated). In the United States, several power plants have been affected by low water flows or high water temperatures (U.S. DOE 2013). In India, a thermal power plant had to shut down due to a severe water shortage (Rajput 2013). France has been forced to reduce or halt energy production in nuclear power plants during heat waves, due to high water temperatures threatening cooling processes (van der Elst 2011). Recurring and prolonged droughts are threatening hydropower capacity in many countries, such as Brazil (Barrucho 2013), China (Stanway 2011), Sri Lanka (Sirilal 2012). The likely consequences are alarming enough to require more accurate integrated planning tools urgently.

Box 6.1. **The difference between water withdrawn and water consumed**

To ensure that water-energy indicators are useful, it is important to understand the difference between water withdrawn and water consumed, as the amounts vary greatly.

Withdrawal is typically defined as the amount of water taken from a water source (such as lake, river, ocean, or aquifer). Consumption is the water not returned to the water body after use. Discharge is the amount of water returned to the water source, and its quality matters for environmental reasons. These requirements for and impacts on water resources can differ sharply depending on the type of process or technology employed.

Hydropower, for example, requires large quantities of water, but the water is only diverted and can be used downstream by other sectors, such as agriculture. However, depending on certain climate conditions, some water evaporates from the reservoirs. In biofuels, most of the water is consumed through irrigation, and a small amount is returned to the water body. In thermal power plants, large quantities of water are withdrawn for cooling, but most of the water is returned to the freshwater source. For example in the United States, the thermal power sector accounts for about 40 percent of total freshwater withdrawals, but only 4 percent of consumption (Maupin et al. 2014).

However, even if water use does not involve consumption, the timing of water releases and other water quality issues can have material impacts on other sectors or hinder other simultaneous use. This can raise trade-offs and potential conflicts with other water uses, particularly in water scarce regions and basins.

There are no simple solutions, as seen in the fact that raising the share of water-intensive RE sources, such as irrigated biofuels and thermal power sources,[6] can increase demand for water, exacerbating competition with other sectors and creating social tensions among users. However, greater use of RE sources that require small volumes of water, such as PV panels and wind energy,[7] could reduce energy's water needs (IRENA 2015; Liu et al. 2015). The state of Texas, for example, to cope with drought and the state's arid climate, has seen over 12 GW of wind energy plants installed (U.S. DOE 2014).

Similarly, increasing the share of hydropower may facilitate water access to other sectors if the multipurpose benefits of dams are developed. Hydropower planners are of course fully conversant with the energy-water nexus, and hydropower normally sees only small water consumption caused by evaporation from the reservoir. However, reservoir water can also be used for irrigation, water supply, flood control, and recreation. And while hydropower projects are sparse consumers of water, they may materially affect the quality of downstream flows (timing, route, and duration), stressing fish and other aquatic life (IRENA 2015). Run-of-river hydropower plants, which store no water, have water-evaporative losses near zero but are less likely to be used for generation of peak loads or during dry seasons. They can also have potential cumulative ecological impacts downstream.

Despite the potential losses from reservoirs, hydropower dams may increase water availability for downstream users when needed most, as during a drought. They may also be used to mitigate impacts from other extreme events such as floods—all of which underlines the benefits of joint planning for equitable, sustainable power and water infrastructure in river basins.

The impact of biofuels and biodiesel on water use varies substantially, depending on where the biofuel crop is planted, and whether it implies land conversion or land use changes, requires irrigation, or replaces a more (or less) water-intensive crop (Gerbens-Leenes and Hoekstra 2011; Stone et al. 2010). Ambitious plans in China and India to boost domestic production of biofuels could therefore place extra pressure on already scarce water supplies, if traditionally irrigated food crops are used to meet bioenergy targets. If biofuels are grown in rain-fed regions, however, they may have only a slight impact on water allocations. For example, in Brazil, where most sugarcane is rain-fed, a liter of ethanol requires only 90 liters of irrigation water to produce. But in India a liter of ethanol can take up to 3,500 liters of irrigation water (IWMI 2008). Again, plans and forward-looking assessments are needed.

Solar-based solutions can offer an alternative to grid- or diesel-based electricity for water pumping, water heating, and desalination, mitigating environmental impacts and in some places reducing energy subsidies. That is why, despite high capital costs and lack of established solar pump markets, India plans to replace 26 million groundwater pumps for irrigation with solar pumps. The drawback is that solar pumps can stimulate excessive (and unsustainable) water withdrawal given that operational costs are negligible (IRENA 2015). Solar water heaters are generally competitive with electricity- and gas-based heating and are making their way into emerging markets such as China (IRENA 2015). And although desalination based on solar energy is still expensive, moves like Saudi Arabia's Solar Water Desalination initiative will drive down costs and advance the technology, no doubt turning solar desalination into a competitive solution in the long term (IRENA 2015).

But beyond RE production increases, increased efficiency on the supply and demand sides must be maximized. On the supply side, one approach to enhancing efficiency is to shift from old, inefficient power plants to new and more efficient ones, both to save energy and water and to decrease greenhouse gas emissions. The amount of cooling water withdrawn and consumed by thermal power plants (with the same cooling system) is determined mainly by the power plants' efficiency (Delgado 2012). For example, old coal power plants with an efficiency of 25 percent may well require almost twice the amount of water of new coal power plants with an efficiency of 36 percent (with the same type of cooling system). Combined-cycle gas turbines (CCGTs) waste less heat per unit of electricity produced due to higher thermal efficiency, and so they require less cooling (IEA 2012). Water-use efficiency may also be improved by fostering water-efficient cooling systems in thermal power plants such as dry-cooling systems.[8]

All options carry a series of trade-offs, however: power plants with dry-cooling systems consume up to 90 percent less water than power plants with cooling towers (U.S. DOE 2014), but dry-cooled systems can cost 2–16 percent more than closed-loop cooled systems (Maulbetsch and DiFilippo 2006). Dry cooling also decreases the energy efficiency of the power plant, particularly in hot and dry climates. These trade-offs must be evaluated case by case, considering factors such as regional conditions, ambient conditions, and regulations.

On the demand side, energy efficiency gains—those, for example, from energy-efficient appliances and equipment and improved insulation—would decrease demand for energy, saving water (given that most energy generation requires water).

Increased energy efficiency in the water sector may cut the cost of delivering water and save water. Electricity costs usually stand at 5–30 percent of total operating costs for water and wastewater utilities. The share is usually higher in developing countries, where it might hit 40 percent or more. Such energy costs often contribute to high and unsustainable operating costs that directly affect utilities' financial health (ESMAP 2012). Finally, because treating and distributing water requires heavy energy consumption, leakage reduction is a cost-effective way to save not only water but also energy. And it is a solution often adopted alongside more efficient pumps (Barry 2007).

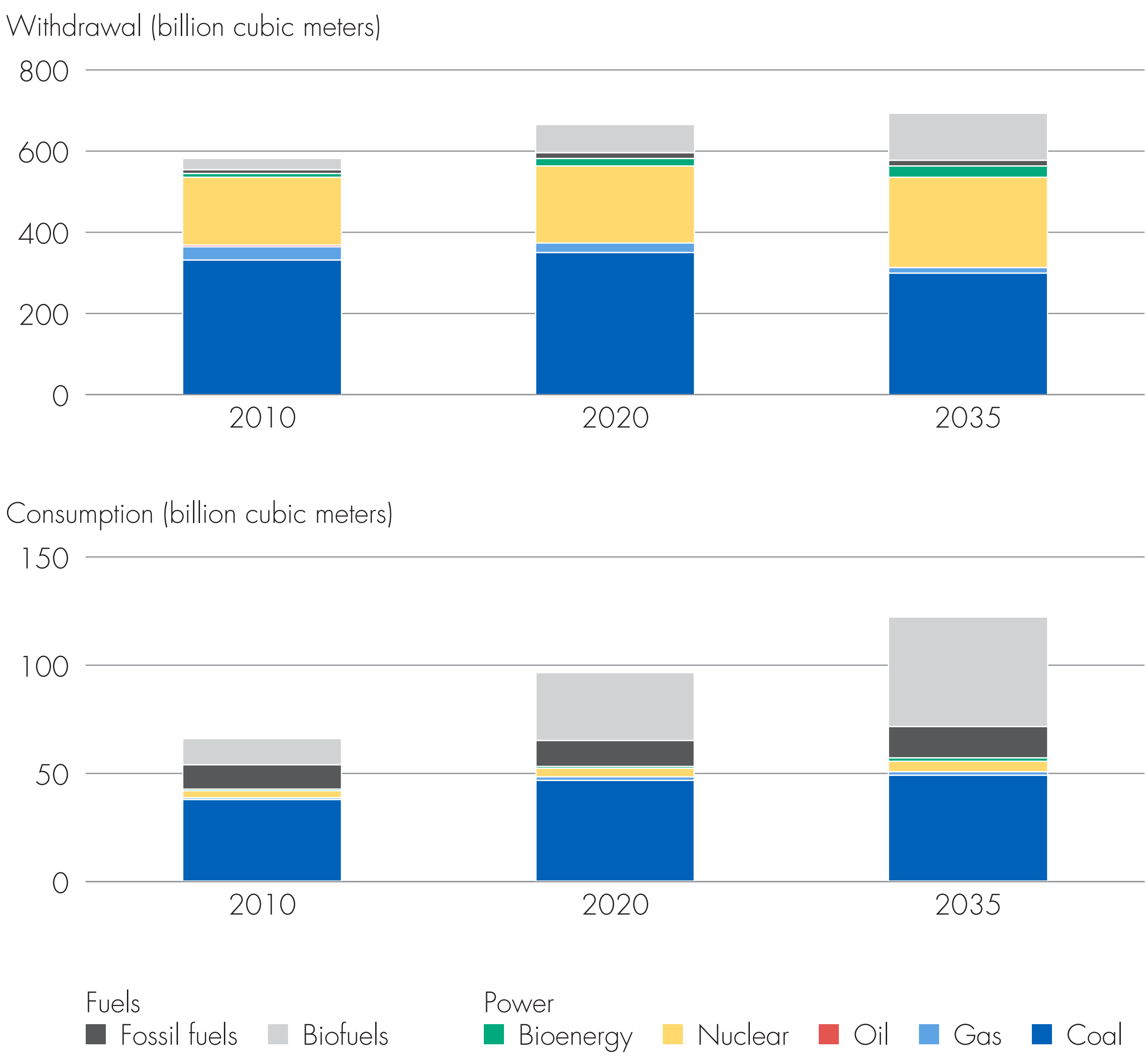
Existing indicators and challenges

Data open to the public on water use are usually statistics on water withdrawal and the volumes of wastewater. The Aquastat database of the UN Food and Agriculture Organization (FAO) is one of the most frequently used water data sets. Water withdrawals are tracked in the residential, industry, and agriculture sectors at country level. But for some countries, data sets may be limited, out of date, or nonexistent. In addition, the energy sector is lumped with the industry sector, making it impossible to estimate water withdrawals tied to power generation or to energy extraction. Water consumption data are not available, nor are estimates on water supply variability, which are critical for operations and planning across sectors (see box 6.1). Produced, collected, treated, and non-treated municipal wastewater is tracked at country level.

Most existing global estimates on the water needs of the energy sector are derived from assumptions. Some researchers use an average number of cubic meters per gigajoule (m^3/GJ) for each energy source, multiplied by projected future energy demand. Such average calculation is misleading, however, because water requirements vary greatly even within the same energy process or source. As seen, water requirements vary at all stages of energy operations and depend on several factors (including technology employed in energy generation and production, regional variable conditions such as climate, and efficiency of the process), and so there is no single "water factor" (water requirement per unit of energy produced) for a given energy process (Madani and Khatami 2015).

In 2012, the IEA published a set of macro-level indicators measuring global trends of global water use for energy production. Such measurements help capture upcoming changes globally, but are less useful for the operational and planning needs of, for example, developing countries alone (figure 6.4).

Figure 6.4. **Global water use for energy production in the New Policies Scenario by fuel and power generation type**



Source: IEA 2012.

Note: The New Policies Scenario refers to IEA's baseline scenario. For the difference between water withdrawal and consumption, see box 6.1.

To fully understand water requirements by energy source, lifecycle analysis should be adopted. IRENA (2015) argues that RE usually requires less water than fossil fuels based on a lifecycle assessment of water used in energy production. For example, a solar thermal power plant might require more water than a coal power plant to generate electricity (using the same type of cooling system). But because of the water needed for coal mining, the solar thermal process requires a lot less water. These vast differences have to be considered in analyzing and quantifying constraints.

The *World Water Development Report 2014* of the United Nations (UN) is a first attempt to gather indicators on the energy-water nexus. It argues that indicators are indispensable tools for establishing common ground for examining status, measuring progress, and planning targets (WWAP 2014). Its "Data and Indicators Annex" has 41 indicators, analyzing demographic statistics, global water demand statistics, and data on global energy supply by source and energy consumption, among other indicators. It has specific indicators on water and energy interactions, including "global water use for energy production by scenario," "indicative energy use of municipal water and wastewater services," and "energy requirements and cost implications of desalination by technology." These UN indicators are relatively complete, but still make it hard to identify energy-water hot spots. Moreover, most of the energy-water data are from other sources using global estimations with modeled averages. As said, this is not enough to begin to appreciate the challenge facing developing countries.

At a more micro level, indicators measuring companies' water risk due to variable supply and quality expose how business strategies have adapted to changes and uncertainties. Water risk indicators aim to highlight regional differences and complement data on water uses. Since 2010, the Carbon Disclosure Program (CDP) *Global Water Report* provides investors with information on how companies identify, manage, and mitigate risks and opportunities related to water. The CDP water questionnaire generates data for indicators on water risk, governance, accounting, and strategy (CDP 2014a). In 2014, 86 percent of utility companies and 82 percent of energy companies indicated that water was a "substantive risk" to business operations. Physical water risks such as water stress and floods presented the most prevalent water-related threat for utilities. Other water risks included a decline in incoming water quality, reputational damage, and regulatory uncertainty. In addition, 50 percent of utility companies and 41 percent of energy companies had experienced water-related business impacts in the reporting year (CDP 2014b).

Data gaps and required indicators

Reliable and comprehensive data on the energy-water nexus are scarce, inhibiting informed decisions on operations and investments and on monitoring them over the long term. Data on energy consumption and production by country are usually more abundant and accurate than data on water, as energy data often convey the importance of the sector to economic development, while conversely the central role of water is under-acknowledged. Even when energy data are collected in detail, those on water requirements or risks are patchy. Monitoring availability and use of water is a continuing challenge, especially given variable distribution of water over time and space, and given country differences in data availability of surface versus ground water. Water resource management and wider decision making are thus difficult, making it extremely hard to implement water-sensitive policies to improve energy access and efficiency.

One reason why it is hard in most countries to obtain water-related data from the energy sector (such as power plant operators, mining and oil extraction facilities) is that companies may not be legally required to report information on their water use and discharge. Critical topics suffer from data paucity, such as water withdrawn and discharged (thus consumed) by the energy sector, use of alternative water sources in energy (such as saline water and wastewater), and type of cooling system in power plants. Therefore making credible assumptions on the energy sector's water needs is problematic (Madani and Khatami 2015).

Hence it is recommended that governments request all energy production facilities to start reporting water-related information, in the same way that energy operators report on, for example, greenhouse gas emissions. Before that request, however, the number of energy companies disclosing their water use (withdrawal, consumption, and discharge) should be assessed, and context-specific information on the efficiency of power plants and water use (and its competing uses in, for example agriculture, industry, urban, and other sectors) should be gathered and analyzed.

As energy's environmental impact on water resources is rarely well documented, indicators on water use in energy processes should also consider that area—whether through companies withdrawing or discharging water at critical times, polluting water resources, or making other impacts. Indicators that focus solely on the amount of water used could incentivize unsustainable practices: for example, reducing the water withdrawn from a water source per unit of energy produced is not always better for the environment if the quality of discharged water prevents its future use, due to changes to temperature and chemical or sedimentary load of the water.

Indicators measuring sustainable water use are critical for the energy sector and should reflect region-specific challenges. Energy infrastructure is designed to last for decades. So decisions should consider future water availability, including climate change impacts, exposure to extreme weather events, and future competing water demands. Electricité de France is leading the Water for Energy Framework (W4EF), an official Action Group of the European Innovation Partnership on Water (EIP Water). W4EF is developing a common terminology and methodology to help energy actors assess and report on the relations between energy production activities and the local water environment, which requires going further than simple volume estimates. This framework will consider quantity and quality issues of water use and systematically relate use to the local conditions (EIP Water 2015). Such assessments are necessary for balancing trade-offs between water sustainability and energy production costs.

Definitions, metering, and measurements of energy by the water sector are rarely fully aligned. It is important, for instance, to rectify the mismatch of flow data for water and wastewater, as current end-use metering is not universal, and as not all wastewater is treated. Energy use per unit of water produced is used as an indicator, instead of water delivered, overlooking physical network losses (World Bank 2012b). Additionally, indicators capturing regional differences of water's demand on energy must be developed. In the United States, national water-related energy use is expected to increase as water-stressed states—like California, Florida, and Texas—shift to more energy-intensive technologies (Sanders and Webber 2012). In short, the economic value of water should be recorded in assessment tools.

Energy needs for water differ vastly, as energy use for water extraction, treatment, and transport depends on location, technology, and amount of water treatment necessary. At present, indicators aim to quantify both energy required to treat water—whether groundwater or surface water—and energy needed for water and wastewater service—whether pumping, distribution, or wastewater collection, treatment, or sludge disposal (World Bank 2012b). Yet operating conditions and processing technologies are often incomparable, due to differences including daily flow, length of water mains, and mix of water sources (World Bank 2012b). More energy-intensive water treatment processes, such as desalination, have energy use indicators for the different technologies involved (IRENA 2012).

Integrated policy and planning indicators are needed to inform country policies and help ensure sustainable and efficient use of water and energy resources. Such indicators could measure how governments plan and invest, whether they do so in an integrated manner that considers water requirements of different scenarios and alternative uses, whether water is a factor in decision making and in how the energy mix is selected, and whether water is considered at the planning stage or during project development. The Thirsty Energy Initiative by the World Bank, for example, aims to help countries to ensure a sustainable development of their water and energy resources breaking disciplinary silos and fostering cross-sectoral planning.

A first attempt to compile possible indicators for tracking the energy-water nexus across countries is shown in table 6.1 and are intended to stimulate discussions on a future nexus-tracking framework. It appears that most of these indicators have only limited data that would eventually enable consistent tracking over time. Data may be limited to only some countries, or not open to the public, or available mainly through self-reporting, driven by initiatives that encourage energy and water companies to respond to survey questionnaires.

Conclusion

If achieved, the SE4All objectives can improve water security. But they cannot be met unless water aspects are properly addressed and incorporated into the planning and implementation of energy investments. The water sector can benefit from moving toward the SE4All objectives by improving access to reliable, affordable, and safe water supplies. Yet meeting rising energy demand may have a

Table 6.1. **Possible indicators for tracking the energy-water nexus at country level worldwide**

Component	Indicator	Data availability	Current or potential source
Impacts of energy on water access	Water (m^3) pumped/treated/distributed/desalinated by energy source/technology (if off grid)	Limited data at utility level	
	Shutdown time (hours) and operational losses ($) due to energy-related issues (at the water utility level)	No public data	
Energy requirements of the water sector	Energy intensity (GJ/m^3) and unit cost ($\$/m^3$) by energy source/technology (if off grid) of drinkable water/treated wastewater/desalinated water	Limited data at utility level	*World Water Development Report* 2014
	Energy intensity (GJ/m^3) and unit cost ($\$/m^3$) of water heating by energy source/technology (if off grid)	No data	

(continued)

Table 6.1. **Possible indicators for tracking the energy-water nexus at country level worldwide** *(continued)*

Component	Indicator	Data availability	Current or potential source
Water requirements of the energy sector	Water (m^3) withdrawn/consumed/discharged by energy source (and cooling technology) at the energy production facility level	Limited data	IEA 2012/ Carbon Disclosure Program (CDP)
	Number of operating power plants by energy source and cooling technology	Limited data	IEA 2012/CDP
	Intensity of water withdrawn/consumed/discharged (gallons per megawatt-hour) by energy source at the energy production facility level—disclosing type of cooling system (for thermal power plants), type of water used (freshwater, saline, wastewater, other) and regional climate	Limited or no public data	CDP/Water for Energy Framework (W4EF)
	Yields (kilograms or hectares) and water requirements (m^3) for major biofuel crops (at the country level)	Limited data	FAO
	Cost of water withdrawn ($/liter) for the energy sector (by energy facility)	Limited or no public data	
	Number of energy companies disclosing their water use (withdrawal, consumption, discharge) and water risks	Limited data	CDP
Impacts of the energy sector on water resources	Percentage of water treated prior to discharge at the energy production facility level	Limited data	CDP
	Number of aquifers contaminated during drilling related to energy extraction	Limited data	
	Number of energy extraction facilities that recycle water	Limited data	
	Percentage of available water (in the water body) used by energy activities	Limited data	W4EF
	Water stress levels prior and after the establishment of energy activities	Limited data	W4EF
Water risks for energy companies	Percentage of energy companies considering water-related issues as a major risk to business operations	Limited data	CDP
	Percentage of energy companies that have water risk assessment	Limited data	CDP
Integrated policy and planning	Perceived change over the past 20 years in the importance of water for energy by country governments (percentage scale, from significant decrease to significant increase)	Limited data	UNEP 2012
	National energy policy/strategy/plan with water resources management component (percentage scale; water resources management ranked from not relevant to fully implemented)	Limited data	UNEP 2012
	Water requirements and water sustainability considered at planning stage or during project development (yes/no)	No data	
	Percentage of energy companies with water integrated into their business strategy	Limited data	CDP

negative impact on water resources as water supply is necessary for most energy production processes. Thus water-related risks could well affect the energy sector and hinder progress to the objectives.

Nexus indicators measuring inter-sectoral links are necessary for optimizing management of water and energy resources, as the international community lacks a common language and methodology to assess water use by the energy sector. Data on water-related risks (actual or perceived) facing energy companies should be accompanied by indicators tracking integrated policies and planning processes. Indicators should be used together to reveal the full effect of an energy development decision—avoiding unintended outcomes and degraded water resources—and to feed into policies that are contextualized to enhance their utility and relevance. Improved information could also drive technological innovation, which would also help improve efficient and integrated management of water and energy resources.

Energy and food security

Introduction

Any assessment of the links between energy and food security requires an understanding of what food security means. The internationally agreed definition states that "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (World Food Summit 1996). Based on this definition, food security has four dimensions, which need to be fulfilled simultaneously:

- *Availability:* Availability of sufficient quantities of food of appropriate quality.
- *Access:* Whether households or individuals have enough resources to acquire enough, quality food. It encompasses income, expenditure, and buying capacity of households or individuals.
- *Utilization:* Concerns the nutritional outcome of the food eaten by an individual. It is appropriate and optimum only when food is prepared and cooked properly, diversity of diet is adequate, and proper feeding and care are practiced. Thus having enough energy to cook food for a long-enough time matters.
- *Stability:* Stability of the other three dimensions over time. People cannot be considered food secure until they feel so. Major factors affecting stability are swings in market prices of staples, inadequate capacity to bear adverse conditions (such as natural disasters or bad weather), political instability, and unemployment.

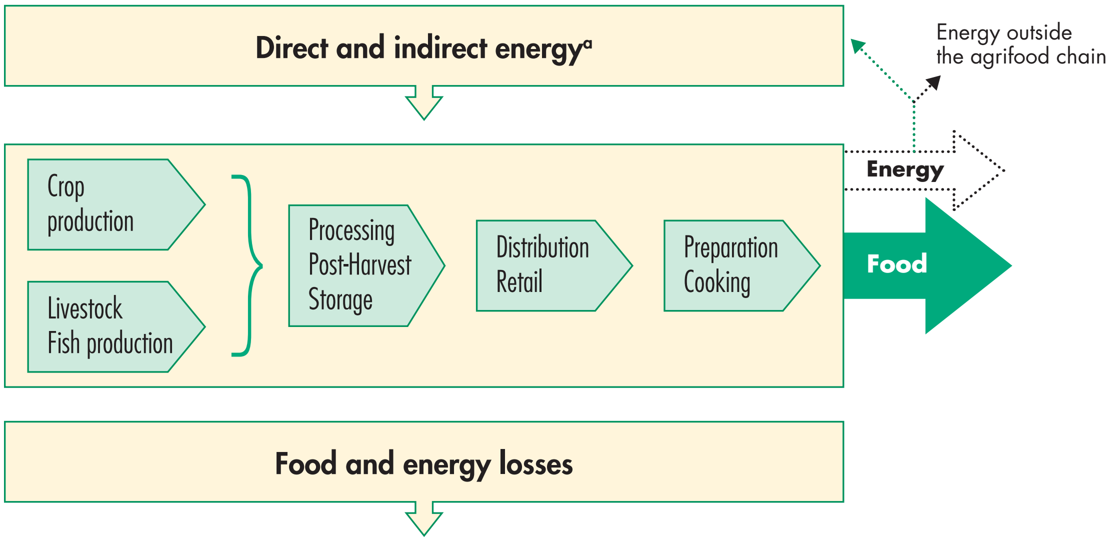
Energy—direct and indirect—is essential to all steps of the agrifood chain: in both the agricultural stages, for crops, fish, livestock, and forest products; and the postharvest stages, including food storage and processing, transport and distribution, and preparation (figure 6.5). Direct energy includes electricity; mechanical power; and solid, liquid, and gaseous fuels. Indirect energy is that required to manufacture inputs such as machinery, farm equipment, fertilizers, and pesticides. Agrifood systems not only are energy consumers, but can also produce energy, helping improve energy access.

Relying on cheap fossil fuels, modernized agrifood systems have increased food security over the last several decades. Energy from fossil fuels has further mechanized farm activities, food processing, and transport, helped expand irrigated land areas, and expanded use of inorganic fertilizers (FAO 2011, 2012). Yet the global food sector's dependence on fossil fuels is a concern, amid projections that food production will rise by 70 percent by 2050 compared with 2005–07 levels (FAO 2012).

Food prices are often influenced by energy prices given energy's large share in production costs in most farming (figure 6.6). After world oil prices surged in 2007 and 2008, higher food prices hit food access, leading millions of people into food insecurity, and worsening conditions for the many who were already food insecure (FAO 2012).

Agrifood systems consume 30 percent of the world's energy; 70 percent is consumed beyond the farm gate. Energy use per capita for food and agriculture amount to 35 GJ per year (nearly half in processing and distribution) in developed countries, but only 8 GJ (nearly half for cooking) in developing countries (FAO 2012, figure 6.7). Agrifood systems produce about 20 percent of the world's greenhouse gas emissions,[10] with the largest share attributed to livestock. Yet over one-third of the food produced is lost or wasted, and with it about 38 percent of the energy consumed in the agrifood sector. In low-income countries, food losses occur mainly during harvest and storage, while in high-income countries, food waste

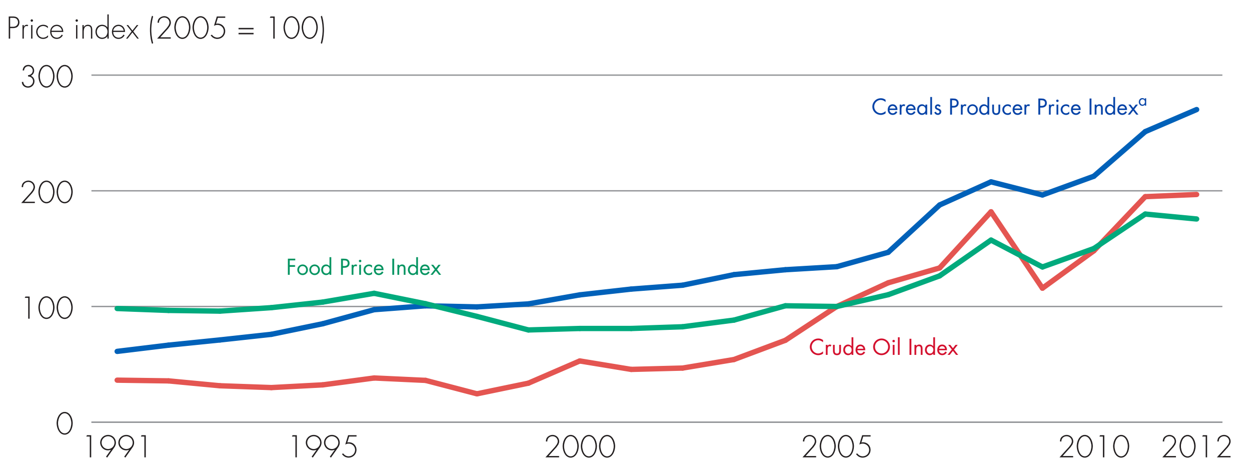
Figure 6.5. **Energy to and from the agrifood chain**



Source: FAO 2012.

a. *Direct energy* includes electricity, mechanical power, and solid, liquid, and gaseous fuels, among other sources. *Indirect energy* refers to the energy required to manufacture inputs such as machinery, equipment, fertilizers, and pesticides.

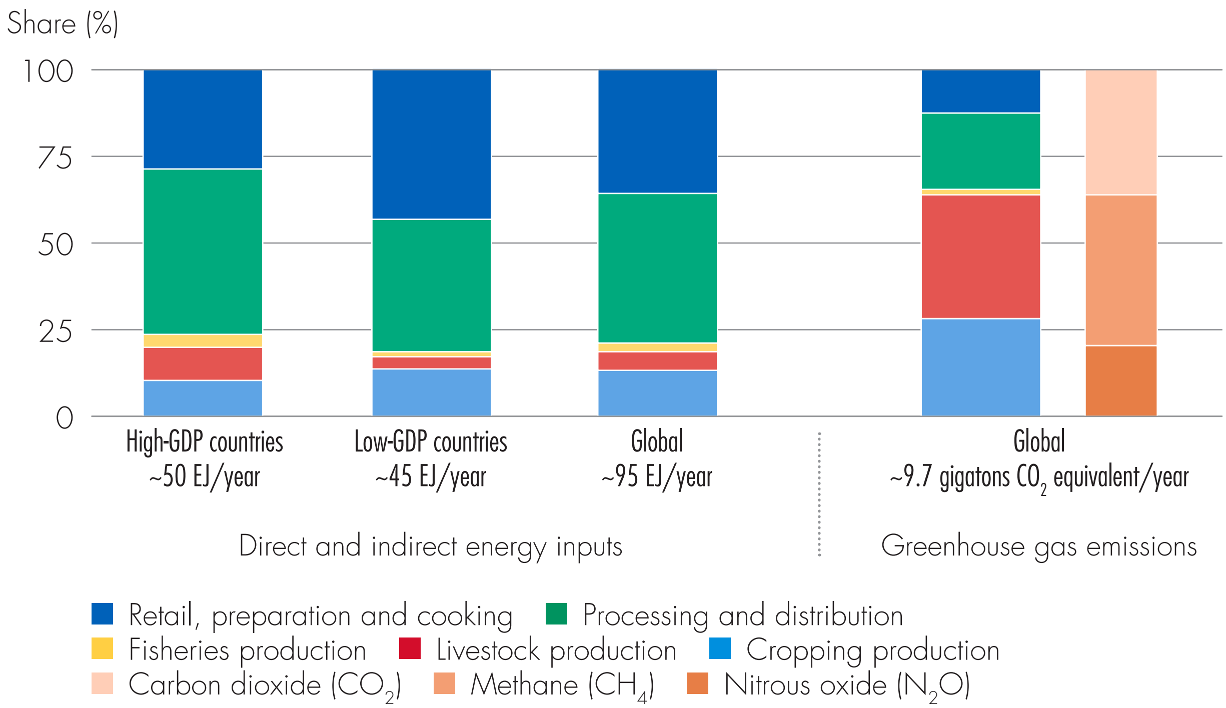
Figure 6.6. **Comparative trends of food, crude oil, and cereals price indices, 1991–2012[9]**



Source: The Commodity Food Price Index and the Crude Oil (petroleum) Price Index are from IMF 2014. The Total Cereals Producer Price Index is from FAO 2015. For details, see endnote 9.

a. Based on a value of 100 for 2004–06.

Figure 6.7. **Energy consumption and greenhouse gas emissions in the agrifood chain**



Source: FAO 2011.

occurs mainly during the retail, preparation, cooking, and consumption stages (FAO 2012).

Energy-food nexus and the SE4All objectives

Universal access to modern energy services in agriculture can help increase food supply through higher productivity via, for example, greater use of water pumps in irrigation, mechanization, and fertilizers. (Mechanized production also often reduces food losses.) It may also improve the livelihood of subsistence farmers and fishers, and lift small farmers' incomes, again via greater productivity. New opportunities for income generation may emerge from increased irrigation capacity and improved crop processing and storage (FAO 2012). Universal access to modern cooking solutions and refrigeration can vastly raise food quality and nutrition, at household level through longer cooking time and frequency, and food conservation.

Greater access to energy may, however, put more pressure on natural resources. Access to electric water pumps raises the chances of depleting underground aquifers, and causing water runoffs and erosion, which could reduce yields and put food stability at risk in the long run. Yields can in fact be sustainably increased in other ways, including good soil management, organic fertilizers, and minimum tillage. Similarly, the link between the embedded energy used in the manufacture of inputs and production or even yields is not obvious, while more mechanized agriculture and greater use of fertilizers and pesticides may deteriorate soil condition.

RE in agrifood systems can replace fossil fuels and help decouple food prices from fossil fuel prices, replacing fossil fuels and leading to energy cost savings in the long run. On-site power generation (solar, wind, or biogas) can cut electricity costs, facilitating post-harvesting operation. Greater liquid biofuel production can reduce dependence of fossil fuels for land management and transportation. Increased production of biofuels can also increase and diversify farm income. Excess energy can be sold outside the farm. For example, recent findings show that bioelectricity could provide almost 40 percent of Cameroon's electricity consumption (including agrifood industries) without compromising national food security (Ackom et al. 2013; IEA 2014). Biogas coproducts can also help raise yields.

The production and use of biofuels is increasing around the world as countries seek to diversify their energy sources, while promoting economic development, energy security, and environmental sustainability. Modern biofuels can provide multiple benefits, including promoting rural economic development, increasing household income, mitigating climate change, and providing access to modern energy services.

One disadvantage of biofuels is that any quality change or price fluctuation is likely to affect the sustainability of such a system (IRENA 2015). A reliable and affordable feedstock supply is thus a key factor. Another drawback is that a sharp increase in biofuel production may have a negative effect on food availability due to increased competition, because the production and use of energy crops may cause biodiversity loss, deforestation, additional pressure on water resources, and increased demand for agricultural inputs, land, and commodities.

Unless they are harvested sustainably, reliance on solid biofuels such as wood fuel or charcoal can degrade forests and destroy water catchments used for other activities, affecting local livelihoods. Time spent in gathering cooking and heating fuels may also rise when the local population needs to walk further.

Energy efficiency in the agrifood chain usually has a positive effect on economic returns of food production in the long run through savings on energy costs. New technologies and practices, such as energy-efficient engines for farm machinery and minimum tillage can reduce the use of fossil fuels while maintaining a stable food production. Biogas production, using animal waste and manure, increases the overall energy efficiency of meat production, while providing low-cost fertilizers that help increase yields sustainably.

Energy-efficient cookstoves may allow for longer cooking times and improve nutrition outcomes, as they have high heat transfer and thus need less fuel, directly translating into lower household outlays on fuel or time spent collecting it.

Conversely, energy efficiency in the food chain may be undermined by increasing long-distance food transport. Although international food trade can help mitigate domestic food price volatility, it also raises "food miles"—the distance that food travels from where it is grown to where it is ultimately consumed—and associated pollution.

Existing indicators and challenges

A pragmatic approach in two steps is proposed for national targets and indicators for the energy-food security nexus. Both require heavy efforts in developing methodologies, gathering data, and building capacity.

1. Start with targets and indicators that, while capturing all types of energy inputs and outputs from agrifood chains, are currently measurable. These concern primarily fossil fuels inputs to "behind the farm gate" operations; traditional wood fuel use; and changes caused by bioenergy development on the supply and prices of national food basket elements.

2. Complement these indicators with important information on energy currently not measured by national statistics. These include energy used to manufacture agrifood chain inputs; energy used beyond the farm gate (such as in the food cold chain); and RE produced along agrifood chains.

Partial measurement of the energy-food security links can be measured through indicators related to fossil fuel use in agriculture, using current data. Data on energy use can be combined with data on arable land area, the value of agricultural output, and the calorie equivalent of output. All three can be developed with data from FAOSTAT[11] and FAO Food Balance Sheets, generating three energy intensity indicators on fossil fuel used on farms:

- Direct use of fossil fuel energy in agriculture per hectare of arable land (possibly differentiated by agricultural product) (in J/ha).

- Direct use of fossil fuel energy in agriculture per unit of value of output (J/$).

- Direct use of fossil fuel energy in agriculture per unit of calorie of food produced (J/cal).

The value of capital stock of machinery per unit of arable land, available from FAOSTAT, can be used as a proxy indicator of agricultural mechanization. Indicators on fossil fuel use in agriculture should be normalized by mechanization levels, that is, levels of capital stock of machinery per unit of arable land. A combination of such normalized indicators should capture the efficiency of energy use in agriculture.

Access to cooking fuel can be measured using cooking fuel distribution across households. The role of energy in the food utilization and quality dimensions (see the start of chapter) could be approximate with an indicator measuring access to different cooking fuels. Access to fuel-efficient cooking solutions may be reflected through an indicator measuring cooking time to ensure food quality.

Measurement of the effects of bioenergy on food price and supply can reflect the links between RE and food security. The only internationally agreed indicator on these links is on the effects of bioenergy use and domestic production on the price and supply of a national food basket. This indicator is part of the Global Bioenergy Partnership sustainability indicators (GBEP 2011), whose practical applicability is still being tested.

Meeting the SE4All objectives, given their multifaceted links to food security, can make a critical contribution to achieving the Zero Hunger Challenge program of the UN Secretary General. This program aims to achieve 100 percent access to adequate food all year round; zero stunted children under two years of age; sustainability of food systems; 100 percent increase in smallholder productivity and income; and zero loss or waste of food.

Data gaps and required indicators

Any attempt to comprehensively measure energy-food links requires national data on use of energy to manufacture agricultural inputs, on energy use beyond the farm gate, and RE for and from agrifood chains, including the cold chain. Further needed indicators include energy used in agrifood systems (including postharvest stages) and energy intensity per economic value of production; amount of RE produced by agrifood systems; changes in food prices; and farming or land income/revenue impacts of access to modern energy services.

A nexus-assessment methodology has been developed under the SE4All High Impact Opportunities in Sustainable Bioenergy and the Water-Energy-Food Nexus.[12] The nexus assessment methodology aims to help governments and investors address water, energy, and food/land demand in an integrated way. It starts by raising awareness on possible trade-offs and synergies between these sectors. It then uses index matrices to assess the pressure on the nexus factors, including energy, water, food, income, and labor. Finally, it proposes a simple way to assess the performance of specific interventions from a nexus perspective and how they should be assessed against the context status.

A first attempt to compile possible indicators for tracking the energy-food nexus across countries is shown in table 6.2. These are intended to stimulate discussions on a future "nexus-tracking" framework.

Conclusion

There is increasing consensus that agrifood systems have to become "energy smart" (see just below) to meet future energy and food challenges. A shift to energy-smart agrifood systems would involve greater use of RE sources and energy efficiency technologies, while integrating food and energy production, to reduce dependency on fossil fuels and build resilience against energy price fluctuations. This shift should also improve productivity in the food sector, reduce energy poverty in rural areas, and help achieve goals for national food security, climate change, and sustainable development (FAO 2012).

FAO has launched the Energy-Smart Food for People and Climate Program, a multi-partner initiative to assist member countries make the shift. The Program focuses on improving: energy efficiency in agrifood systems, use of RE in these systems, and access to modern energy services through integrated food and energy production. The Program follows an interdisciplinary "nexus" approach.

A substantial effort in methodological development, data gathering, and capacity building will be required to measure the energy and food nexus indicators. Beyond measurement of direct fossil fuel use in agriculture, additional indicators are required for monitoring RE production and use by the agrifood sector, including biofuels, as well as indirect energy inputs. Energy intensity should also be tracked. All indicators need to capture national circumstances and capacities.

Energy and health

Introduction

Energy is a prerequisite of good health and a source of many serious health risks, notably air pollution. It offers multiple health benefits by ensuring clean water, improving food quality and nutrition through cooking and refrigeration, and enabling health facilities to improve delivery of health services. However, dirty fuels and inefficient technologies generate air pollution. Poor planning of, for example, housing and urban transport can also increase air pollution. Optimizing the health benefits of energy access,

Table 6.2. **Possible indicators for tracking the energy-food nexus at country level worldwide**

Component	Indicator	Data availability	Current/ potential source
Energy use for food production	Direct use of fossil fuel energy in agriculture per hectare of arable land (by agricultural product) (J/ha) per unit of value of output (joule/$) per unit of calorie of food produced (joule/calorie)	Yes	FAO
	Energy inputs in agrifood chains (beyond farm gate), by type of energy source	Limited public data	UNSD, IEA
	Energy intensity in agrifood systems per economic value of production	Limited public data	UNSD, IEA, FAO
Energy use for cooking	Percentage of people using modern cooking solutions as primary cooking solution	Yes[a]	USAID, WHO
Energy produced by the agrifood sector	Energy output across the agrifood sector by type of energy source	No data	FAO
	Correlation rate of changes in price and supply of a national food basket and changes in domestic biofuel production and use	No data	FAO

a. The available data track solid versus non-solid fuels.

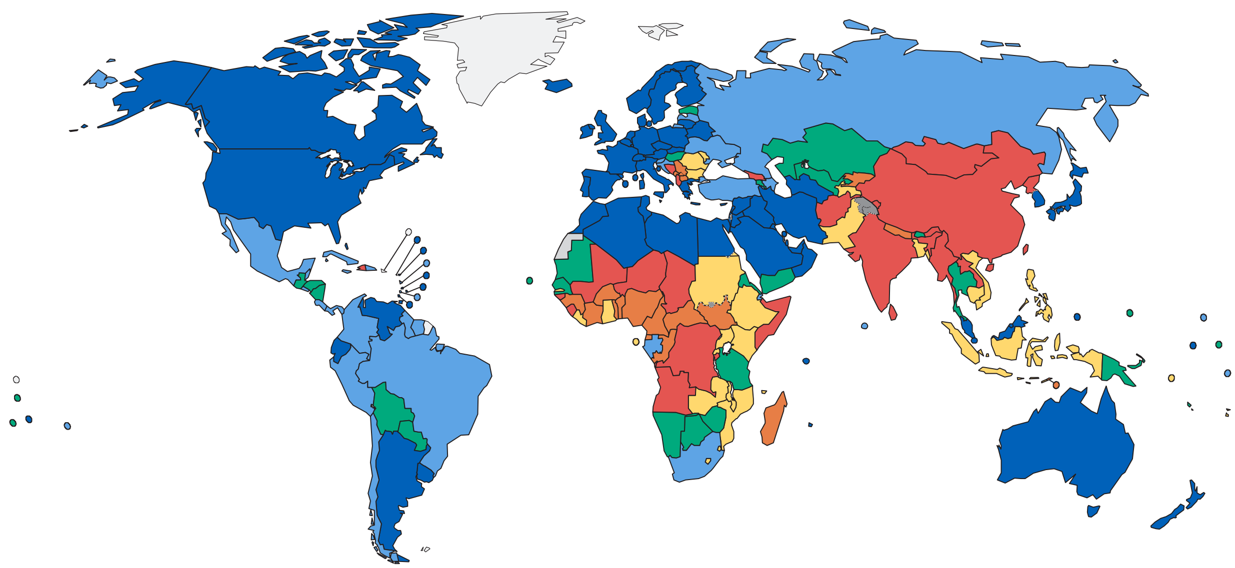
efficiencies, and use of renewables, while minimizing energy-related risks, is thus critical to achieving the SDGs of the SE4All initiative.

The greatest single health risk along the energy nexus is air pollution. Outdoor (ambient) and indoor (household) air pollution are responsible for about 7 million premature deaths annually, making air pollution one of the largest single causes of premature mortality and morbidity worldwide (figures 6.8 and 6.9). Inefficient production, use, and distribution of energy services compound polluting emissions. Energy risks to health are thus closely associated with the built environment, and in the way we produce and use energy at household, community, and urban levels.

Besides air pollution are many other health risks associated with a lack of modern energy access or inefficient energy use. Reliance upon rudimentary solid fuel cookstoves or kerosene lamps, for instance, can be a factor in domestic injuries such as burns or poisonings. Energy-inefficient buildings and homes not only require more heat and power, but also leave occupants more exposed to extreme weather, placing vulnerable groups, such as the elderly, at increased risk of heat stress and heat-related stroke or, conversely, hypothermia (WHO 2011). Increased incidences of asthma, allergy, and respiratory illness are also associated with chronic damp and cold housing conditions that are more common in energy-inefficient dwellings and affect more the poor, elderly, and children. In urban areas, physical inactivity and pedestrian traffic injury rates tend to be higher when public transport systems are weak and inefficient, leaving people reliant on private motor vehicles, which burn more energy and produce more air pollution per unit of travel than efficient rapid transit modes (Hosking, Mudu, and Dora 2011).

Modern energy provision is a critical enabler of universal access to health care and universal health coverage. Although the world's attention on the need for expanded access to life-saving interventions has focused on skilled care, essential medicines, and medical technologies for priority diseases and health conditions, less attention has been given to energy's vital role as an enabler of health care delivery. Without energy, many life-saving interventions cannot be undertaken, and essential medical devices and appliances for prevention, diagnosis, and treatment cannot be powered. Yet data and anecdotal examples indicate that even the most basic modern energy services are often unavailable in thousands of facilities across the developing world. One study covering 11 countries in Sub-Saharan Africa found that on average one in four health facilities had no access to electricity and that 34 percent of hospitals had unreliable access to electricity[13] (Adair-Rohani et al. 2013).

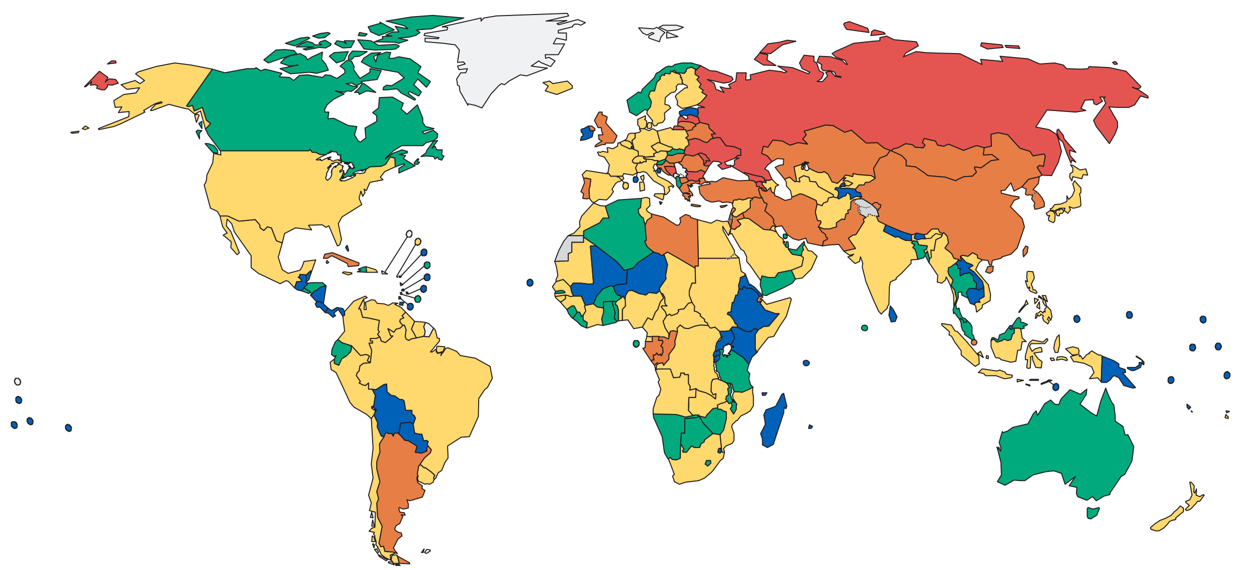
Figure 6.8. **Deaths attributable to indoor air pollution from solid fuels, 2012**



Deaths per 100,000 population
■ 0–5 ■ 6–29 ■ 30–49 ■ 50–69 ■ 70–89 ■ 90 or more
■ Data not available ■ Not applicable

Source: WHO.

Figure 6.9. **Deaths attributable to outdoor air pollution, 2008**



Deaths per 100,000 population
■ 0–5 ■ 6–10 ■ 11–20 ■ 21–40 ■ More than 40
■ Data not available ■ Not applicable

Source: WHO.

Health sector energy needs of low- and middle-income countries are expected to grow steeply: needs for vaccine cold storage space are slated to grow eightfold or more in coming decades (PATH-WHO 2008). The growing need to fight non-communicable diseases, which requires complex interventions, will drive additional energy requirements (such as those of imaging equipment for cancer detection) (WHO and World Bank 2014).

Energy-health nexus and the SE4All objectives

Universal access to reliable and affordable modern energy solutions can greatly reduce the burden of diseases associated with indoor air pollution, burns, and poisonings. Increasing access to and sustained adoption of clean cooking solutions—such as liquefied petroleum gas (LPG), natural gas, electric induction stoves, and biogas[14]—would reduce the long-term exposure to health-damaging pollutants[15] created by inefficient open fires and to traditional solid biofuel and coal cookstoves. These exposure reductions would decrease the burden from cardiovascular disease (ischaemic heart disease) and respiratory disease (such as childhood pneumonia, chronic obstructive pulmonary disease, or lung cancer) as well as stroke. Use of clean and safe cooking solutions will also reduce the risk for burns, scalds, and poisonings. By replacing polluting and dangerous kerosene lamps with electric lighting, health risks related to exposure to indoor air pollution, burns, and poisonings can be reduced.[16] Similarly, increasing access to modern energy heating services will reduce health risks linked to indoor air pollution and safety risks from inefficient space heating —common in low- and middle-income households— and such risks tied to inadequate and unsafe indoor temperatures.[17]

More reliable energy access in health facilities can significantly enhance health care provision. It can provide lighting, power medical devices, and enable refrigeration for blood and vaccines. Electricity access seems to have a notable impact on some key health service indicators, such as prolonging nighttime service provision, attracting and retaining skilled health workers (especially in rural areas), and providing faster emergency response, including for childbirth. Electricity access also enables mobile-health and telehealth applications and facilitates public health education and information. Thermal energy is also critical for space and water heating, sterilizing medical equipment, and incinerating medical waste safely.

RE can reduce indoor air pollution. PV power can significantly reduce indoor air pollution as it provides a non-polluting alternative to kerosene-based lighting in households and health facilities. Fuels such as ethanol and biogas have a high supply potential, low carbon and pollution emissions, and broad social acceptability. Millions of households in countries such as China and Nepal already use biogas produced from livestock manure, agriculture waste, and other raw materials as a cooking fuel, replacing coal and wood. In rural homes, the domestic biogas digester systems also use fecal sludge from household latrines, in an onsite waste management system.

Passive solar design and active solar thermal or solar PV systems can support space heating, space cooling, and hot water for homes and health facilities (WHO 2011). For space and water heating, rooftop-based thermal solar water heating systems and advanced biomass heating stoves of the kind common in northern latitudes' developed countries (such as sealed pellet stoves) also support sustainable energy and health goals (WHO 2011).

RE sources powering medical devices may improve delivery of health services, particularly in the most remote settings. New portable, low-energy direct current medical devices are being introduced for simple procedures such as ultrasound or blood oxygen measurement, and they can also operate from PV solar power panels. LED-illuminated microscopes and direct current vaccine refrigerators can store solar energy in freezer packs, rather than a battery, thus avoiding the costs of battery maintenance and replacement. Increased access to such portable devices is creating new opportunities to improve health care delivery even in the most remote settings, where PV solar power systems are increasingly available. Small and medium PV power arrays can usually cover lighting, communications, and a few basic medical devices or one water pump. For facilities with higher energy requirements, hybrid systems combining PV solar and fuel-based generators can provide a generator boost during peak power demand, saving fuel when solar power is available (USAID 2013; Anayochukwu and Nnene 2013).

A transition to RE sources should gradually reduce occupational respiratory diseases, injuries, and cancers related to fossil fuel extraction (such as coal mining or oil refining). More immediately, it will reduce indoor air pollution in small shops, workshops, and off-grid cottage industries that now rely on kerosene lamps or portable diesel generators. Solar-powered electricity may also raise workers' productivity in these places. Even so, production and use of RE also create new hazards and risks, such as those from dust particles generated in production of silicon PV solar panels and the risk of falling from wind power installations.

Health can be improved by increased urban energy efficiency. This entails compact cities with efficient rapid transit systems with dedicated roads or tracks, walkable mixed-use neighborhoods with services close to homes, and more energy-efficient housing and buildings. Cities are a critical nexus point in the built environment where public health benefits from greater energy efficiency, as over two-thirds of global energy consumption is in urban areas (IPCC 2007). Energy efficiency in housing and transport can be optimized through more compact, "smart" urban design that yields a range of health benefits including, for a start, lower air pollution. In this approach neighborhoods are closer to services, making it easier to walk and cycle, and employment centers or other city center destinations are clustered, enabling better public transport. Partly due to such features, mid-rise European cities are among the most energy-efficient cities. Conversely, low-density North American cities are among the heaviest users of energy, particularly in transport (Hosking, Mudu, and Dora 2011).

Infrastructure investments in energy-efficient rapid transit, including pedestrian and bike systems, encourage healthy active transport and support mobility of vulnerable socioeconomic groups that lack access to cars, protecting them far more from traffic injury. The benefits of safe access to energy-efficient urban transit and pedestrian/bike lanes can be enjoyed very broadly. This is because a high proportion of trips in low-income countries are on foot or by public transport. And many groups—including women, children, the elderly, and people with disabilities—make many local trips, often by foot or bicycle. High rates of urban walking and cycling not only drive reductions in energy use for transport and consequent urban pollution, but also help decrease obesity risks through more physical activity.

Energy efficiency gains through housing structures and design features improve inhabitants' health. Housing thermal envelopes better protect occupants from cold- and damp-related illnesses and allergies. "Daylighting" can improve mental health. Good landscaping and natural ventilation for cooling reduces the need for air conditioning, which is energy intensive, produces noise harmful to health, and can exacerbate transmission of infectious bacteria and allergens. Housing energy efficiency measures and green building certification labels need to consider health parameters as, for instance, weather-proofed buildings that restrict ventilation too greatly can be unhealthy insofar as they may allow the buildup of indoor air pollutants. Ensuring use of non-toxic insulation and building materials is also critical for health, along with consideration of energy efficiency ratings.

Energy efficiency gains and health benefits can be maximized through multiunit housing, a feature of more compact cities that is typically more energy efficient than low-density housing of the same building style and standard. Compact housing forms—including mid-rise, multiunit buildings with shared walls—are more energy efficient than stand-alone structures of similar size and quality. Compact urban housing forms also lend themselves more readily to district heating systems or combined heat and power (CHP) cogeneration[18] (WHO 2011) and to efficient provision of sewage and sanitation, power, and waste management.

With very high-rise structures, some energy efficiency gains from greater housing densities may be offset by increased power requirements of large elevator systems and heating, ventilation, and air conditioning. This is because natural ventilation is more complex in such environments. Young children can also face barriers against moving safely and independently, as they are dependent on elevators, restricting physical activity.[19] In very low-rise buildings in sprawling neighborhoods, adolescents often lack access to public transport and depend on their parents for personal mobility (WHO 2011).

CHP cogeneration can provide a reliable and more energy-efficient form of electricity and thermal energy to institutional and commercial buildings than the grid (IPCC 2007). Nowhere is this reliability more important than in the hospital sector, one of the largest building energy consumers in high-income countries. Many hospitals across North America and Europe—as well as some in emerging economies (such as Brazil and India)—have adopted CHP technologies to reduce energy expenses, protect vital health care services from extreme weather and chronic grid failure, and reduce environmental emissions (WHO and World Bank 2014; Carbon Trust 2013). Such technology may play a key role in the fast-growing global health sector of low- and middle-income countries.

Existing indicators and challenges

WHO's Global Household Energy Database has data from over 800 household surveys in 157 countries and has been updated annually for over a decade from national household surveys and censuses.[20] These health and energy statistics are used for monitoring health impacts of energy access policies and programs at national, regional, and global scales.

The share of the population relying primarily on solid fuels for cooking, whose value comes from this database, serves as a useful proxy to measure exposure to household air pollution. This indicator fails, however, to consider the full range of health impacts resulting from lack of modern heating or lighting and from use of non-solid fuels like kerosene. Nor does it reflect practices of fuel and technology "stacking"—the parallel use of modern cooking fuels, such as LPG, with, for example, less efficient solid fuels.

The burden of disease from indoor air pollution exposure is estimated from data on primary household cooking fuel use by country (from the Global Household Energy database) in association with multi-country studies of average air pollution concentrations in homes where such fuels are used (WHO 2014a). Based on those exposure estimates, estimates of premature mortality and morbidity from cardiovascular disease, stroke, and cataract and respiratory diseases are made, using risk estimates based on epidemiological meta-analysis or dose-response curves integrating exposures to fine particulate matter (particles less than 2.5 micrometers in diameter) ($PM_{2.5}$) across combustion sources (for example, second-hand smoke) and location (for example, an outdoor environment).

Data on outdoor air pollution for some 1,600 cities are collected in WHO's Ambient Air Pollution in Cities database[21] and are regularly updated with new air quality measurements. But gaps remain: fewer than a dozen cities in Africa have air quality monitoring systems, and many major cities in Latin America and Asia also lack them. There are problems with data quality due to frequent breakdowns in monitoring equipment as well as problems with transparency (such as conflicting data reporting from civil society and official sources) and locations of data collection. Only 12 percent of the world's urban population lives in cities that meet WHO guideline levels for air pollution, and most developing cities of the world have $PM_{2.5}$ annual average concentrations several times higher than the WHO guideline level of 10 micrograms per cubic meter ($\mu g/m^3$).

WHO regularly estimates the burden of disease from exposure to outdoor air pollution of $PM_{2.5}$ exceeding its air quality guidelines. WHO's global estimates are calculated using information from satellites combined with data from chemical transport models, which are calibrated using ground-level measurement data. WHO then examines exposure estimates to air pollution worldwide and by region, combined with excess risks estimated by an integrated dose-response curve, to estimate disease incidence at the corresponding ambient $PM_{2.5}$ concentrations. WHO is improving the model to increase the depth and breadth of ground-monitoring data worldwide and the resolution of satellite imagery.

An important indicator of energy access is being developed by the World Bank and WHO: electricity access in health facilities. Data on electricity for about 20 developing countries are available in a WHO Health Facility Energy Access database. Data held in that database come primarily from the two most common and comprehensive health care facility surveys administered at country level: the U.S. Agency for International Development's (USAID's) Service Provision Assessment and WHO's Service Availability and Readiness Assessment (SARA). Those surveys have traditionally referred to a small set of questions on whether electricity is available; whether it is from a grid, a backup generator, or another source; and whether the generator has fuel and is functioning. Recently the SARA survey questions were expanded to include more detailed questions. These now include all the types of primary and backup electricity sources used; the reliability of electricity supply; and a rough indicator of the quantity of power available (whether power is enough for lighting only, enough for lighting and one or two medical devices, or enough for all facility needs).

Data gaps and required indicators

Indicators measuring household air pollution caused by lack of access to lighting and heating are required to accurately assess the total burden of disease related to energy access in homes. It is essential to track all fuels and technologies used in the household for all cooking, heating, and lighting activities. To advance data collection for these indicators, WHO has started expanding its Global Household Energy database to include survey data on fuels and technologies used for lighting and space heating. It is also harmonizing questions in national surveys to better account for the health impacts of home energy use for cooking, heating, and lighting. WHO recently published new indoor air quality guidelines for household fuel combustion, which establish performance standards for household fuels and stove technologies (WHO 2014a). These health-based guidelines provide emission rate targets for the sum of energy technologies, with and without a chimney, used in the home, and recommendations to avoid use of unprocessed coal and kerosene.

Performance and safety standards for cooking solutions were proposed by the Partnership for Clean Indoor Air (PCIA) and the International Organization for Standardization (ISO) in 2012 (PCIA 2012). Under an International Workshop Agreement overseen by ISO, experts have developed a set of voluntary standards for cookstoves in low- and middle-income countries. Based on emerging consensus that not all reductions in emissions are of equal value to human health, the Agreement provides the basis for measuring cookstove performance on four technical attributes: efficiency, indoor pollution, overall pollution, and safety. This is the first step toward full ISO standards, which are being developed.

WHO's database of urban air pollution exposure, while very broad, does not include many major cities in low- and middle-income countries, and suffers from shortcomings in data collection. Improved monitoring efforts in urban areas are needed to generate more data of higher quality, for a broader range of cities. The new WHO global platform on air quality monitoring aims to address current data shortcomings created by a dearth of ground-monitoring stations in rural areas, by integrating satellite-monitoring and emissions (chemical transport) data.[22]

Outdoor air pollution concentrations and exposure should be measured for each economic sector. While the most-polluting sources are transport, power generation, building emissions, industry, and waste incineration, their proportionate contributions vary by region and city around the world. Knowing what the heaviest local sources of pollution are can help policymakers assess and prioritize the most effective interventions.

A combined indicator, or index, reflecting the proportion of cyclists and pedestrians who can travel safely is required to measure sustainable transport systems in cities. Such an index would potentially measure the proportion of urban trips via walking or cycling (typical range being 1–40 percent) in association with either the proportion of pedestrian or cyclist fatalities in total traffic fatalities (typical range being 10–40 percent) or the proportion of total kilometers travelled annually by pedestrians and cyclists.

A multitier approach measuring energy access in health care facilities, proposed by WHO-World Bank (2014), requires new data from health facility surveys. Most current survey tools and indicators are based on a simple binary indicator: availability or not of electricity. Richer surveys capturing more indicators of the different attributes of energy—such as reliability, quality, peak and average daily power capacity, and operational and environmental sustainability—are being developed, within the multitier tracking framework.

A first attempt to compile possible indicators for tracking the energy-health nexus across countries is summarized in table 6.3. These are intended to stimulate discussions on a future "nexus-tracking" framework.

Conclusion

Universal access to modern energy sources can contribute to improving health, by reducing the burden of disease related to air pollution and by improving the delivery of health services. Improved energy efficiencies and increased use of renewables can significantly reduce a range of energy-related health risks, such as air pollution, but can also increase energy access in remote areas by small-scale RE solutions for homes and health facilities.

Existing indicators capture most of the energy and health links, and data improvements are being developed. WHO's databases on household fuel, indoor and outdoor air pollution, and access to energy in health care facilities provide essential indicators for monitoring the health and social benefits from the energy transition. Additional work to map emission rates by type of cooking and heating technology is under way, aiming to accurately monitor health benefits of improved biomass stoves. A multitier framework for accurately measuring electricity access in health facilities aims to better understand the role that energy access has on health service delivery. Indicators for energy efficiency in the urban environment are being developed based on a scientific understanding of the links from transport, buildings, and land use to human health.

Table 6.3. **Possible indicators for tracking the energy-health nexus at country level worldwide**

Component	Indicator	Data availability	Current/ potential source
Household air pollution	Estimated burden of disease related to indoor air pollution: Type of primary cooking fuel used in households. Household air pollution indicators. Estimated indoor air pollution exposure.	Yes	WHO
	Type of primary cookstove used in households.	Limited	
	Type of secondary (and beyond) cooking fuel and cookstoves used in households.	Limited	
	Type of lighting and heating fuels and stoves/devices used in households.	Limited	
	Mortality and morbidity attributed to household air pollution from all cooking, heating, and lighting activities.	No	WHO
Outdoor air pollution	Air quality measures in urban areas.	Yes	WHO
	Estimated burden of disease related to outdoor air pollution.	Yes	WHO
Built environment	Outdoor air pollution concentrations by sector (for example, transport- or housing-related emissions).	No	WHO
	Percentage of safe active urban transport.	No	
	Percentage of urban trips via walking/cycling.	Yes	OECD/UNECE
	Percentage of pedestrian and cyclist fatalities in total traffic fatalities.	No	OECD/UNECE
	Pedestrian and cyclist fatalities per kilometers of annual pedestrian/ cyclist travel.	Limited	
Energy access in health facilities	Percentage of health care facilities with access to a reliable, affordable, and sustainable source of electricity (using the multitier frameworks).	Limited	WHO/USAID

Energy and gender

Introduction

Gender and energy have emerged as a point of discourse in development since the Beijing Conference in 1995 (Clancy et al. 2011). As highlighted in *World Development Report (WDR) 2012* (World Bank 2012a) and *World Survey on the Role of Women in Development 2014* (UN Women 2014a), gender equality is critical for development across all sectors. Access to sustainable energy often liberates men and women from drudgery and frees time for leisure, rest, and investing in human capital. However, women in most developing countries suffer more severely than men from energy deficits and energy poverty (UNIDO-UN Women 2013).[23]

Energy interventions are likely to affect women and men differently, as they have different roles and voices in the household and wider community (World Bank 2005). For example, electric light after dark may improve the quality of life for some, by allowing reading, entertainment, or education via radio and television, whereas for other it may simply extend the working day. Reaching equitable outcomes is challenging as women often have less influence over decisions and exercise less control over their own lives and resources.

Energy projects, including those focusing on cookstoves, do not always take a gendered perspective. Instead projects resort to using the term "people," "community," or "consumers."[24] The terms "women" and "gender" are often used interchangeably, but are distinctly different concepts: this section uses "gender"—defining the socially constructed relations between women and men—rather than "women," as the second includes the first, while the first does not necessarily include the second.

Gender issues are interspersed all along the nexus chain.[25] It includes energy demands based on women and men's roles, which are met through energy supply chains of different degrees of formality (from self-collection to commercial provision). At household level, men generally make the final decision on energy access (Clancy et al. 2011). At macro level, decisions on policy instruments (including incentives to encourage a transition to cleaner energy) require gender analysis and gender budgeting to avoid inadvertent gender blindness or bias in energy policies (Clancy 2009). All along the chain are entry points where women can be a target group and can benefit in three specific areas: time poverty and drudgery reduction, economic empowerment, and health and safety improvement.

Women are particularly time poor, and the associated drudgery of their tasks (particularly collecting firewood, fetching water, and processing food) is mainly fulfilled through their own physical labor, which has implications for their health and the well-being of their children and families. Time poverty can be conceptualized as the condition in which an individual does not have enough time for rest and leisure after the time spent on productive and reproductive work.[26] Time poverty has been increasingly recognized as a dimension of poverty (World Bank 2005; Blackden and Wodon 2006). Studies have shown that women, as well as girls, can have longer working days than men, particularly in rural areas, and carry (usually on their heads) more weight than men (Bardasi and Wodon 2006; Charmes 2006). Women are often the main fuelwood collectors, although men tend to take over responsibility when the fuelwood supply close to the household decreases (Cooke, Köhlin, and Hyde 2008), when greater amounts of physical capital and machinery are required to harvest fuelwood, or in urban areas (Blackden and Wodon 2006). Time spent on reproductive activities varies by gender depending on environmental conditions, social setup, and distance to forest, wasteland, and water resources.

Energy is often a key input to the production process, driving higher efficiency and greater returns for most activities. However, external factors such as access to finance, to natural and human resources, and to technology are often required for establishing productive activities. Barriers related to low levels of ownership and control over resources, illiteracy, lack of exposure, and poor information and training may affect women more than men, as women are often excluded from decision making. Dutta and Clancy (2005) indicate that the informal nature of many women's enterprises is linked to problems of access to credit, equipment, and other support services. UN statistics show that the informal sector (which includes micro and small enterprises) is a larger source of employment for women than for men (ILO 2002), particularly outside agriculture (Chen 2014).

Encouraging women to become involved in the energy sector, for example as energy entrepreneurs, offers multiple development benefits, like expanding economic activities for women, diversifying productive options, and creating new sources of wealth and income to support family investments in education and health.[27] Women's economic empowerment in energy (as in other sectors) contributes to broader aspects of empowerment, such as political participation and consultation in interventions where women are the identified beneficiaries.

Women and children bear the heaviest burden of indoor air pollution, which causes 4.3 million premature deaths worldwide (WHO 2014b), due to their high exposure. It leads to more deaths than HIV/AIDS, malaria, tuberculosis, and malnutrition combined (Lim et al. 2012). There is emerging evidence that men's health can also be affected by exposure to indoor air pollution when they spend time in the kitchen, increasing their mortality risk when combined with other health issues (World Bank 2012c). Depending on culture, boys or girls spend more time in the kitchen, and hence siblings have different exposure levels.[28] Before preparing the food, women and men may suffer skeletal damage from carrying heavy loads, such as fuelwood and water. At that time, women may also be exposed to sexual and other forms of violence.[29, 30]

Energy-gender nexus and the SE4All objectives

Access to affordable modern energy services can reduce both time and effort spent in reproductive and productive labor. By increasing efficiency and productivity, better access improves well-being and frees up time for leisure and rest. Time spent on fetching water can be sharply reduced through piped water supply, often made possible through fuel-based water pumps. The use of non-solid (liquid or gaseous) cooking fuel can decrease time spent in collecting fuelwood, while reducing indoor air pollution. Access to electric labor-saving appliances, such as food processors or washing machines, further improves women's quality of life, and may create income-generating opportunities. Micro hydro plants powering grain mills in Nepal were instrumental in bringing down women's workload considerably, from at least two hours of grain processing by hand to around half an hour with mechanization (Mahat 2004). But the time saved by improved energy access is often used differently by men and women. Men are more likely to use it for recreation and leisure, while women tend to use the time for housework and child care, as well as for resting, socializing, and watching TV, and not necessarily for income-generating activities (Matly 2003).

Although machines now perform much of the hard labor formerly done by people, there are some drawbacks. Evidence from Bangladesh and Indonesia suggests that women lost jobs as agriculture mechanized (Cecelski 2004). And in China electrical technologies increased women's workloads as they took over many agricultural tasks from men (Ramani and Heijndermans 2003).

Although social norms and values can take time to adjust after new technologies are brought in,[31] empirical evidence suggests that street lighting may increase women's and girls' mobility after dark and in the early morning (Cecelski et al. 2005). Street lighting may also reduce the risk of gender-based violence (Doleac and Sanders 2012).

Access to energy in health care facilities is a critical enabler for vital health care services and can improve maternal care and facilitate childbirth deliveries. Every day, some 800 women die worldwide from preventable causes related to pregnancy and childbirth (SE4All 2013). Access to electricity in health facilities can increase the number of successful childbirth deliveries, especially at night. Electricity is also needed for sterilization and obstetric equipment.

Besides being energy consumers, women can with men be important energy providers, expanding energy access to poor and hard-to-reach customers, individually and through their networks. A growing number of energy enterprises have begun to employ women as sales representatives to reach low-income consumers at the base of the pyramid with lighting and cooking solutions. Women help ensure that energy products reflect the priorities of women users, increasing the likelihood of adoption and continued use. One example is dissemination of improved cookstoves through women artisans in Nepal by the Centre for Rural Technology (CRT/N 2014). A second example is sales of clean energy and water products by Kopernik Solutions in Indonesia through largely women-run Tech Kiosks and Tech Agents (Hamakawa, Nakamura, and Wojkowska 2014). And a third example is sales of solar lights, mobile phone chargers, and other products in Africa by Solar Sister (Lucey 2014).

High up-front costs of access to modern energy services may more severely affect female-headed households, often overrepresented in poorer quintiles. Low-income groups, particularly women, rarely have access to finance from formal institutions (Alstone et al. 2011). This circumstance prompted the introduction of a range of financing schemes beyond microcredit (which offers only very small amounts). A key design feature aiming to match women's capacity to pay has been used in two of the best-known programs: Grameen Shakti, promoting solar home systems in Bangladesh (Schalatek 2009); and the ENSIGN project of the Asia/Pacific Development Centre and UNDP, working with the Self-Employed Women's Association Bank in India, promoting process-heat technologies (Ramani 2002).

As with time saved and interventions tied to electricity, women and men respond differently to energy efficiency incentives and energy use alternatives. Women are usually the primary energy users in the household as they perform most household chores that require energy (such as cooking, washing, or cleaning) and are therefore in good position to manage electricity use. However, women are not always involved in making decisions on use of energy sources or appliances, particularly in traditional contexts, and often lack access to finance for investing in energy-efficient appliances in their homes or businesses (ENERGIA 2006). A recent study in the Europe and Central Asia region finds that men are better informed and active in applying energy efficiency measures because insulation repairs are commonly perceived as a "man's job." Conversely, women are interested in the economic aspect of energy efficiency, such as cost and potential savings, but such information is not always easily accessible (World Bank 2014).

Finally, women's empowerment can support the energy efficiency goal. Evidence has shown that where there is a monetary opportunity cost of women's time, people are more open to adopting energy saving devices and to making adjustments within the family to share the burden of, for instance, fuelwood collection, facilitating women's participation in economic activities (Kelkar and Nathan 2005).

Existing indicators and challenges

Statistics on the energy-gender nexus come from global surveys such as the Living Standards Measurement Study (LSMS), the Demographic and Health Survey (DHS), and the Multiple Indicator Cluster Survey (MICS). Other studies can also be important sources.

Rates of access to modern energy services are often obtained with the gender of the head of the household. Access to electricity is tracked in household surveys through questions related to presence of a grid connection or electric lighting in the household. The use of solid versus non-solid fuels as a primary cooking fuel is also monitored (Chapter 2). Most surveys report whether the head of the household is male or female and usually have a roster of household members by gender and age among other socioeconomic characteristics. Thus the share of male- or female-headed households with access to electricity and to non-solid fuels for cooking[32] can be reported. Data have been compiled for high-impact countries, represented in figures 6.10, 6.11, and 6.12.[33]

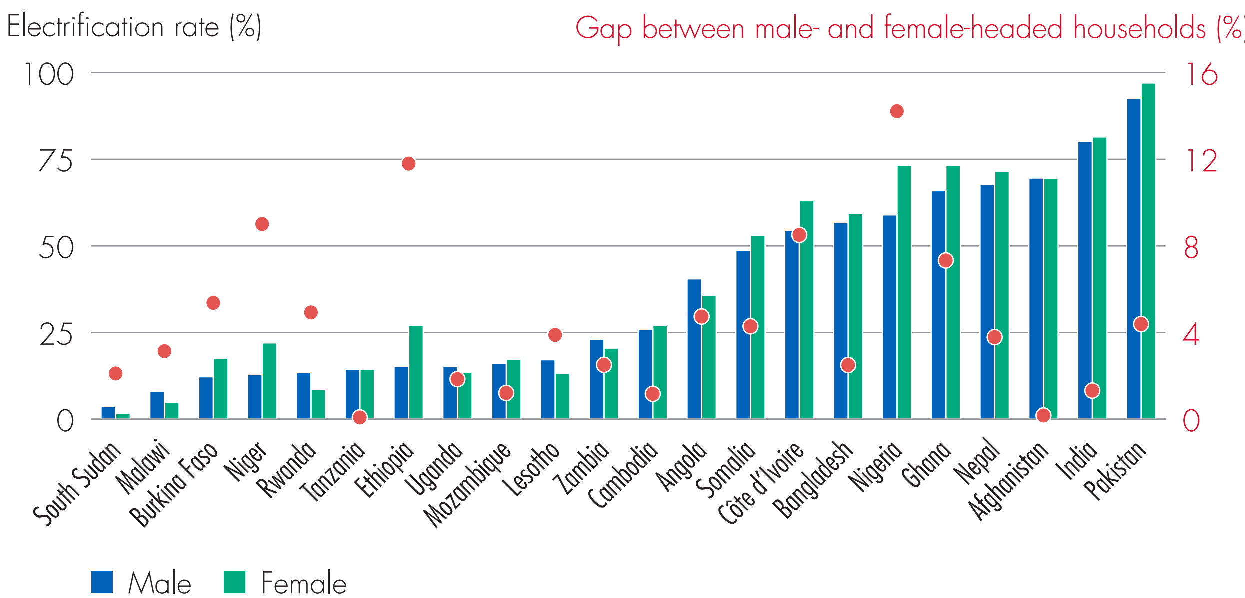
Electrification rates for 22 high-impact countries range from 2 percent to 97 percent (see figure 6.10). In 14 countries, female-headed households have higher access rates than male-headed households. In countries with nationwide electrification rates under 20 percent, male-headed households show higher access rates in six out of 10 countries. In countries with nationwide electrification rates over 60 percent, female-headed households show higher access rates in five out of six countries. The access gap between female- and male-headed households does not seem to be strongly correlated with the level of access. And it ranges from close to zero in Tanzania and Afghanistan to over 10 percent in Ethiopia and Nigeria.

In 12 out of 20 countries, female-headed households have higher access rates to non-solid cooking fuel than male-headed households (see figure 6.11). Among the 10 countries with the highest access rates, female-headed households show better rates in eight countries. By contrast, among the 10 countries with the lowest access rates, male-headed households show better rates in six countries. The access gap for non-solid cooking fuel between female- and male-headed households is generally smaller than that for electrification, at less than one percent in 12 countries, and only one country (Nigeria) has a gap of more than 10 percent.

The share of electrification expenditure as a share of total expenditure is higher for female-headed households across 20 countries (except Tanzania). The gap is generally very small (< 1 percent in 17 countries) and does not exceed 2 percent (see figure 6.12).

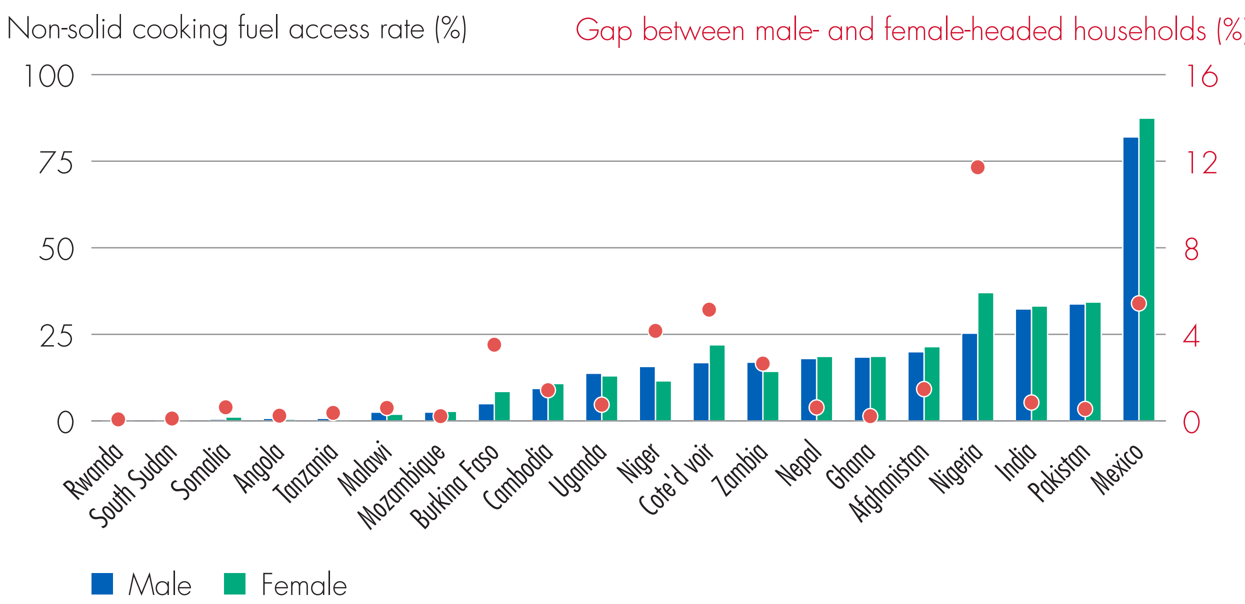
Depending on data availability, further disaggregation between urban and rural households, as well as by income quintile, can be made, as raw data are available for most

Figure 6.10. **Electrification rate by gender of head of household, 2012, and gap**



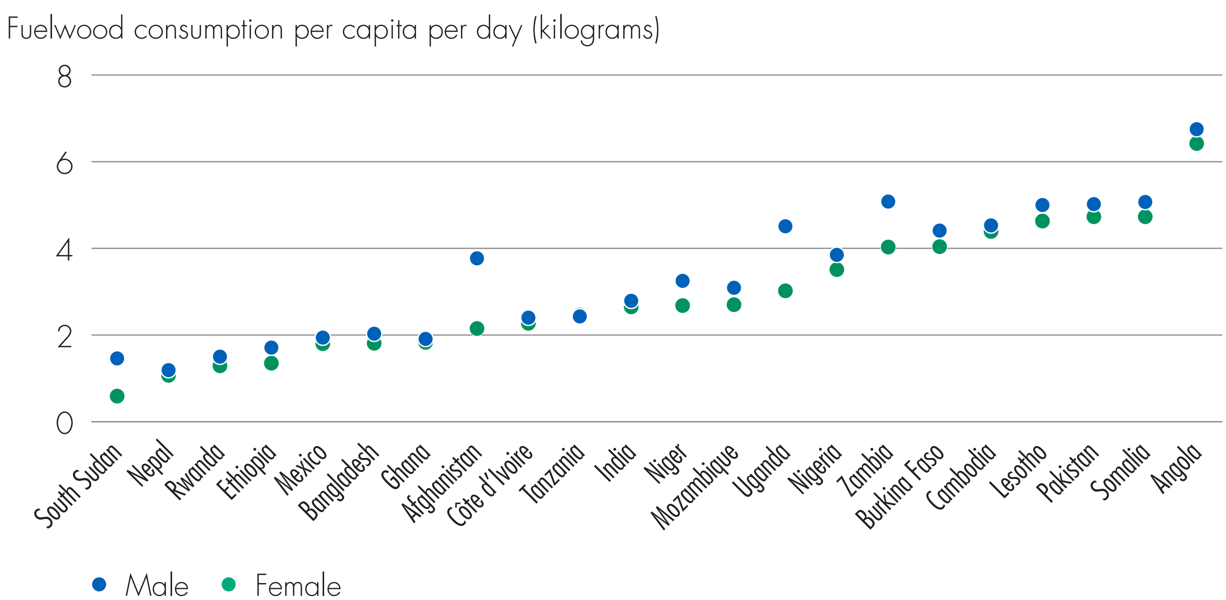
Source: Household surveys.

Figure 6.11. **Non-solid cooking fuel access rate by gender of head of household, 2012, and gap**



Source: Household surveys.

Figure 6.12. **Share of electricity expenditure by gender of head of household, 2012**



Source: Household surveys.

countries. But such indicators have not been systematically tracked globally.

Time allocation by men and women on productive tasks such as engaging in farms, shops, and small businesses, as well as nonmarket tasks such as fetching water, collecting firewood, cooking, and carrying out other household chores are tracked by several household surveys, including LSMS. However, indicators are challenging to track due to multiple methodological issues related to data consistency (questions vary across countries).[34]

Other standardization challenges in time-use surveys relate to the inventory and definition of tasks. For example, people have different notions of how to measure time, not everyone uses a clock or a watch, and some people may use "fluctuations of nature such as day time or the season" (Blackden and Wodon, 2006). This variation requires special data-gathering tools to translate local perceptions of time. Also, women in particular often multitask but may report only one task, thus causing miscounting as all activities are not fully captured. Further, some surveys may not consider household chores as productive.[35] Data on average time spent on fuel collection in male- and female-headed households can usually be compiled. Some surveys may also report which member of the household performs the task, enabling further analysis.

Women's economic empowerment can be tracked through labor statistics. The International Labour Organization (ILO) database covers over 100 sex-disaggregated indicators and 230 countries, with labor force participation rates, self-employment rates, distribution of employed population by sector (agriculture, industry, and services), unemployment rates, and so on (ILO 2014). Along with formal employment, the ILO also reports informal employment (for some countries only). But tracking employment in the informal sector (a large part of women's employment) can be methodologically difficult, given the sector's diffuse nature, which renders sampling difficult, and given the reluctance of informants to reveal sensitive data. Variations in survey techniques, particularly sample size and source of information, such as individual versus enterprise data add to the complexity (Margolis 2014).

Data on mortality and morbidity due to indoor air pollution come from WHO. With other researchers, WHO has built since the mid-1980s a large body of evidence and data on the links between women's health and such pollution (Rehfuess 2006). However, fewer data sets on men's exposure to indoor air pollution are comprehensive, and data on children's exposure are seldom disaggregated by sex (World Bank 2012c).

Data gaps and required indicators

Gender analysis asks questions in relation to women and men about who is doing what, who owns what, who makes decisions about what and how, and who gains and who loses by a planned intervention. Gender as a concept explains the differentiated responses of household members to energy interventions (such as improved cookstoves and electrification) and identifies how the benefits accrue within the household (Clancy et al. 2011).[36]

Quantitative assessments of differential impacts of energy on the lives of women, men, girls, and boys are scarce. Sex-disaggregated data on energy use are lacking, with most of the data qualitative and limited to rural areas. When available, evidence focuses on women rather than on women and men. There are only a few insights into men's activities and on changes in gender roles. The scarcity of impact data partly stems from methodological difficulties such as relying on respondent recall and allocation of time to tasks carried out simultaneously. These obstacles are, however, beginning to ease slightly as several multi- and bilateral development agencies have started to mainstream gender into their policies and operations, including energy. Organizations such as the Norwegian Agency for Development Cooperation (Norad), World Bank, and Global Environment Facility (GEF) Small Grants Programme are now tracking gender within energy projects and energy sector operations (Norad 2011; ESMAP 2013; GEF 2014).

Yet there's a long way to go. The impact of energy access on household income and how that income is used from a gender perspective is not well documented. Also evidence is limited about the way energy interventions influence accumulation of assets, including the types of assets women and men own. Nor is the evidence on the impact of modern energy on small enterprises extensive from a gender perspective, with the two most comprehensive studies more than 10 years old (Meadows et al. 2003; Ramani and Heijndermans 2003). Most studies focus on electricity with little attention to process heat (used by many women in their enterprises) and mechanical energy in small and informal sector enterprises. Finally, it is not well understood from a gender perspective how the cost of energy or the promotion of energy efficiency affects enterprise profitability.

The impacts of energy access on health conditions related to drudgery and nutrition are not monitored with gender-disaggregated data. There is little robust epidemiological data on the drudgery and physical injuries resulting from fuel and water collection, and evidence is largely anecdotal. The health links between improved nutrition, access to enough clean water, and energy access also receive little attention. No empirical studies look at the impacts of modern energy—or the lack of it—on HIV/AIDS infected populations, and none specifically on the connections among gender, energy, and major diseases such as malaria. These illnesses can reduce the capacity to undertake physical labor, such as wood collection, while healthy household members also suffer additional stress when having to care for the sick, who may require more warmth, more nutritious meals, and more boiled water (ENERGIA 2006).

Qualitative indicators measuring viewpoints, judgments and perceptions of women and men can show important perspectives on the adoption of an energy source or solution. Focus group discussions or in-depth interviews can gather data about opinions, beliefs, perceptions, benefits, and impacts related to energy interventions (IOB 2013). Such indicators may offer insight into social systems and explain the effectiveness of energy interventions. The ultimate goal of many rural electrification projects for example is to 'improve people's quality of life'. However, notions of what constitutes a good quality of life are multifarious and perceptions will vary from person to person. A more holistic understanding of the level of access to energy and the impact of interventions may be obtained when qualitative indicators are used in combination with quantitative data.[37]

Gender sensitive surveys should interview both male and female household members, not focus on the head of household. This is because—although the "household" is typically considered as a unified entity that pools resources whose preferences can be expressed in terms of a single utility function—it is inaccurate to assume, for example, that when household income increases the well-being of all household members improves equally. The household is the center of both cooperation and conflict between women and men, who have different interests and priorities (World Bank, 2005). Tracking progress toward meeting women's and men's interests and priorities is necessary for ensuring equalities of outcomes. Although this approach increases the complexity and hence the time and cost of data gathering and analysis, it also contributes to better-informed policies and interventions. A comparison may be drawn with the health sector, where surveys such as USAID's DHS collecting information at the individual level led to robust data on diseases and health issues across the world.

Based on a series of indicators recently proposed by UN initiatives aiming to monitor gender across several areas, a list of existing and new indicators focusing on the energy and gender nexus has been compiled to track access to modern energy services, time poverty, women's empowerment, and health. In February 2013, the UN Statistical Commission (UNSC) identified a minimum set of gender indicators comprising 52 quantitative and 11 qualitative indicators covering norms and laws on gender equality, as a guide for the national production and international compilation of gender statistics (UN 2014).[38] In June 2013, UN Women suggested a series of indicators to monitor gender equality, women's rights, and women's empowerment in the post-2015 development framework and the SDGs (UN Women 2013, 2014b). Platforms such as the World Bank Gender Data Portal[39] and the Evidence and Data for Gender Equality (EDGE) initiative[40] may be used for hosting and promoting new gender data and indicators.

A first attempt to compile possible indicators for tracking the energy-gender nexus across countries is summarized in table 6.4. These are intended to stimulate discussions on a future "nexus-tracking" framework.

Conclusion

Improved access to sustainable energy services has the potential to reduce drudgery and the time burden, as well as increase income-generating opportunities for women and men. Gender-informed investments in sustainable energy can increase income and well-being for women and men, improve food security and nutrition, and reduce time poverty. Supporting women to become energy entrepreneurs can help increase energy access and improve energy efficiency.

Data disaggregated by sex can ensure that SE4All objectives are met in a gender equitable way, and contribute to better understanding the effectiveness of energy interventions and adoption of sustainable energy solutions. The collection and use of such data should become the standard practice, and gender-neutral terms such as "consumer," "children," and "community" should be avoided. Marketing campaigns promoting RE solutions or energy-efficient devices should be targeted to women and men to maximize impact and improve adoption rates.

Table 6.4. **Possible indicators for tracking the energy-gender nexus at country level worldwide**

Component	Indicator	Data availability	Current/ potential source
Access to modern energy services	Percentage of households with access to electricity, by sex of household head	Yes[a]	UN Women
	Use of electrical appliances available in the household, by sex of household member	No	
	Percentage of households using modern cooking solutions as primary cooking solution, by sex of household head	Yes[a,b]	UN Women
	Percentage of micro and small businesses with access to electricity/modern cooking and heating solutions, by sex of owner	No	
Time poverty	Average weekly time spent on fuelwood collection, by sex and age of household member	Limited[c]	UN Women
	Average weekly time spent in water collection (including waiting time at public supply points), by sex and age of household member	Limited[c]	UN Women
	Average weekly hours spent on reproductive work, by sex and age of household member	Limited[c]	UNSC, UN Women
	Average weekly time spent in hand processing grain/tubers, by sex and age of household member	No	
Women's empowerment	Percentage of enterprises owned by women	Yes	ILO
	Female share of employment in the energy sector	Yes	ILO
	Number of energy entrepreneurs, by sex	No	
Health	Percentage of births supported by electricity	No	WHO
	Mortality and morbidity rates due to indoor/outdoor air pollution, by sex	Yes	WHO

a. Raw data generally available, but not treated.

b. Available data track solid versus non-solid fuels.

c. Depending on type of survey.

Notes

1. Physical water scarcity occurs when the demand outstrips the land's ability to provide the needed water.
2. Economic water scarcity exists when a population does not have the necessary monetary means to utilize an adequate source of water.
3. Water security refers to the capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socioeconomic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (UNU 2013).
4. Thermal power plants generate around 80 percent of the world's electricity (IEA 2013).
5. Once-through cooling requires large amounts of water, but consumes a very small fraction of it. Closed-loop cooling systems withdraw much less water but consume most of it as water evaporates. Dry-cooling systems use air instead of water to cool the steam, hence there is no water used or consumed in the process. The cooling system employed by the power plant affects power plant efficiency, capital and operating costs, water consumption, water withdrawal, and the environment.

6. Water intensity of thermal power sources (such as geo-, solar, and biomass thermal), depends on the type of cooling system. Dry-cooling systems can lower water needs by 90 percent.
7. Solar PV systems require small quantities of water for mirror washing (which can nonetheless be challenging in arid locations), while wind turbines do not require any water for operations.
8. Other ways to increase water efficiency in power plants are using non-freshwater for cooling (such as seawater or wastewater) and recycling and reusing water in energy-extraction facilities.
9. The Commodity Food Price Index has price indices for cereals, vegetable oils, meat, seafood, sugar, bananas, and oranges, from IMF data (index, 2005 = 100). The Crude Oil (petroleum) Price Index is the simple average of three spot prices: dated Brent, West Texas Intermediate, and the Dubai Fateh, retrieved from IMF data (index, 2005 = 100); the Total Cereals Producer Price Index is retrieved from FAOSTAT (index, 2004–06 = 100, divided by 100).
10. This includes both direct and indirect energy inputs along the whole agrifood chain and agricultural emissions. It excludes forestry and land use emissions.
11. The FAO Corporate Statistical Database (FAOSTAT) website disseminates statistical data collected and maintained by the FAO. FAOSTAT data are provided as a time-series from 1961 in most agricultural domains for 245 countries in English, Spanish, and French. http://faostat3.fao.org/home/E.
12. High Impact Opportunities are categories of action that have been identified as having significant potential to advance the three objectives of SE4All, providing a platform for stakeholders from the private sector, public sector, and civil society to work together.
13. Fuel-based power generators meant to serve as a facility's "back-up" solution may be the only source of electricity, but often they are broken or lack fuel. The above review found that in six countries with data, only one in three generators were operational.
14. Although advanced combustion biomass cookstoves have undergone technological development, many still emit pollutants into the air at rates above WHO guidelines. Such technologies must be measured against health-relevant standards (WHO 2014a).
15. Health-harmful household emissions include fine particulate matter ($PM_{2.5}$) as well as carbon monoxide, oxides of nitrogen (NOx), carcinogens such as benzene, and in the case of unprocessed coal or liquid fuels such as kerosene and diesel, a range of other toxins and heavy metals (WHO 2006).
16. WHO discourages the use of kerosene as a household fuel in the new indoor air quality guidelines for household fuel combustion (WHO 2014a).
17. Exposure to persistent cold or damp can cause morbidity (including asthma, allergies, and respiratory illnesses) and death.
18. CHP is far more efficient than conventional centralized grid power plants.
19. Many countries forbid children under the age of 14 to use an elevator unaccompanied.
20. The main nationally representative household surveys collecting data on primary cooking fuel use are USAID's Demographic Health Surveys (DHS) and World Bank's Living Standard and Measurement Surveys (LSMS), along with national censuses.
21. Ambient (outdoor) air pollution in cities database 2014. http://www.who.int/phe/health_topics/outdoorair/databases/cities/en.
22. Ambient (outdoor) air pollution in cities database 2014. http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/.
23. Energy poverty can be defined as an absence of sufficient choice in accessing adequate, affordable, reliable, clean, high-quality, safe and benign energy services to support economic and human development (Clancy, Skutsch, and Bachelor 2003).
24. The benchmark paper by Barnes (1994) on stoves is a good example.
25. Detailed reviews of the energy-gender nexus may be found in Clancy et al. (2011), Köhlin et al. (2011), and World Bank (2005).
26. Reproductive work refers to the unpaid work performed in the home, usually by women, and encompasses tasks related to caring for, nurturing, and sustaining human beings, including bearing and rearing children, cooking and feeding, caring for the sick, cleaning and washing, and so on.
27. Resources controlled by women tend to be invested more heavily in children (at the margin) than resources controlled by men (World Bank 2001).
28. For instance, incidence of acute respiratory infections among boys is higher than among girls in India (World Bank 2012c).
29. Women living in war-torn areas and camps for displaced persons seem particularly vulnerable to sexual violence while they search for fuelwood in surrounding areas (Kasirye, Clancy, and Matinga 2009).
30. See Matinga (2010) for a review of the literature.
31. In hill tribes in northern India, perceptions that existed before the advent of street lighting about women who leave the home after dark continued to act as

a barrier to women's mobility (Kelkar and Nathan 2007).

32. To increase data accuracy on access to primary cooking fuels, it is preferable to interview the cook of the household, not the head of the household.
33. These include (subject to data availability) the 40 countries with the highest access deficits (number of people without access) and the 40 countries with the lowest electrification/access rate to non-solid cooking fuels.
34. Some surveys ask how many times per day or week household members collect fuel, but do not specify duration. Other surveys focus on the time required for reaching the location where fuel is collected but do not ask for overall time commitment.
35. Nonmarket tasks are not always covered in national surveys as they are not considered to contribute to the productive economy (Charmes 2006).
36. For a review of gender and urban energy issues see Clancy, Maduka, and Lumampao (2007).
37. The evaluation of rural electrification on the quality of life in Bhutan collected both quantitative and qualitative data. Qualitative data gathered through focus group interviews provided additional insights that would have been difficult to capture through standard questionnaires; for example, feelings about social inclusion and discussions about personal matters such as family size.
38. The list of indicators is also available at: http://genderstats.org.
39. http://datatopics.worldbank.org/gender.
40. http://unstats.un.org/unsd/gender/default.html.

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CHAPTER 7
CONCLUSION

Conclusion

This second edition of the Global Tracking Framework provided an update of how the world has been moving toward the three objectives of the Sustainable Energy for All initiative. Based on the latest data, it focused on reporting for 2010–12 and shed light on the underlying drivers of progress. It also assessed whether progress has been on track to meet the objectives for 2030.

The report also explored four complementary themes. First, it provided further analysis of the investment volume needed to meet the three SE4All objectives. Second, it explored the extent to which countries around the world have access to the technology and knowledge to progress toward those objectives. Third, it identified the improvements in data collection methodologies and capacity building needed to provide a more accurate and nuanced picture of progress over time. Fourth, it introduced and explored nexus concepts focusing on the links between energy and four priority areas of development: food, water, gender, and human health.

The measurement and tracking of SE4All indicators show that progress over the tracking period accelerated noticeably in 2010–12, yet it is still far from what it is required to attain the SE4All objectives.

Energy access

The absolute population living without electricity fell from 1.2 billion to 1.1 billion during the tracking period of 2010–12. The 222 million people who benefited from first time access between 2010 and 2012 exceed the population of Brazil. The annual access increment of 11 million people is a substantial acceleration from around 84 million people a year over 1990–2000 and 88 million in 2000–10. Despite the improvement, universal access to electricity is still some distance away, for the required pace of growth from 2012 to 2030 is even higher at 135 million people a year.

The annual growth in access to electricity during the tracking period reached 0.6 percent, much higher than the growth of 0.1 percent over 1990–2010 and very close to the target growth rate of 0.7 percent required to reach universal access by 2030.

The absolute population without access to non-solid fuels as a primary source for cooking stayed at about 2.9 billion during the tracking period, or 41 percent of the global population in 2012. Between 2010 and 2012, 123 million benefited from new access to non-solid fuel. The incremental growth was entirely in urban areas, with rural areas registering no visible change. Global annual net growth of –0.1 percent in 2010–12 is about the same as that between 1990 and 2010. The net increase falls dismally short of the pace required to meet the global objective of universal access to modern cooking solutions, 1.7 percent annually from 2012 to 2030. East Asia reported the fastest growth at 0.4 percent, still far from the required 1.7 percent growth.

Access growth rate needs to be accelerated manifold to achieve the 2030 SE4All energy access goal of universal access to modern cooking fuels—which includes not only the use of non-solid fuel but also very efficient biomass cookstoves.

Energy efficiency

If energy intensity had not changed since 2000, energy consumption in 2012 would have been 25 percent higher in 2012. The incremental change in energy intensity from 2010 to 2012 alone (when primary energy use rose 1.8 percent a year) avoided primary energy use of 20 EJ in 2012, or more energy than Japan used that year. Primary energy intensity fell by more than 1.7 percent a year from 2010 to 2012, substantially more than the average drop of 1.3 percent a year from 1990 to 2010. But even that improvement falls far short of the 2.6 percent annual improvement needed between 2010 and 2030 to double the historical decline in energy intensity.

Renewable energy

The share of renewable energy in total final energy consumption increased from 17.8 percent to 18.1 percent globally in 2010–12, with an absolute increment of 2.9 EJ, equal to the national consumption of Thailand or Pakistan.

The average annual change of 0.17 percentage points compares favorably with the 0.04 percentage points in the preceding decade, but it is still far from the 0.89 average annual percentage point increase required to double the share of renewables by 2030.

Renewable energy consumption has expanded rapidly since 1990, and particularly since 2000, with a compound annual growth rate of 1.6 percent in 1990–00 and 2.3 percent in 2000–10. The rate in 2010–12 remained fairly close to that of the previous decade, at 2.4 percent, lower than the estimated rate of 3.8 percent to achieve the SE4All objective.

Nexus

The energy sector's interactions with food, water, gender, and human health are tied to energy services and energy systems. A nexus perspective increases understanding of the interdependencies across sectors to enhance efficiency, balance tradeoffs, build synergies, and improve governance. The three SE4All objectives are closely interwoven with the four nexus areas. Providing universal access to modern energy services, increasing the share of renewable energy, and improving energy efficiency will improve water security, food security, global health, and gender equality.

The SDG process and links

The Open Working Group on Sustainable Development Goals (SDGs) of the UN General Assembly concluded its deliberations in July 2014 and proposed 17 SDGs and 169 targets.[1] Goal Number 7 on Energy—Ensure access to affordable, reliable, sustainable, and modern energy for all—includes the following targets and means of implementation (7a and 7b):

- *Target 7.1:* By 2030, ensure universal access to affordable, reliable, and modern energy services.
- *Target 7.2:* By 2030, increase substantially the share of renewable energy in the global energy mix.
- *Target 7.3:* By 2030, double the global rate of improvement in energy efficiency.
- *Target 7a:* By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency, and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology.
- *Target 7b:* By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries and small island developing states.

There has been a growing realization that a more integrated approach to sustainable development policy and practice is needed post-2015 to break down the silos in policymaking and to focus instead on the interconnectedness of sustainable development goals and targets. Indeed, the energy SDG seems interlinked with other goals and targets, such as poverty eradication, food security and nutrition, health, population, education, gender, water and sanitation, economic growth, industrialization, infrastructure, sustainable consumption and production, and climate change.

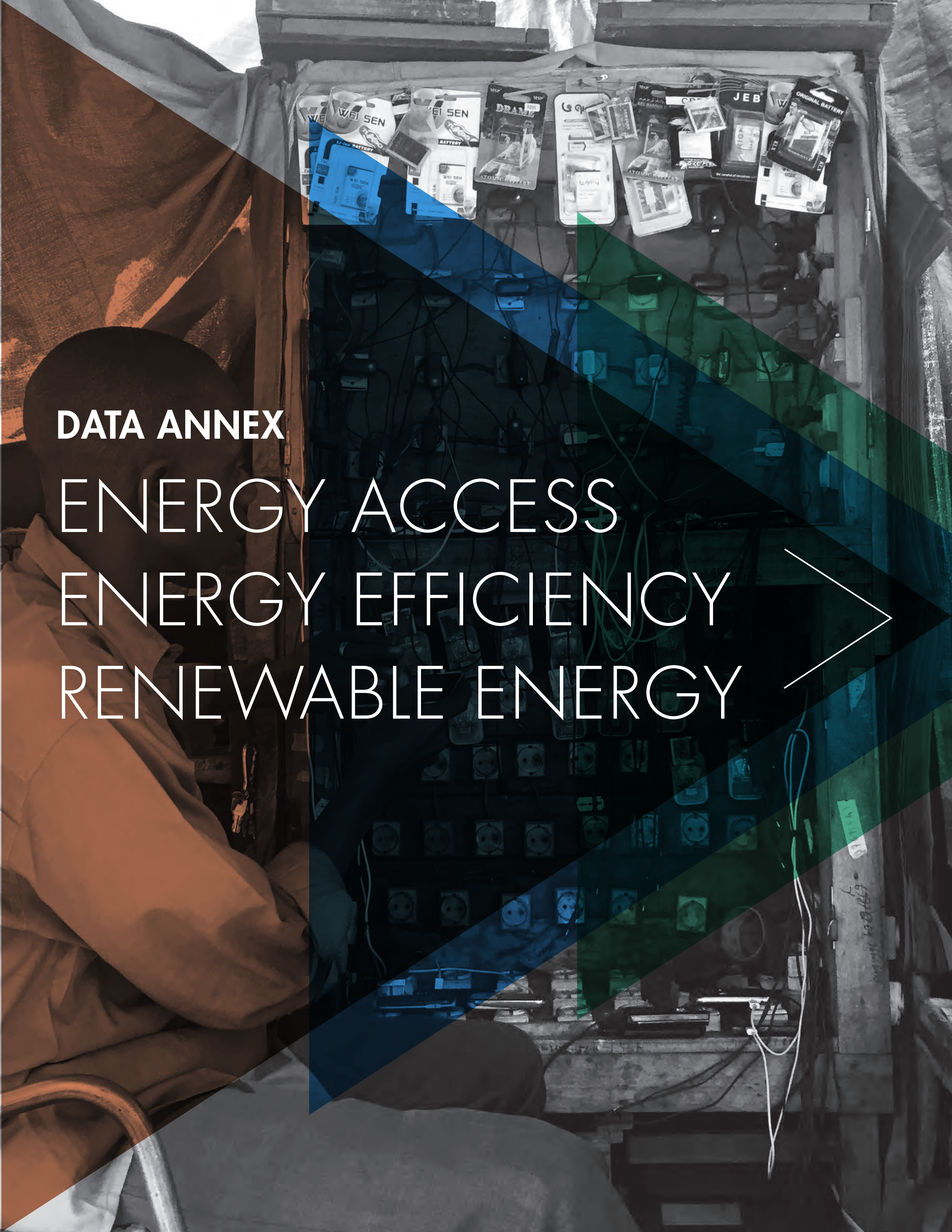
The General Assembly of the United Nations will discuss, negotiate, and decide on the final SDGs in September 2015. Although the proposed energy SDG and its targets are consistent with the objectives of the SE4All initiative, some differences should be considered if the aim is to achieve convergence in the definition of indicators for measuring and monitoring progress toward sustainable energy. The indicators in this Global Tracking Framework 2015 correspond closely to the targets articulated by the Open Working Group. To achieve the truly transformative impact of the energy SDG, policies and partnerships for its implementation should focus on the interconnectedness between the economic, environmental, and social challenges of achieving sustainable energy for all and on the need for integrated data to track progress and report results.

Note

1. United Nations. 2014. Open Working Group Proposal for Sustainable Development Goals; Open Working Group of the General Assembly on Sustainable Development Goals. New York: Division for Sustainable Development. https://sustainabledevelopment.un.org/content/documents/1579SDGs%20Proposal.pdf.

DATA ANNEX

ENERGY ACCESS ENERGY EFFICIENCY RENEWABLE ENERGY



DATA ANNEX: ENERGY ACCESS

		Access to electricity (% of population)							Access to non-solid fuel (% of population)						
		Total				Rural	Urban		Total				Rural	Urban	
Region	Country	1990	2000	2010	2012	2012	2012	Latest available source[a]	1990	2000	2010	2012	2012	2012	Latest available source[a]
SA	Afghanistan	35	37	41	43	32	83	2010 DHS[b]	4	14	19	19	4	72	WHO[c]
DEV	Albania	100	100	100	100	100	100	Assumption	36	51	60	62	42	84	WHO[c]
NA	Algeria	94	98	99	100	100	100	Estimate	86	96	100	100	100	100	WHO[c]
Oceania	American Samoa	49	53	56	59	45	60	Estimate							
DEV	Andorra	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
SSA	Angola	28	31	35	37	6	83	2011 DHS[b]	2	21	40	44	10	79	WHO[c]
LAC	Antigua and Barbuda	81	85	88	91	80	100	Estimate	86	95	100	100	100	100	Assumption
LAC	Argentina	88	92	94	100	96	100	Estimate	83	93	98	99	100	100	WHO[c]
CCA	Armenia	94	98	100	100	100	100	2010 DHS[b]	8	49	85	93	95	100	WHO[c]
LAC	Aruba	81	85	88	91	80	100	Estimate							
DEV	Australia	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
DEV	Austria	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
CCA	Azerbaijan	93	96	100	100	100	100	Estimate	54	74	90	93	82	100	WHO[c]
LAC	Bahamas	92	96	100	100	100	100	Estimate	100	100	100	100	100	100	Assumption
WA	Bahrain	87	91	94	98	93	98	Estimate	100	100	100	100	100	100	Assumption
SA	Bangladesh	22	32	55	60	49	90	2011 DHS[b]	7	11	11	11	2	44	WHO[c]
LAC	Barbados	81	85	88	91	80	100	Estimate	94	99	100	100	99	100	WHO[c]
DEV	Belarus	100	100	100	100	100	100	Assumption	82	93	99	100	97	100	WHO[c]
DEV	Belgium	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
LAC	Belize	91	95	99	100	100	100	Estimate	73	82	85	86	76	97	WHO[c]
SSA	Benin	22	25	28	38	15	68	2012 DHS[b]	2	6	6	6	2	11	WHO[c]
DEV	Bermuda	100	100	100	100	100	100	Assumption							
SA	Bhutan	66	68	72	76	53	100	Estimate	23	44	60	63	49	98	WHO[c]
LAC	Bolivia, Plurinational State of	67	66	80	91	73	99	2012 SEDLAC	51	65	74	76	39	95	WHO[c]
DEV	Bosnia and Herzegovina	94	99	100	100	100	100	Assumption	52	50	43	42	24	69	WHO[c]
SSA	Botswana	37	40	43	53	24	71	2011 Census	37	51	61	62	39	90	WHO[c]
LAC	Brazil	93	97	98	100	97	100	2012 SEDLAC	77	87	93	94	66	96	WHO[c]
SEA	Brunei Darussalam	66	69	73	76	67	79	Estimate	100	100	100	100	100	100	Assumption
DEV	Bulgaria	100	100	100	100	100	100	Assumption	70	81	87	89	100	100	WHO[c]

		Access to electricity (% of population)							Access to non-solid fuel (% of population)						
		Total				Rural	Urban		Total				Rural	Urban	
Region	Country	1990	2000	2010	2012	2012	2012	Latest available source[a]	1990	2000	2010	2012	2012	2012	Latest available source[a]
SSA	Burkina Faso	6	7	13	13	1	49	2010 DHS[b]	2	4	5	5	2	20	WHO[c]
SSA	Burundi	0	4	5	7	1	59	2012 DHS[b]	2	2	2	2	2	2	WHO[c]
SEA	Cambodia	19	17	31	31	19	91	2010 DHS[b]	2	6	11	11	4	49	WHO[c]
SSA	Cameroon	29	46	49	54	19	88	2011 DHS[b]	14	20	22	22	4	41	WHO[c]
DEV	Canada	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
SSA	Cape Verde	58	59	67	71	47	84	Estimate	46	59	67	69	33	88	WHO[c]
LAC	Cayman Islands	81	85	88	91	80	91	Estimate							
SSA	Central African Republic	3	6	10	11	8	15	2010 MICS	2	2	3	3	2	3	WHO[c]
SSA	Chad	0	2	4	6	3	18	2011 MICS	2	5	5	5	2	10	WHO[c]
DEV	Channel Islands	100	100	100	100	100	100	Assumption							
LAC	Chile	95	99	99	100	98	100	2011 SEDLAC	77	87	92	93	55	97	WHO[c]
EA	China	94	98	100	100	100	100	Estimate	35	47	54	55	17	84	WHO[c]
EA	China, Hong Kong SAR	100	100	100	100	100	100	Estimate							
EA	China, Macau SAR	81	84	88	91	72	91	Estimate							
LAC	Colombia	92	97	97	97	88	100	2012 GEIH-National	72	81	85	86	50	98	WHO[c]
SSA	Comoros	42	45	52	69	61	85	2012 DHS[b]	13	21	25	26	10	54	WHO[c]
SSA	Congo	24	21	37	42	12	59	2012 DHS[b]	3	15	23	25	5	36	WHO[c]
SSA	Congo, Dem. Rep. of the	6	7	15	16	6	36	2012 Census	2	3	5	5	2	11	WHO[c]
LAC	Costa Rica	91	98	98	100	99	100	2012 ENAHO	76	87	93	94	81	98	WHO[c]
SSA	Côte d'Ivoire	37	51	59	56	29	88	2012 DHS[b]	12	18	19	19	2	35	WHO[c]
DEV	Croatia	100	100	100	100	100	100	Assumption	74	85	91	92	81	95	WHO[c]
LAC	Cuba	93	97	100	100	95	100	Estimate	82	89	93	93	88	96	WHO[c]
LAC	Curacao	81	85	88	91	80	91	Estimate							
DEV	Cyprus	96	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
DEV	Czech Republic	100	100	100	100	100	100	Assumption	84	95	100	100	100	100	WHO[c]
DEV	Denmark	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
SSA	Djibouti	43	46	50	53	13	65	Estimate	79	84	84	84	23	84	WHO[c]
LAC	Dominica	84	88	92	93	80	99	Estimate	60	78	91	94	100	100	WHO[c]
LAC	Dominican Republic	78	90	98	98	97	99	Estimate	68	81	89	91	77	96	WHO[c]
SEA	East Timor	32	34	38	42	27	78	Estimate	5	8	7	7	2	21	WHO[c]

		Access to electricity (% of population)							Access to non-solid fuel (% of population)						
		Total				Rural	Urban		Total				Rural	Urban	
Region	Country	1990	2000	2010	2012	2012	2012	Latest available source[a]	1990	2000	2010	2012	2012	2012	Latest available source[a]
LAC	Ecuador	89	94	97	97	92	100	2012 ENEMDU	75	87	95	96	85	100	WHO[c]
NA	Egypt	96	98	100	100	100	100	Estimate	88	97	100	100	100	100	WHO[c]
LAC	El Salvador	77	87	92	94	86	98	2012 Census	42	62	76	79	51	93	WHO[c]
SSA	Equatorial Guinea	57	61	65	66	43	93	2011 DHS[b]	28	43	53	55	25	91	WHO[c]
SSA	Eritrea	23	32	33	36	12	100	Estimate	16	28	35	36	13	66	WHO[c]
DEV	Estonia	100	100	100	100	100	100	Assumption	72	82	87	88	70	95	WHO[c]
SSA	Ethiopia	10	13	23	27	8	100	Estimate	4	6	3	2	2	18	WHO[c]
DEV	Faeroe Islands	100	100	100	100	100	100	Assumption							
Oceania	Fiji	49	53	56	59	45	72	Estimate	45	54	59	60	30	85	WHO[c]
DEV	Finland	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
DEV	France	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
Oceania	French Polynesia	49	53	56	59	45	72	Estimate							
SSA	Gabon	73	74	82	89	45	98	2012 DHS[b]	45	63	76	79	31	89	WHO[c]
SSA	Gambia	18	34	31	35	26	41	Estimate	2	4	5	5	2	6	WHO[c]
CCA	Georgia	97	100	100	100	100	100	Estimate	44	51	53	54	16	87	WHO[c]
DEV	Germany	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
SSA	Ghana	31	45	61	64	41	85	2010 MICS	2	8	15	17	4	29	WHO[c]
DEV	Greece	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
DEV	Greenland	100	100	100	100	100	100	Assumption							
LAC	Grenada	81	85	88	91	80	100	Estimate	72	89	100	100	100	99	WHO[c]
Oceania	Guam	49	53	56	59	45	60	Estimate							
LAC	Guatemala	72	78	78	79	72	85	2011 ENCOVI	38	40	37	37	10	71	WHO[c]
SSA	Guinea	14	16	20	26	3	74	2012 DHS[b]	2	2	2	2	2	3	WHO[c]
SSA	Guinea-Bissau	51	54	57	61	21	100	Estimate	2	2	2	2	2	4	WHO[c]
LAC	Guyana	72	75	77	79	75	91	Estimate	74	86	92	93	91	99	WHO[c]
LAC	Haiti	31	31	34	38	15	72	2012 DHS[b]	3	8	8	8	4	16	WHO[c]
LAC	Honduras	64	67	80	82	66	97	2011 INE	34	43	48	49	17	79	WHO[c]
DEV	Hungary	100	100	100	100	100	100	Assumption	70	81	87	89	100	100	WHO[c]
DEV	Iceland	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
SA	India	51	62	75	79	70	98	2012 NSS	22	31	35	36	12	72	WHO[c]
SEA	Indonesia	67	88	94	96	93	99	2012 DHS[b]	23	42	56	59	29	82	WHO[c]

		Access to electricity (% of population)							Access to non-solid fuel (% of population)						
		Total				Rural	Urban		Total				Rural	Urban	
Region	Country	1990	2000	2010	2012	2012	2012	Latest available source[a]	1990	2000	2010	2012	2012	2012	Latest available source[a]
SA	Iran, Islamic Republic of	94	98	98	100	97	100	Estimate	88	96	100	100	100	100	WHO[c]
WA	Iraq	92	94	98	100	97	100	Estimate	87	95	98	99	95	100	WHO[c]
DEV	Ireland	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
DEV	Isle of Man	100	100	100	100	100	100	Assumption							
DEV	Israel	96	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
DEV	Italy	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
LAC	Jamaica	85	86	92	93	87	98	Estimate	62	76	86	88	77	94	WHO[c]
DEV	Japan	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
WA	Jordan	95	100	99	100	99	100	2012 DHS[b]	88	97	100	100	100	100	WHO[c]
CCA	Kazakhstan	94	97	100	100	100	100	Estimate	72	83	89	90	80	97	WHO[c]
SSA	Kenya	11	15	23	23	7	58	2010 DHS[b]	19	20	17	16	3	49	WHO[c]
Oceania	Kiribati	49	53	56	59	45	77	Estimate	34	46	53	54	100	100	WHO[c]
EA	Korea, Dem. People's Rep. of	20	22	26	30	13	41	Estimate	2	6	8	8	3	11	WHO[c]
EA	Korea, Republic of	94	98	100	100	100	100	Estimate	81	100	100	100	100	100	WHO[c]
DEV	Kosovo	100	100	100	100	100	100	Assumption							
WA	Kuwait	87	91	94	98	93	98	Estimate	100	100	100	100	100	100	Assumption
CCA	Kyrgyzstan	97	100	100	100	100	100	2012 DHS[b]							WHO[c]
SEA	Lao People's Dem. Rep.	52	46	66	70	55	98	2011 agriculture survey	3	5	3	2	2	11	WHO[c]
DEV	Latvia	100	100	100	100	100	100	Assumption	78	88	93	94	78	99	WHO[c]
WA	Lebanon	93	95	100	100	100	100	Estimate	93	100	100	100	100	100	Assumption
SSA	Lesotho	6	5	17	21	10	47	Estimate	36	39	38	38	19	93	WHO[c]
SSA	Liberia	0	1	4	10	1	19	2013 DHS[b]	2	2	2	2	2	2	WHO[c]
NA	Libya	97	100	100	100	100	100	Estimate	90	99	100	100	100	100	Assumption
DEV	Liechtenstein	100	100	100	100	100	100	Assumption							
DEV	Lithuania	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
DEV	Luxembourg	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
DEV	Macedonia, Former Yugoslav Rep. of	93	95	99	100	100	100	Assumption	53	62	66	67	43	84	WHO[c]
SSA	Madagascar	9	11	14	15	8	61	2013 DHS[b]	2	2	2	2	2	2	WHO[c]
SSA	Malawi	3	5	9	10	2	37	2012 DHS[b]	2	2	3	3	2	11	WHO[c]
SEA	Malaysia	93	96	99	100	100	100	Estimate	82	94	100	100	100	98	WHO[c]

		Access to electricity (% of population)							Access to non-solid fuel (% of population)						
		Total				Rural	Urban		Total				Rural	Urban	
Region	Country	1990	2000	2010	2012	2012	2012	Latest available source[a]	1990	2000	2010	2012	2012	2012	Latest available source[a]
SA	Maldives	94	96	100	100	100	100	Estimate	42	68	88	92	95	98	WHO[c]
SSA	Mali	12	17	17	26	12	50	2012 DHS[b]	2	2	2	2	2	3	WHO[c]
DEV	Malta	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
Oceania	Marshall Islands	49	53	56	59	45	65	Estimate	74	74	69	68	8	92	WHO[c]
SSA	Mauritania	12	15	18	22	4	46	Estimate	18	32	40	42	20	66	WHO[c]
SSA	Mauritius	97	99	100	100	100	100	Estimate	83	93	98	99	99	98	WHO[c]
LAC	Mexico	96	98	99	99	97	100	2012 SEDLAC	76	83	85	85	53	95	WHO[c]
Oceania	Micronesia, Federated States of	49	53	56	59	45	100	Estimate	43	53	57	58	100	100	WHO[c]
DEV	Moldova, Republic of	92	95	99	100	100	100	Assumption	73	84	90	91	86	100	WHO[c]
DEV	Monaco	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
EA	Mongolia	80	83	86	90	70	99	Estimate	15	27	35	37	10	54	WHO[c]
DEV	Montenegro	100	100	100	100	100	100	Assumption	60	63	62	62	47	84	WHO[c]
NA	Morocco	49	71	99	100	100	100	Estimate	81	91	96	97	85	100	WHO[c]
SSA	Mozambique	6	7	15	20	5	55	2011 DHS[b]	2	2	4	4	2	10	WHO[c]
SEA	Myanmar	43	47	49	52	31	95	Estimate	2	5	7	7	2	19	WHO[c]
SSA	Namibia	26	37	44	47	17	94	Estimate	26	37	44	45	15	83	WHO[c]
SA	Nepal	70	73	76	76	72	97	2011 DHS[b]	22	24	21	20	14	70	WHO[c]
DEV	Netherlands	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
Oceania	New Caledonia	49	53	56	59	45	68	Estimate							
DEV	New Zealand	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
LAC	Nicaragua	71	72	73	78	43	100	2009 SEDLAC	24	37	45	46	9	72	WHO[c]
SSA	Niger	6	7	9	14	5	62	2012 DHS[b]	2	2	3	3	2	7	WHO[c]
SSA	Nigeria	42	45	48	56	34	84	2013 DHS[b]	23	26	25	25	11	55	WHO[c]
DEV	Norway	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
WA	Oman	87	91	94	98	93	99	Estimate	100	100	100	100	100	100	Assumption
SA	Pakistan	60	80	91	94	91	100	2013 DHS[b]	7	25	38	41	14	84	WHO[c]
Oceania	Palau	49	53	56	59	45	62	Estimate	92	98	98	98	100	100	WHO[c]
LAC	Panama	81	85	88	91	80	94	Estimate	73	81	84	85	70	98	WHO[c]
Oceania	Papua New Guinea	8	11	15	18	10	72	Estimate	4	19	30	32	13	71	WHO[c]
LAC	Paraguay	86	93	97	98	96	99	2011 Census	35	48	56	58	30	78	WHO[c]
LAC	Peru	69	73	85	91	73	98	2012 DHS[b]	38	53	63	65	14	89	WHO[c]

		Access to electricity (% of population)							Access to non-solid fuel (% of population)						
		Total				Rural	Urban		Total				Rural	Urban	
Region	Country	1990	2000	2010	2012	2012	2012	Latest available source[a]	1990	2000	2010	2012	2012	2012	Latest available source[a]
SEA	Philippines	65	71	83	88	82	94	2013 DHS[b]	42	47	46	46	22	64	WHO[c]
DEV	Poland	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
DEV	Portugal	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
LAC	Puerto Rico	81	85	88	91	80	91	Estimate							
WA	Qatar	87	91	94	98	93	98	Estimate	90	98	100	100	100	100	Assumption
DEV	Romania	100	100	100	100	100	100	Assumption	63	73	78	79	56	96	WHO[c]
DEV	Russian Federation	100	100	100	100	100	100	Assumption	82	93	98	99	91	99	WHO[c]
SSA	Rwanda	2	6	11	18	8	62	2012 Census	2	2	2	2	2	2	WHO[c]
LAC	Saint Lucia	81	85	88	91	80	100	Estimate	65	83	97	99	97	96	WHO[c]
Oceania	Samoa	80	89	100	100	93	100	Estimate	36	40	39	38	23	71	WHO[c]
DEV	San Marino	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
SSA	Sao Tome and Principe	50	53	57	60	47	68	Estimate	8	20	27	29	16	42	WHO[c]
WA	Saudi Arabia	87	91	94	98	93	99	Estimate	92	99	100	100	100	100	Assumption
SSA	Senegal	26	37	57	57	27	88	Estimate	32	38	39	39	8	69	WHO[c]
DEV	Serbia	100	100	100	100	100	100	Assumption	49	61	67	69	46	87	WHO[c]
SSA	Seychelles	97	99	100	100	17	100	Estimate	78	91	99	100	100	100	Assumption
SSA	Sierra Leone	6	9	12	14	1	47	2013 DHS[b]	6	6	2	2	2	2	WHO[c]
SEA	Singapore	100	100	100	100	99	100	Estimate	100	100	100	100	100	100	Assumption
DEV	Slovak Republic	100	100	100	100	100	100	Assumption	83	94	100	100	100	99	WHO[c]
DEV	Slovenia	100	100	100	100	100	100	Assumption	78	89	95	96	100	100	WHO[c]
Oceania	Solomon Islands	13	16	19	23	13	62	Estimate	9	12	9	9	5	44	WHO[c]
SSA	Somalia	22	26	29	33	17	58	Estimate	2	2	4	5	4	5	WHO[c]
SSA	South Africa	65	66	83	85	67	97	Estimate	60	75	85	87	67	96	WHO[c]
SSA	South Sudan	0	0	2	5	3	12	2012 Census	2	2	2	2	2	2	WHO[c]
DEV	Spain	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	WHO[c]
SA	Sri Lanka	78	81	85	89	86	100	Estimate	12	21	25	26	15	66	WHO[c]
LAC	St. Kitts and Nevis	81	85	88	91	80	100	Estimate	100	100	100	100	100	100	Assumption
LAC	St. Martin (French part)	81	85	88	91	80	92	Estimate							
LAC	St. Vincent and the Grenadines	67	71	75	76	32	100	Estimate	48	78	100	100	100	100	Assumption
SSA	Sudan	23	25	29	33	18	62	Estimate	2	8	25	28	16	42	WHO[c]
LAC	Suriname	95	100	100	100	100	100	Estimate	70	81	87	89	75	94	WHO[c]

		Access to electricity (% of population)							Access to non-solid fuel (% of population)						
		Total				Rural	Urban		Total				Rural	Urban	
Region	Country	1990	2000	2010	2012	2012	2012	Latest available source[a]	1990	2000	2010	2012	2012	2012	Latest available source[a]
SSA	Swaziland	29	32	35	42	24	100	2010 MICS	26	34	38	38	20	87	WHO[c]
DEV	Sweden	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
DEV	Switzerland	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
WA	Syrian Arab Republic	85	87	93	96	81	100	Estimate	85	96	100	100	100	100	WHO[c]
CCA	Tajikistan	95	99	100	100	100	100	2012 DHS[b]	21	45	65	69	58	95	WHO[c]
SSA	Tanzania, United Republic of	7	9	15	15	4	46	Estimate	2	5	4	4	2	15	WHO[c]
SEA	Thailand	80	83	100	100	100	100	Estimate	35	56	73	76	62	86	WHO[c]
SSA	Togo	10	17	28	31	9	68	2010 MICS	2	2	4	5	2	9	WHO[c]
Oceania	Tonga	80	86	92	96	83	100	Estimate	27	43	53	55	54	91	WHO[c]
LAC	Trinidad and Tobago	91	95	99	100	99	100	Estimate	88	97	100	100	100	100	Assumption
NA	Tunisia	93	95	100	100	100	100	Estimate	84	94	100	100	100	100	WHO[c]
WA	Turkey	100	100	100	100	100	100	Estimate	80	90	95	96	100	100	WHO[c]
CCA	Turkmenistan	95	100	100	100	100	100	Estimate	89	98	100	100	100	100	WHO[c]
LAC	Turks and Caicos Islands	81	85	88	91	80	92	Estimate							
Oceania	Tuvalu	35	37	41	45	32	57	Estimate	38	61	79	82	100	100	WHO[c]
SSA	Uganda	7	9	15	18	8	71	Estimate	2	3	3	3	2	10	WHO[c]
DEV	Ukraine	93	96	100	100	100	100	Assumption	81	91	95	96	89	99	WHO[c]
WA	United Arab Emirates	87	91	94	98	93	99	Estimate	86	97	100	100	100	100	WHO[c]
DEV	United Kingdom of Great Britain and Northern Ireland	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
DEV	United States of America	100	100	100	100	100	100	Assumption	100	100	100	100	100	100	Assumption
LAC	Uruguay	96	97	99	100	95	100	2012 Census	90	97	99	99	81	100	WHO[c]
CCA	Uzbekistan	97	100	100	100	100	100	Estimate	70	81	87	88	79	100	WHO[c]
Oceania	Vanuatu	18	19	24	27	18	55	Estimate	16	18	16	15	5	47	WHO[c]
LAC	Venezuela, Bolivarian Republic of	98	99	100	100	100	100	Estimate	93	96	94	94	78	98	WHO[c]
SEA	Vietnam	88	89	96	99	98	100	2011 MICS	2	25	47	51	36	82	WHO[c]
LAC	Virgin Islands (U.S.)	81	85	88	91	80	91	Estimate							
WA	West Bank and Gaza	87	91	94	98	93	99	Estimate							
WA	Yemen	38	41	45	48	33	79	Estimate	52	62	67	68	52	100	WHO[c]
SSA	Zambia	13	17	19	22	6	47	Estimate	4	13	17	17	3	42	WHO[c]
SSA	Zimbabwe	28	34	37	40	16	78	Estimate	33	34	30	30	6	84	WHO[c]

Aggregated by income level

	Access to electricity (% of population)						Access to non-solid fuel (% of population)					
	Total				Rural	Urban	Total				Rural	Urban
	1990	2000	2010	2012	2012	2012	1990	2000	2010	2012	2012	2012
High income: non-OECD	90	93	95	97	92	98	91	97	99	99	94	100
High income: OECD	100	100	100	100	100	100	98	100	100	100	100	100
Low income	20	24	32	34	21	66	6	9	9	9	4	22
Lower middle income	58	68	77	81	72	95	27	38	43	45	21	80
Upper middle income	93	96	98	99	98	99	52	63	70	71	35	94

Aggregated by region

		Access to electricity (% of population)						Access to non-solid fuel (% of population)					
		Total				Rural	Urban	Total				Rural	Urban
		1990	2000	2010	2012	2012	2012	1990	2000	2010	2012	2012	2012
CCA	Caucasus and Central Asia	95	99	100	100	100	100	59	74	83	85	74	98
DEV	Developed countries	100	100	100	100	100	100	94	97	98	99	95	100
EA	Eastern Asia	93	97	98	99	99	99	36	48	54	56	17	89
LAC	Latin America and Caribbean	89	93	95	96	87	99	71	80	85	86	52	94
NA	Northern Africa	85	92	99	100	100	100	86	95	99	99	97	100
Oceania	Oceania	21	23	25	29	17	71	13	25	32	34	16	83
SA	Southern Asia	52	63	75	79	70	97	22	31	36	36	13	83
SEA	Southeastern Asia	70	80	88	90	83	98	25	40	52	54	31	81
SSA	Sub-Saharan Africa	23	26	32	35	15	69	13	17	18	18	7	37
WA	Western Asia	89	89	91	93	80	98	82	90	94	95	87	98
World	World	76	79	83	85	72	96	48	55	58	59	27	87

Note: DEV is developed countries. CCA is Caucasus and Central Asia. EA is Eastern Asia. LAC is Latin America and Caribbean. NA is Northern Africa. SA is Southern Asia. SEA is Southeastern Asia. SSA is Sub-Saharan Africa. WA is Western Asia. DHS is Demographic and Health Survey. ENAHO is Encuesta Nacional de Hogares (National Household Survey). ENCOVI is Encuesta Nacional de Condiciones de Vida (National Survey of Quality of Life). ENEMDU is Encuesta de Empleo, Desempleo y Subempleo (National Survey on Employment, Unemployment and Underemployment). GEIH is Gran Encuesta Integrada de Hogares (Large Integrated Household Survey). INE is Instituto Nacional de Estadística Survey (National Statistical Office Survey). MICS is Multiple Indicators Cluster Survey. NSS is National Sample Survey. SEDLAC is Socio-Economic Database for Latin America and the Caribbean.

a. Provides the name and date of the latest household survey from which the figure is taken, indicates that the figure is an estimate based on the statistical model described in annex 2 or chapter 2, or indicates that the figure is based on the assumption of universal access in countries classified by the United Nations as developed.

b. Demographic and Health Surveys report data on percentage of households with access to electricity rather than percentage of population.

c. Data are from the WHO Global Health Observatory at http://apps.who.int/gho/data/node.main.134?lang=en (accessed 15 January 2015).

DATA ANNEX: ENERGY EFFICIENCY

Country	Source[b]	Primary energy intensity improvement, compound annual growth rate (%)				Level of primary energy intensity (megajoules per 2011 PPP $)			Decomposition analysis, compound annual growth rate[a] (%)		Final energy intensity improvement, compound annual growth rate (%)		Cumulative avoided energy consumption (petajoules)	
		1990–2000	2000–10	1990–2010	2010–12	1990	2010	2012	1990–2010	2010–12	1990–2010	2010–12	1991–2010	2011–12
Afghanistan[c]	UN/WDI	—	10.2	—	17.92	—	3.1	4.6	3.1	8.5	11.43	23.40	–85	–253
Albania	IEA/WDI	–5.37	–3.25	–4.32	–2.94	7.7	3.2	3.0	–1.0	0.6	–3.41	–2.41	230	47
Algeria	IEA/WDI	0.29	0.06	0.18	4.28	3.5	3.6	3.9	–0.5	5.1	1.23	4.22	573	151
Angola	IEA/WDI	1.68	–4.68	–1.55	–1.86	5.6	4.1	4.0	–0.3	–0.2	–1.42	–1.18	340	12
Antigua and Barbuda	UN/WDI	–5.99	2.64	–1.77	0.34	6.9	4.8	4.9	0.7	2.3	0.72	0.30	6	–2
Argentina	IEA/WDI	–1.53	–1.28	–1.41	–3.57	5.5	4.1	3.9	–1.4	–0.6	–1.04	–2.32	5,129	2,282
Armenia	IEA/WDI	–9.09	–5.40	–7.27	3.24	24.4	5.4	5.7	–7.7	5.3	–7.79	1.69	3,343	574
Aruba	UN/WDI	n.a.	n.a.	n.a.	n.a.	11.6	126.5	127.4	7.7	1.4	8.94	1.30	–22	–2
Australia	IEA/WDI	–1.01	–1.73	–1.37	–0.57	7.4	5.6	5.6	–1.3	–1.1	–1.59	–0.79	9,710	2,319
Austria	IEA/WDI	–1.25	0.30	–0.48	–3.29	4.5	4.1	3.8	0.0	–3.3	–0.19	–3.57	502	177
Azerbaijan	IEA/WDI	–1.65	–12.78	–7.38	7.50	15.6	3.4	3.9	–5.3	4.8	–8.47	4.61	5,939	2,022
Bahamas	UN/WDI	–6.36	3.00	–1.79	–10.57	7.4	5.2	4.1	4.2	0.1	7.53	1.29	–25	–2
Bahrain	IEA/WDI	–1.21	–0.72	–0.97	–2.09	12.5	10.3	9.8	–0.8	–2.0	0.53	–2.78	476	80
Bangladesh	IEA/WDI	–1.08	–0.49	–0.79	–2.19	4.7	4.0	3.8	0.5	0.4	–1.18	–1.62	–275	–234
Barbados[c]	UN/WDI	–5.14	1.91	–1.68	1.23	8.0	5.7	5.8	–0.6	–3.4	0.39	–3.04	25	6
Belarus	IEA/WDI	–4.84	–5.84	–5.34	1.64	23.1	7.7	8.0	–3.8	–2.6	–4.79	–2.00	8,682	2,584
Belgium	IEA/WDI	–0.27	–1.05	–0.66	–4.63	6.7	5.9	5.3	–0.4	–2.8	–0.87	–1.50	637	407
Belize	UN/WDI	–0.04	–5.64	–2.88	0.03	9.0	5.0	5.0	0.8	–3.2	0.76	–1.26	–26	–4
Benin	IEA/WDI	–2.62	2.30	–0.19	–0.90	10.2	9.8	9.7	3.1	0.2	–0.11	–0.63	–517	–138
Bermuda	UN/WDI	–3.59	–1.61	–2.61	–2.98	4.2	2.5	2.3	3.2	–3.5	6.84	–4.94	–15	–1
Bhutan	UN/WDI	–3.11	–5.41	–4.27	–3.03	30.0	12.6	11.8	5.5	0.9	0.91	–3.16	–452	–74
Bolivia, Plurinational State of	IEA/WDI	4.37	–1.20	1.55	1.33	4.3	5.9	6.0	0.8	–0.1	1.33	–1.07	–286	–107
Bosnia and Herzegovina[c]	IEA/WDI	–16.55	–0.05	–8.67	1.44	47.3	7.7	7.9	–5.9	–1.3	–10.28	–0.42	7,180	1,144
Botswana	IEA/WDI	–0.96	–1.72	–1.34	–5.37	4.6	3.5	3.1	–1.3	2.7	–0.23	–3.61	174	44
Brazil	IEA/WDI	0.40	–0.06	0.17	1.04	3.9	4.1	4.1	0.5	1.8	0.19	1.62	–9,559	–2,279
British Virgin Islands	UN/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Brunei Darussalam	IEA/WDI	1.02	1.73	1.37	6.85	3.7	4.8	5.5	1.8	–1.6	2.83	4.34	–113	–48
Bulgaria	IEA/WDI	–2.87	–4.34	–3.60	0.04	13.9	6.7	6.7	–5.7	0.8	–4.36	1.01	10,781	1,867
Burkina Faso	UN/WDI	–7.01	0.76	–3.20	–2.36	14.1	7.4	7.0	–1.5	2.0	–3.45	–1.66	401	85

Country	Source[b]	Primary energy intensity improvement, compound annual growth rate (%)				Level of primary energy intensity (megajoules per 2011 PPP $)			Decomposition analysis, compound annual growth rate[a] (%)		Final energy intensity improvement, compound annual growth rate (%)		Cumulative avoided energy consumption (petajoules)	
		1990–2000	2000–10	1990–2010	2010–12	1990	2010	2012	1990–2010	2010–12	1990–2010	2010–12	1991–2010	2011–12
Burundi	UN/WDI	0.86	1.44	1.15	–2.05	10.8	13.5	13.0	6.8	–0.3	8.53	–2.12	–813	–123
Cambodia[d]	IEA/WDI	–2.97	–3.76	–3.36	–2.55	—	5.8	5.5	–1.3	1.2	–4.20	–1.71	463	60
Cameroon	IEA/WDI	1.01	–2.27	–0.64	–4.04	6.5	5.7	5.3	–2.1	–0.3	–1.27	–1.63	800	292
Canada	IEA/WDI	–0.94	–1.88	–1.41	–2.11	10.1	7.6	7.3	–1.0	–1.1	–1.33	–0.56	17,499	4,142
Cape Verde	UN/WDI	–4.38	–1.01	–2.71	11.77	4.8	2.8	3.5	1.8	21.7	–3.36	18.02	–11	–6
Cayman Islands	UN/WDI	0.00	1.63	0.81	2.13	3.1	3.7	3.8	0.6	2.2	0.63	2.40	6	–1
Central African Republic	UN/WDI	–4.11	–2.28	–3.20	–0.42	13.8	7.2	7.2	–7.7	–7.5	–5.31	–4.85	417	111
Chad	UN/WDI	0.22	–7.39	–3.66	–2.26	7.9	3.7	3.6	n.a.	–1.6	3.24	–2.69	–670	–78
Chile	IEA/WDI	–0.34	–1.73	–1.04	4.01	4.8	3.9	4.2	–0.2	–0.7	–0.95	–2.45	306	114
China	IEA/WDI	–6.40	–2.17	–4.31	–1.33	20.7	8.6	8.3	–3.5	–1.7	–5.49	–2.73	671,451	196,036
China, Hong Kong SAR	IEA/WDI	0.62	–3.52	–1.47	–1.31	2.4	1.7	1.7	–0.3	–1.3	–1.58	–0.51	–897	14
China, Macao SAR	UN/WDI	1.98	–8.87	–3.59	–14.08	1.3	0.6	0.5	–1.8	–8.8	–2.86	–9.39	–3	2
Colombia	IEA/WDI	–1.97	–2.08	–2.02	–4.46	3.9	2.6	2.4	–2.0	2.1	–2.50	1.00	3,565	953
Comoros	UN/WDI	2.46	1.25	1.86	3.29	4.0	5.8	6.1	0.1	2.9	3.55	4.01	1	0
Congo	IEA/WDI	–0.93	1.76	0.41	2.29	2.6	2.8	2.9	–0.4	–1.7	0.02	1.84	102	3
Congo, Dem. Rep. of the	IEA/WDI	7.70	–1.01	3.26	–4.94	11.2	21.2	19.1	0.9	–1.6	3.62	–5.03	–1,980	–251
Cook Islands	UN/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Costa Rica	IEA/WDI	0.28	0.55	0.42	–3.77	3.1	3.4	3.1	–1.8	–5.5	–0.38	–5.31	465	158
Côte d'Ivoire	IEA/WDI	2.16	2.88	2.52	9.56	4.9	8.1	9.7	0.6	8.1	1.70	8.27	–109	–124
Croatia	IEA/WDI	0.08	–1.46	–0.69	–2.83	4.8	4.1	3.9	–0.4	–1.8	–0.09	–2.63	17	57
Cuba	IEA/WDI	–1.68	–6.05	–3.89	–3.33	5.2	2.3	2.2	–4.6	0.0	–5.85	–1.33	3,181	758
Cyprus	IEA/WDI	0.40	–1.46	–0.54	–3.55	4.3	3.9	3.6	–0.3	–2.9	–0.17	–3.89	3	20
Czech Republic	IEA/WDI	–2.39	–2.47	–2.43	–2.48	10.9	6.7	6.4	–2.0	–2.7	–3.09	–2.97	4,326	1,310
Denmark	IEA/WDI	–1.84	–0.15	–1.00	–5.97	4.3	3.5	3.1	–0.5	–4.4	–0.88	–4.71	1,077	239
Djibouti[c]	UN/WDI	3.04	–0.50	1.26	–24.66	4.8	6.1	3.5	1.1	–1.7	2.15	–3.04	–21	–2
Dominica	UN/WDI	4.61	–0.41	2.07	–0.83	2.2	3.3	3.2	3.3	0.4	3.37	1.18	–7	–1
Dominican Republic	IEA/WDI	–0.28	–4.76	–2.54	–1.10	4.8	2.9	2.8	–2.4	1.4	–1.47	–0.53	622	290
Ecuador	IEA/WDI	1.32	0.21	0.76	–2.57	3.6	4.1	3.9	–0.7	–1.7	–0.13	–1.50	623	179
Egypt	IEA/WDI	–1.89	1.10	–0.41	1.62	4.0	3.7	3.8	–0.5	–0.5	–0.53	0.72	2,920	602
El Salvador	IEA/WDI	0.24	–1.25	–0.51	–0.19	4.3	3.9	3.9	–1.9	0.0	–1.94	0.19	216	102
Equatorial Guinea	UN/WDI	–18.50	10.19	–5.23	4.74	15.4	5.3	5.8	0.5	4.7	–14.63	–0.63	41	20

Country	Source[b]	Primary energy intensity improvement, compound annual growth rate (%)				Level of primary energy intensity (megajoules per 2011 PPP $)			Decomposition analysis, compound annual growth rate[a] (%)		Final energy intensity improvement, compound annual growth rate (%)		Cumulative avoided energy consumption (petajoules)	
		1990–2000	2000–10	1990–2010	2010–12	1990	2010	2012	1990–2010	2010–12	1990–2010	2010–12	1991–2010	2011–12
Eritrea[d]	IEA/WDI	n.a.	–0.37	n.a.	–4.08	—	5.0	4.6	–3.7	–0.6	–4.30	–3.89	152	36
Estonia[c]	IEA/WDI	–6.77	–1.67	–4.25	–7.14	19.9	8.3	7.2	–3.5	–5.5	–4.79	–6.88	2,421	435
Ethiopia	IEA/WDI	0.46	–4.65	–2.13	–4.34	28.6	18.6	17.0	1.0	1.3	–2.43	–5.29	–3,776	–460
Falkland Islands (Malvinas)	UN/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Fiji	UN/WDI	0.02	–0.49	–0.23	–4.16	4.2	4.0	3.7	0.4	–1.1	0.69	–1.79	21	–1
Finland	IEA/WDI	–0.75	–0.48	–0.62	–5.34	8.5	7.6	6.8	–1.1	–1.3	–0.91	–3.07	2,475	595
France	IEA/WDI	–0.77	–0.75	–0.76	–2.69	5.5	4.7	4.5	–1.3	–2.3	–0.78	–3.53	18,194	4,723
French Guiana	UN/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
French Polynesia	UN/WDI	n.a.	n.a.	n.a.	n.a.	—	—	—	1.7	–0.1	n.a.	n.a.	–16	–3
Gabon	IEA/WDI	0.54	1.67	1.10	–3.80	2.7	3.4	3.1	1.1	–1.4	1.09	–4.63	–90	–26
Gambia	UN/WDI	0.01	–0.25	–0.12	–1.27	5.8	5.7	5.5	0.3	–1.4	1.27	–0.07	26	3
Georgia	IEA/WDI	–4.73	–5.07	–4.90	2.23	13.5	4.9	5.2	–3.4	4.4	–4.30	2.49	1,543	316
Germany	IEA/WDI	–2.32	–1.22	–1.77	–4.23	6.0	4.2	3.9	–1.6	–3.7	–1.68	–3.84	42,472	8,838
Ghana	IEA/WDI	–0.55	–3.67	–2.12	–6.51	8.0	5.2	4.6	–2.3	–4.1	–3.09	–5.53	895	271
Gibraltar	IEA/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.0	0.0	n.a.	n.a.	n.a.	n.a.
Greece	IEA/WDI	0.02	–1.81	–0.90	5.49	4.3	3.6	4.0	–1.0	4.3	–0.74	1.66	2,449	302
Grenada	UN/WDI	2.31	1.73	2.02	–0.05	2.7	4.1	4.1	1.5	0.2	1.94	–1.69	–4	–1
Guadeloupe	UN/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Guatemala	IEA/WDI	0.64	0.42	0.53	0.63	3.9	4.3	4.4	–0.6	–1.8	–0.01	–2.25	455	85
Guinea	UN/WDI	–2.19	–0.77	–1.49	–1.76	16.7	12.3	11.9	–1.5	0.5	–1.46	–1.49	540	95
Guinea-Bissau	UN/WDI	0.79	–0.25	0.27	–0.24	14.4	15.2	15.1	–1.7	–0.5	0.53	–0.34	56	17
Guyana	UN/WDI	–1.76	–1.42	–1.59	0.77	10.9	7.9	8.0	–0.3	1.3	–1.58	1.29	92	25
Haiti[c]	IEA/WDI	n.a.	6.46	n.a.	–0.62	—	10.6	10.5	2.1	–1.9	2.77	–3.45	–380	–75
Honduras	IEA/WDI	–0.94	0.18	–0.38	1.57	6.3	5.9	6.1	–2.0	0.9	–0.96	0.47	785	141
Hungary	IEA/WDI	–1.65	–1.66	–1.66	–4.27	6.8	4.9	4.5	–1.6	–5.6	–1.89	–5.31	3,212	667
Iceland	IEA/WDI	1.44	3.40	2.42	0.91	11.7	18.9	19.3	1.2	–0.9	0.14	–0.24	–81	–35
India	IEA/WDI	–1.75	–2.62	–2.18	–1.18	8.4	5.4	5.3	–1.6	0.3	–3.16	–1.73	72,812	19,706
Indonesia	IEA/WDI	0.43	–2.11	–0.85	–5.06	5.4	4.5	4.1	–1.1	–3.0	–1.27	–3.63	6,997	4,383
Iran, Islamic Rep. of[c]	IEA/WDI	2.10	0.17	1.13	–0.12	5.9	7.4	7.4	0.1	–0.1	1.07	–1.99	–4,516	523
Iraq[c]	IEA/WDI	n.a.	0.48	n.a.	0.08	—	4.0	4.0	1.1	1.9	–4.81	2.34	–2,449	–528
Ireland[c]	IEA/WDI	–3.87	–1.96	–2.92	–4.80	5.6	3.1	2.8	–1.3	–3.1	–2.41	–5.91	1,242	303

Country	Source[b]	Primary energy intensity improvement, compound annual growth rate (%)				Level of primary energy intensity (megajoules per 2011 PPP $)			Decomposition analysis, compound annual growth rate[a] (%)		Final energy intensity improvement, compound annual growth rate (%)		Cumulative avoided energy consumption (petajoules)	
		1990–2000	2000–10	1990–2010	2010–12	1990	2010	2012	1990–2010	2010–12	1990–2010	2010–12	1991–2010	2011–12
Israel	IEA/WDI	–0.97	–0.94	–0.96	–1.60	5.3	4.3	4.2	–0.2	–5.2	–0.64	–4.67	552	172
Italy	IEA/WDI	–0.02	–0.42	–0.22	–2.54	3.6	3.5	3.3	–0.8	–1.5	–0.27	–1.45	11,426	1,978
Jamaica	IEA/WDI	1.43	–4.10	–1.37	0.86	6.6	5.0	5.1	–1.4	3.1	–1.46	1.56	95	35
Japan	IEA/WDI	0.55	–1.15	–0.30	–5.24	5.0	4.7	4.3	–0.4	–1.7	–0.60	–2.48	1,580	2,796
Jordan	IEA/WDI	–1.04	–2.30	–1.68	0.96	6.1	4.4	4.5	–1.5	1.7	–1.99	1.67	344	135
Kazakhstan	IEA/WDI	–3.51	–1.33	–2.42	–2.05	14.8	9.0	8.7	2.0	–3.8	–4.13	–2.53	–2,946	–732
Kenya	IEA/WDI	0.92	–0.63	0.14	–2.54	9.5	9.7	9.3	–0.4	–1.6	–0.12	–2.88	457	149
Kiribati	UN/WDI	0.85	4.69	2.75	–4.89	3.5	6.0	5.4	n.a.	n.a.	6.01	–5.79	–4	–1
Korea, Dem. People's Rep. of	IEA/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Korea, Republic of	IEA/WDI	0.73	–1.47	–0.38	–0.32	7.5	7.0	6.9	–1.8	–1.3	–1.72	–1.42	15,093	4,987
Kuwait[c]	IEA/WDI	5.46	0.86	n.a.	–2.42	—	5.6	5.3	–0.7	0.7	2.56	–0.08	1,025	374
Kyrgyzstan	IEA/WDI	–7.37	–2.28	–4.86	19.06	20.5	7.6	10.7	–3.3	22.5	–5.55	21.73	720	129
Lao People's Dem. Rep.	UN/WDI	–3.62	–5.80	–4.72	–9.01	8.2	3.1	2.6	–0.6	–0.8	–5.00	–5.87	48	15
Latvia	IEA/WDI	–4.23	–1.66	–2.95	–7.26	9.1	5.0	4.3	–2.5	–6.4	–2.47	–7.56	1,617	293
Lebanon	IEA/WDI	2.78	–3.03	–0.17	3.85	3.9	3.8	4.1	0.6	6.0	–0.10	4.79	–710	14
Lesotho	UN/WDI	0.44	4.89	2.64	–2.81	6.9	11.6	11.0	n.a.	–0.4	18.76	–2.65	–206	–73
Liberia	UN/WDI	–0.22	–2.61	–1.42	–5.09	40.7	30.5	27.5	–3.3	–0.2	–0.09	–4.60	31	37
Libya[c]	IEA/WDI	3.10	–1.67	n.a.	3.70	—	4.7	5.1	–2.7	2.4	n.a.	11.56	1,961	246
Lithuania	IEA/WDI	–4.73	–4.29	–4.51	–2.43	11.5	4.6	4.4	–3.9	–3.7	–3.97	–3.97	3,499	617
Luxembourg	IEA/WDI	–4.95	–0.18	–2.59	–2.35	6.6	3.9	3.7	–2.5	–3.9	–1.96	–2.00	1,337	228
Macedonia, Former Yugoslav Rep. of	IEA/WDI	1.67	–1.75	–0.05	0.27	5.1	5.0	5.1	0.6	–1.4	0.32	–0.42	–279	–19
Madagascar	UN/WDI	2.54	–0.73	0.89	0.76	5.3	6.3	6.4	–2.0	–0.8	0.16	0.24	267	82
Malawi	UN/WDI	–0.42	–2.71	–1.57	–1.42	14.3	10.5	10.2	–1.3	–1.1	–3.03	–1.78	179	31
Malaysia	IEA/WDI	1.18	–0.26	0.45	–1.67	5.0	5.5	5.3	–0.1	–0.3	–0.43	–3.64	–3,312	210
Maldives[c]	UN/WDI	4.38	0.97	2.66	–0.18	2.8	4.7	4.7	n.a.	2.1	5.71	1.09	–18	–5
Mali	UN/WDI	–0.93	–3.66	–2.31	0.75	5.2	3.2	3.3	–0.9	–1.2	–2.77	–0.04	93	39
Malta	IEA/WDI	–5.30	0.68	–2.36	–12.20	4.8	3.0	2.3	–0.4	–1.7	–1.90	–1.90	9	3
Martinique	UN/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Mauritania	UN/WDI	–11.74	–1.59	–6.81	28.07	19.5	4.8	7.8	–4.1	0.9	–1.10	–0.58	743	240
Mauritius	UN/WDI	–1.76	–0.61	–1.19	–1.98	8.2	6.5	6.2	–2.8	–1.1	–2.37	–3.10	397	100
Mexico	IEA/WDI	–1.83	0.20	–0.82	–0.61	4.8	4.0	4.0	–0.9	–1.9	–0.95	–2.06	14,604	2,444

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		1990–2000	2000–10	1990–2010	2010–12	1990	2010	2012	1990–2010	2010–12	1990–2010	2010–12	1991–2010	2011–12
Moldova, Republic of	IEA/WDI	–1.98	–3.29	–2.64	–4.75	17.5	10.2	9.3	0.9	–4.5	–2.65	–4.69	–381	–35
Mongolia	IEA/WDI	–3.44	–2.65	–3.04	–6.75	15.2	8.2	7.1	–3.3	1.7	–3.71	–4.38	904	208
Montenegro[d]	IEA/WDI	n.a.	–1.30	n.a.	–5.26	—	5.8	5.2	–1.5	–2.0	–4.18	–4.26	0	0
Montserrat	UN/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Morocco	IEA/WDI	1.37	–0.52	0.42	1.48	3.1	3.4	3.5	–0.1	–1.3	0.60	0.96	–83	44
Mozambique	IEA/WDI	–3.33	–4.19	–3.76	–4.28	42.1	19.5	17.9	–1.3	–6.0	–3.84	–9.01	1,310	381
Myanmar	IEA/WDI	–4.94	–9.96	–7.48	–1.65	15.6	3.3	3.2	–2.0	2.0	–7.26	–0.69	3,194	1,190
Namibia	IEA/WDI	1.08	–0.36	n.a.	–2.60	—	3.5	3.3	1.3	–1.5	0.55	–2.59	–72	–12
Nepal	IEA/WDI	–1.49	–1.52	–1.51	–4.49	10.8	8.0	7.3	–1.7	–2.6	–1.53	–4.49	987	143
Netherlands	IEA/WDI	–2.01	–0.03	–1.02	–2.80	6.0	4.9	4.6	–1.0	–2.4	–1.09	–2.85	4,843	1,284
Netherlands Antilles	IEA/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
New Caledonia	UN/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	–0.1	0.1	n.a.	n.a.	n.a.	n.a.
New Zealand	IEA/WDI	–0.18	–1.84	–1.02	–0.60	6.9	5.6	5.5	–1.3	–0.9	–1.44	–2.20	1,680	340
Nicaragua	IEA/WDI	–1.12	–1.18	–1.15	0.46	6.7	5.3	5.4	–1.5	–2.7	–1.32	–3.37	260	66
Niger	UN/WDI	0.92	–6.00	–2.60	0.60	10.6	6.2	6.3	–1.5	–3.3	–1.45	–4.72	–69	58
Nigeria	IEA/WDI	0.75	–5.06	–2.20	0.95	9.6	6.2	6.3	–0.9	0.4	–2.25	–0.02	2,071	1,585
Norway	IEA/WDI	–1.46	0.69	–0.39	–7.00	4.8	4.5	3.9	–0.5	–4.2	–1.53	–4.70	2,155	363
Oman	IEA/WDI	1.52	6.03	3.75	3.69	3.3	7.0	7.5	n.a.	n.a.	5.83	4.42	–1,517	–987
Pakistan	IEA/WDI	0.16	–1.35	–0.60	–2.51	5.5	4.8	4.6	0.2	–1.3	–0.62	–1.68	–3,027	–145
Palau[c]	UN/WDI	2.14	4.64	3.39	–4.14	—	12.3	11.3	1.3	0.1	2.48	–4.61	0	0
Panama	IEA/WDI	0.50	–2.21	–0.86	–4.26	3.4	2.8	2.6	–1.4	–4.4	–0.92	–4.92	189	108
Papua New Guinea	UN/WDI	–2.87	1.64	–0.64	–7.31	13.9	12.3	10.5	–1.9	–4.0	–2.30	–6.31	730	155
Paraguay	IEA/WDI	–0.12	–1.16	–0.64	0.43	5.1	4.4	4.5	–1.2	–1.2	–0.94	0.33	457	110
Peru	IEA/WDI	–1.61	–0.91	–1.26	0.08	3.6	2.8	2.8	–1.3	–3.2	–1.88	–3.37	2,512	452
Philippines	IEA/WDI	0.49	–4.42	–2.00	–2.58	4.8	3.2	3.1	–2.9	–3.8	–2.73	–4.40	5,036	1,576
Poland	IEA/WDI	–5.04	–2.59	–3.82	–4.42	11.4	5.3	4.8	–3.5	–5.9	–3.09	–5.36	44,701	9,095
Portugal	IEA/WDI	0.90	–1.13	–0.12	–2.39	3.7	3.6	3.4	0.3	–5.1	0.31	–3.93	–1,217	18
Puerto Rico	UN/WDI	1.85	1.80	1.83	–0.28	0.6	0.9	0.9	–0.8	–3.6	2.04	–0.82	–78	–7
Qatar[c]	IEA/WDI	–1.30	–2.66	–1.98	7.18	7.9	5.3	6.1	–1.3	2.8	–1.98	0.21	731	552
Reunion	UN/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Romania	IEA/WDI	–3.63	–4.47	–4.05	–1.47	10.0	4.4	4.2	–4.0	–0.3	–4.47	–0.27	14,740	2,734

Country	Source[b]	Primary energy intensity improvement, compound annual growth rate (%)				Level of primary energy intensity (megajoules per 2011 PPP $)			Decomposition analysis, compound annual growth rate[a] (%)		Final energy intensity improvement, compound annual growth rate (%)		Cumulative avoided energy consumption (petajoules)	
		1990–2000	2000–10	1990–2010	2010–12	1990	2010	2012	1990–2010	2010–12	1990–2010	2010–12	1991–2010	2011–12
Russian Federation	IEA/WDI	0.46	–3.38	–1.48	–0.14	12.8	9.5	9.5	0.0	–0.9	–2.50	–1.90	–54,550	1,703
Rwanda	UN/WDI	4.14	–1.60	1.23	–12.45	5.7	7.3	5.6	–2.0	–15.4	–0.36	–17.52	–27	64
Saint Kitts and Nevis	UN/WDI	–1.29	4.19	1.41	2.57	3.1	4.0	4.3	2.5	1.7	1.78	1.98	–8	–1
Saint Lucia	UN/WDI	4.20	–0.25	1.95	1.76	2.6	3.9	4.0	1.5	3.9	2.37	1.70	–13	–2
Saint Pierre and Miquelon	UN/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Saint Vincent and the Grenadines	UN/WDI	2.97	1.76	2.36	0.75	2.3	3.7	3.7	1.7	0.4	1.98	0.70	–12	–2
Samoa	UN/WDI	–1.27	0.58	–0.35	3.37	5.0	4.7	5.0	–0.1	7.8	19.49	4.26	–3	–1
Sao Tome and Principe[c]	UN/WDI	0.49	–0.91	–0.21	–1.35	6.1	5.8	5.7	1.8	–1.2	0.40	–1.98	–7	–1
Saudi Arabia	IEA/WDI	2.58	1.17	1.88	–3.03	4.3	6.2	5.8	–0.7	–3.4	0.96	–2.41	1,501	2,216
Senegal	IEA/WDI	0.48	0.92	0.70	–0.25	5.1	5.8	5.8	0.2	–0.2	0.83	0.13	35	–6
Serbia	IEA/WDI	2.29	–2.33	–0.05	–3.53	7.7	7.7	7.1	0.8	–6.6	–0.35	–2.10	–1,047	–118
Seychelles	UN/WDI	11.90	0.21	5.89	–10.84	1.8	5.7	4.5	3.2	–6.8	8.63	–17.21	44	6
Sierra Leone	UN/WDI	2.79	–4.98	–1.17	–6.94	11.7	9.2	8.0	–1.5	–3.5	–0.72	–6.82	82	22
Singapore	IEA/WDI	–2.04	–2.53	–2.28	–4.76	4.6	2.9	2.6	–2.8	–2.3	–0.41	–3.89	3,295	871
Slovakia	IEA/WDI	–2.01	–4.53	–3.28	–5.62	11.0	5.7	5.0	–1.2	–2.4	–3.91	–7.68	24	338
Slovenia	IEA/WDI	–0.62	–1.43	–1.03	–0.75	6.5	5.3	5.2	–0.6	–0.4	–0.77	0.04	–94	51
Solomon Islands	UN/WDI	–1.99	–1.99	–1.99	–6.69	10.1	6.8	5.9	–1.9	–2.9	–1.98	–5.53	38	7
Somalia	UN/WDI	n.a.	n.a.	n.a.	n.a.	—	—	—	–2.0	–0.7	n.a.	n.a.	370	66
South Africa	IEA/WDI	0.03	–0.81	–0.39	–3.85	10.9	10.1	9.3	–0.9	–1.2	–1.01	–1.80	5,500	1,295
Spain	IEA/WDI	0.26	–1.55	–0.65	–0.25	4.1	3.6	3.6	0.1	–2.2	–0.19	–3.12	–4,896	1
Sri Lanka	IEA/WDI	–0.96	–3.45	–2.21	0.45	4.1	2.6	2.6	–1.4	–0.1	–2.53	–2.06	590	233
Sudan	IEA/WDI	–3.12	–3.76	–3.44	7.13	9.3	4.6	5.3	–1.1	–2.0	–2.47	6.54	939	273
Suriname	UN/WDI	3.50	–0.23	1.62	–4.30	7.4	10.2	9.4	4.6	–7.0	4.29	–7.64	–376	–39
Swaziland	UN/WDI	6.38	–1.28	2.47	1.10	4.7	7.7	7.8	0.2	0.6	1.48	0.52	–207	–21
Sweden	IEA/WDI	–1.97	–1.44	–1.71	–2.61	7.8	5.6	5.3	–1.8	–3.9	–1.68	–4.36	5,731	1,650
Switzerland	IEA/WDI	–0.82	–1.23	–1.03	–2.51	3.4	2.8	2.6	–0.4	–3.2	–0.77	–3.57	0	287
Syrian Arab Republic	IEA/WDI	–1.58	–1.66	–1.62	–16.50	8.6	6.2	4.3	–1.2	–14.2	–2.66	–14.33	1,433	471
Tajikistan	IEA/WDI	0.61	–7.44	–3.50	–5.02	11.5	5.7	5.1	0.1	–7.3	–3.38	–5.09	–183	21
Thailand	IEA/WDI	1.09	0.62	0.85	0.01	4.9	5.8	5.8	–0.5	3.1	–0.06	0.91	1,575	112
Timor-Leste[d]	UN/WDI	n.a.	n.a.	n.a.	n.a.	—	—	—	0.0	0.0	n.a.	n.a.	n.a.	n.a.
Togo	IEA/WDI	3.02	1.77	2.39	–5.00	10.3	16.6	15.0	1.0	–2.5	2.24	–6.12	–111	–26

Country	Source[b]	Primary energy intensity improvement, compound annual growth rate (%)				Level of primary energy intensity (megajoules per 2011 PPP $)			Decomposition analysis, compound annual growth rate[a] (%)		Final energy intensity improvement, compound annual growth rate (%)		Cumulative avoided energy consumption (petajoules)	
		1990–2000	2000–10	1990–2010	2010–12	1990	2010	2012	1990–2010	2010–12	1990–2010	2010–12	1991–2010	2011–12
Tonga	UN/WDI	0.20	–0.04	0.08	–7.00	3.5	3.6	3.1	1.4	–8.3	22.74	–10.12	–3	0
Trinidad and Tobago	IEA/WDI	1.88	1.63	1.75	–2.04	15.2	21.6	20.7	0.2	0.1	0.18	0.89	221	–25
Tunisia	IEA/WDI	–0.73	–1.13	–0.93	–2.77	4.6	3.9	3.6	–1.3	–2.5	–0.99	–3.25	621	236
Turkey	IEA/WDI	0.09	–0.53	–0.22	–0.02	3.8	3.6	3.6	–0.3	1.5	–0.49	1.18	1,545	211
Turkmenistan	IEA/WDI	0.77	–3.15	–1.21	–5.93	23.9	18.8	16.6	–1.4	–3.6	–1.76	–4.52	–900	405
Turks and Caicos Islands	UN/WDI	9.66	15.65	12.61	1.38	0.5	5.4	5.6	3.3	0.7	6.34	0.54	n.a.	n.a.
Uganda	UN/WDI	–4.31	–4.72	–4.51	–2.76	24.4	9.7	9.1	–2.0	–0.5	–4.43	–2.80	1,284	422
Ukraine	IEA/WDI	2.03	–4.21	–1.14	–6.26	19.3	15.4	13.5	–0.9	–4.0	–1.62	–3.64	–1,105	2,120
United Arab Emirates	IEA/WDI	0.53	2.16	1.34	0.38	4.1	5.3	5.4	0.7	3.7	0.80	3.20	–151	–626
United Kingdom of Great Britain and Northern Ireland	IEA/WDI	–2.19	–2.61	–2.40	–2.98	6.3	3.9	3.6	–1.4	–3.2	–2.24	–3.69	18,294	4,870
United Republic of Tanzania	IEA/WDI	0.24	–2.62	–1.20	–1.90	16.0	12.6	12.1	–0.1	–0.1	–1.35	–2.27	163	45
United States of America	IEA/WDI	–1.67	–1.86	–1.77	–3.92	8.7	6.1	5.6	–1.6	–4.9	–1.74	–3.60	272,173	61,236
Uruguay	IEA/WDI	–0.17	–0.06	–0.11	0.80	3.2	3.1	3.1	–0.5	–2.3	0.14	–3.51	175	38
Uzbekistan	IEA/WDI	1.11	–8.00	–3.55	–2.22	31.1	15.1	14.4	6.0	3.4	–3.77	–1.03	–16,687	–1,655
Vanuatu	UN/WDI	1.71	0.10	0.90	11.69	3.5	4.2	5.3	n.a.	23.2	8.93	14.62	–8	–1
Venezuela, Bolivarian Rep. of	IEA/WDI	0.53	–0.21	0.16	–3.96	6.4	6.6	6.1	0.2	–4.1	0.73	–5.71	–288	292
Viet Nam	IEA/WDI	–2.52	0.78	–0.88	–0.78	7.5	6.3	6.2	0.3	0.9	–1.57	–0.20	1,280	–16
Western Sahara	UN/WDI	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Yemen	IEA/WDI	0.85	1.84	1.34	–2.38	2.6	3.4	3.2	1.4	–2.0	1.57	0.81	–149	–7
Zambia	IEA/WDI	0.71	–2.62	–0.97	–2.17	11.5	9.4	9.0	–0.4	1.0	–1.14	–1.72	69	42
Zimbabwe	IEA/WDI	–1.00	3.98	1.46	–5.52	14.7	19.6	17.5	–0.8	–0.9	1.75	–5.34	899	130

Aggregated by region

Country	Source[b]	Primary energy intensity improvement, compound annual growth rate (%)				Level of primary energy intensity (megajoules per 2011 PPP $)			Decomposition analysis, compound annual growth rate[a] (%)		Final energy intensity improvement, compound annual growth rate (%)		Cumulative avoided energy consumption (petajoules)	
		1990–2000	2000–10	1990–2010	2010–12	1990	2010	2012	1990–2010	2010–12	1990–2010	2010–12	1991–2010	2011–12
Northern America	IEA/WDI	–1.61	–1.86	–1.73	–3.74	8.8	6.2	5.8	–1.63	–3.19	–1.70	–3.25	289,657	65,378
Europe	IEA/WDI	–1.41	–1.10	–1.26	–2.90	5.4	4.2	4.0	–1.13	–2.33	–1.19	–3.13	120,193	28,741
Eastern Europe	IEA/WDI	–0.93	–3.32	–2.13	–1.38	13.4	8.7	8.5	–1.96	–1.31	–2.80	–2.56	15,691	19,648
Caucasian and Central Asia	IEA/WDI	–0.44	–4.56	–2.52	–1.85	18.7	11.2	10.8	–1.87	–1.40	–3.57	–1.16	–19,997	–1,832
Western Asia	IEA/WDI	–0.51	0.28	–0.12	–0.84	5.1	5.0	4.9	–0.39	–1.77	–1.55	–0.18	13,348	4,962
Eastern Asia	IEA/WDI	–1.94	–0.81	–1.38	–1.13	9.9	7.5	7.3	–2.23	–1.86	–2.44	–2.09	688,128	204,043
South Eastern Asia	IEA/WDI	0.15	–1.55	–0.70	–2.80	5.4	4.7	4.4	–1.31	–3.11	–1.26	–2.17	18,577	8,401
Southern Asia	IEA/WDI	–0.83	–1.94	–1.39	–1.17	7.3	5.5	5.4	–2.62	–2.25	–2.09	–1.88	66,013	19,892
Oceania	IEA/WDI	–0.93	–1.64	–1.29	–0.71	7.4	5.7	5.6	–1.30	–0.75	–1.56	–1.07	12,163	2,816
Latin America and Caribbean	IEA/WDI	–0.57	–0.47	–0.52	–0.82	4.6	4.1	4.1	–0.48	–0.73	–0.58	–1.04	23,003	6,102
Northern Africa	IEA/WDI	–0.39	–0.26	–0.32	2.17	4.1	3.8	4.0	–0.99	2.50	–0.51	2.43	6,931	1,552
Sub-Saharan Africa	IEA/WDI	0.08	–2.57	–1.25	–1.40	10.4	8.1	7.9	–3.41	–3.78	–1.40	–1.52	11,302	4,697
World[e]	IEA/WDI	–1.50	–1.23	–1.36	–1.74	8.0	6.1	5.8	–1.31	–2.11	–1.72	–2.11	1,257,655	366,865

Aggregated by income group

Country	Source[b]	Primary energy intensity improvement, compound annual growth rate (%)				Level of primary energy intensity (megajoules per 2011 PPP $)			Decomposition analysis, compound annual growth rate[a] (%)		Final energy intensity improvement, compound annual growth rate (%)		Cumulative avoided energy consumption (petajoules)	
		1990–2000	2000–10	1990–2010	2010–12	1990	2010	2012	1990–2010	2010–12	1990–2010	2010–12	1991–2010	2011–12
High-income economies	IEA/WDI	–1.30	–1.44	–1.37	–2.58	7.3	5.6	5.3	–0.77	–1.32	–1.56	–2.55	431,864	118,727
Upper-middle-income	IEA/WDI	–2.37	–0.53	–1.45	–0.54	8.8	6.6	6.5	–2.39	–0.86	–2.12	–1.44	739,744	214,997
Lower-middle-income	IEA/WDI	–1.96	–2.62	–2.29	–1.86	8.6	5.4	5.2	–3.21	–2.65	–2.59	–1.63	83,566	31,494
Low-income	IEA/WDI	–0.82	–2.91	–1.87	–1.74	11.7	8.0	7.7	–2.59	–1.98	–1.98	–2.86	2,480	1,648

Source: IEA World Energy Statistics and Balance (2014); UN Energy Statistics (2014); World Development Indicators (2014).

a. The decomposition analysis adopts the logarithmic mean divisia index method I, which is detailed in annex 2 of chapter 5. Values in blue indicate that a country has fewer than 20 years of historical data available, and values in red indicate that a country has fewer than 10 years of historical data available. Caution should be used when comparing CAGRs of decomposition analysis and energy intensity for both sets of countries.

b. The IEA World Energy Statistics and Balances provides country level data for 138 countries that account for more than 99 percent of global energy consumption. The rest of the countries are lumped together in three regional groups and reported in an aggregated manner. To increase the country-level coverage, UN Energy Statistics are used for the 68 countries not reported separately by the IEA. However, a number of differences between the two data sources—namely, the application of different methodologies to estimate the use of primary solid biofuels (biomass) and the fact that the UN data were available only through 2010, at the latest—called for an adjustment of the UN data to allow for a fair comparison of energy intensity levels among countries.

c. GDP data were estimated to fill gaps in time series.

d. First available data were used for countries for which 1990 data were unavailable: Cambodia (1995), Eritrea (1992), Montenegro (2005), and Timor-Leste (2002).

Note: For some countries for which energy data were available but GDP data were not, no energy intensity figure is shown. (Energy intensity is a derivative of both energy consumption and GDP.)

DATA ANNEX: RENEWABLE ENERGY

Country	Source	Renewable energy				Share in total final energy consumption (%)								Renewable energy as share of (%)		Total final energy consumption[b] (petajoules)
						Solid biofuels, traditional	Solid biofuels, modern	Hydro	Liquid biofuels	Wind	Solar	Geothermal	Others (biogas, renewable waste, marine)	Electricity capacity	Electricity generation	
		1990	2000	2010	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
Afghanistan	UN[c]	42.4	56.5	19.3	9.7	5.9	0.0	3.7	0.0	0.0	0.0	0.0	0.0	64.6	—	208.6
Albania	IEA	24.9	41.0	37.9	38.2	8.6	2.5	26.5	0.0	0.0	0.6	0.0	0.0	90.3	100.0	78
Algeria	IEA	0.2	0.6	0.3	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	2.0	1.1	1,178
Angola	IEA	72.3	75.5	54.9	57.2	53.3	1.3	2.6	0.0	0.0	0.0	0.0	0.0	49.7	70.9	474
Antigua and Barbuda	UN[c]	—	—	—	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	4
Argentina	IEA	8.9	11.0	9.0	8.8	0.7	2.2	4.1	1.7	0.1	0.0	0.0	0.0	27.9	23.8	2,280
Armenia	IEA	1.9	6.2	9.0	6.6	0.0	0.4	6.1	0.0	0.0	0.0	0.0	0.0	34.3	28.9	87
Aruba	UN[c]	0.8	0.1	0.1	6.3	0.3	0.0	0.0	0.0	6.0	0.0	0.0	0.0	9.4	10.6	6
Australia	IEA	8.0	8.4	7.3	8.4	0.0	5.4	1.4	0.4	0.6	0.5	0.0	0.2	20.6	9.6	3,121
Austria	IEA	25.2	26.5	30.6	34.5	0.0	16.6	13.6	2.0	0.8	0.8	0.1	0.6	69.9	74.5	1,066
Azerbaijan	IEA	0.3	1.6	3.1	2.8	1.1	0.3	1.5	0.0	0.0	0.0	0.0	0.0	15.0	7.9	299
Bahamas	UN[c]	—	—	0.9	1.6	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	—	—	18
Bahrain	IEA	—	—	—	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	—	140
Bangladesh	IEA	72.0	59.5	42.0	38.3	38.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	3.7	1.6	978
Barbados	UN[c]	18.9	13.6	9.8	9.4	0.1	9.3	0.0	0.0	0.0	0.0	0.0	0.0	—	—	13
Belarus	IEA	0.8	4.9	7.0	7.2	2.9	4.1	0.0	0.2	0.0	0.0	0.0	0.0	0.3	0.6	736
Belgium	IEA	1.3	1.5	5.3	7.4	0.0	4.4	0.1	1.1	0.7	0.6	0.0	0.6	40.1	12.8	1,436
Belize	UN[c]	37.0	24.1	35.6	25.3	0.2	13.6	11.5	0.0	0.0	0.0	0.0	0.0	53.1	87.7	10
Benin	IEA	93.7	70.3	51.5	50.6	42.1	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6	145
Bermuda	UN[c]	—	—	—	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	9
Bhutan	UN[c]	96.5	95.2	91.7	90.0	77.7	0.4	11.4	0.0	0.0	0.0	0.0	0.4	98.9	23.5	60
Bolivia, Plurinational State of	IEA	37.4	29.1	31.7	28.0	5.7	19.5	2.8	0.0	0.0	0.0	0.0	0.0	30.1	33.8	267
Bosnia and Herzegovina	IEA	7.3	19.4	19.9	15.3	5.8	0.1	9.4	0.0	0.0	0.0	0.0	0.0	50.0	29.9	127
Botswana	IEA	47.1	35.7	26.4	23.9	23.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	85
Brazil	IEA	49.8	42.8	47.0	43.6	3.3	19.4	14.7	5.7	0.2	0.2	0.0	0.0	81.0	82.5	8,708
British Virgin Islands	UN[c]	100.0	1.6	1.1	—	—	—	—	—	—	—	—	—	—	—	—
Brunei Darussalam	IEA	0.7	—	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	0.1	40

Country	Source	Renewable energy				Share in total final energy consumption (%): Solid biofuels, traditional	Solid biofuels, modern	Hydro	Liquid biofuels	Wind	Solar	Geothermal	Others (biogas, renewable waste, marine)	Renewable energy as share of (%): Electricity capacity	Electricity generation	Total final energy consumption[b] (petajoules)
		1990	2000	2010	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
Bulgaria	IEA	1.9	8.3	14.4	15.8	8.4	2.7	1.8	0.9	0.7	0.6	0.4	0.2	37.1	11.4	380
Burkina Faso	UN[c]	92.4	86.5	85.3	79.1	78.0	0.7	0.4	0.0	0.0	0.0	0.0	0.0	13.4	24.5	137
Burundi	UN[c]	82.6	93.2	96.8	96.6	94.9	0.6	1.1	0.0	0.0	0.0	0.0	0.0	98.2	—	88
Cambodia[d]	IEA	82.5	81.1	73.3	72.6	55.3	15.3	2.0	0.0	0.0	0.0	0.0	0.0	39.3	37.7	197
Cameroon	IEA	81.6	84.5	78.6	78.1	66.3	6.7	5.1	0.0	0.0	0.0	0.0	0.0	71.5	73.0	256
Canada	IEA	20.6	20.5	19.9	20.6	0.0	4.9	14.2	1.0	0.4	0.0	0.0	0.1	71.4	63.2	7,609
Cape Verde	UN[c]	—	1.7	1.5	18.2	17.5	0.0	0.0	0.0	0.7	0.0	0.0	0.0	23.9	5.5	6
Cayman Islands	UN[c]	—	—	—	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	5
Central African Republic	UN[c]	93.9	86.0	81.0	94.0	37.8	53.4	2.8	0.0	0.0	0.0	0.0	0.0	56.8	74.1	17
Chad	UN[c]	95.1	97.9	92.3	90.4	89.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	—	—	63
Chile	IEA	34.0	31.4	27.0	30.3	0.0	23.7	6.4	0.0	0.1	0.1	0.0	0.0	37.9	36.4	1,014
China	IEA	32.3	27.7	18.8	18.4	12.1	0.2	3.9	0.1	0.4	0.9	0.3	0.5	28.2	23.9	65,558
China, Hong Kong SAR	IEA	1.1	0.6	0.7	—	—	—	—	—	—	—	—	—	—	—	—
China, Macao SAR	UN[c]	0.7	0.2	0.2	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	—	—	22
Colombia	IEA	38.3	28.0	28.6	26.3	7.1	5.4	13.6	0.1	0.0	0.0	0.0	0.0	67.9	79.6	1,029
Comoros	UN[c]	1.0	1.0	1.3	46.1	45.6	0.0	0.5	0.0	0.0	0.0	0.0	0.0	4.5	11.5	3
Congo	IEA	66.7	72.7	50.6	48.2	44.3	1.2	2.8	0.0	0.0	0.0	0.0	0.0	80.4	61.2	50
Congo, Dem. Rep. of the	IEA	92.0	97.2	96.2	96.0	73.6	19.3	3.1	0.0	0.0	0.0	0.0	0.0	—	99.6	825
Cook Islands	UN[c]	—	—	—	—	—	—	—	—	—	—	—	—	1.6	—	—
Costa Rica	IEA	55.7	32.7	41.9	38.6	4.9	13.2	16.2	0.0	1.2	0.0	3.1	0.0	69.3	91.8	142
Côte d'Ivoire	IEA	80.2	64.7	75.4	74.4	65.3	7.6	1.5	0.0	0.0	0.0	0.0	0.0	52.4	26.4	291
Croatia	IEA	13.5	17.5	19.4	20.0	7.1	1.1	10.1	0.6	0.7	0.1	0.1	0.2	51.8	48.7	244
Cuba	IEA	44.3	35.7	16.3	18.9	0.2	14.7	0.1	3.8	0.0	0.0	0.0	0.0	1.2	3.7	259
Cyprus	IEA	0.5	3.1	6.4	8.4	0.5	0.6	0.0	1.1	1.0	4.5	0.1	0.6	10.0	5.4	62
Czech Republic	IEA	2.7	4.9	9.5	10.9	0.0	7.5	0.5	1.2	0.1	0.6	0.0	1.0	26.4	9.3	963
Denmark	IEA	7.3	10.9	21.4	27.6	0.0	15.6	0.0	1.8	6.7	0.3	0.0	3.2	43.2	48.3	566
Djibouti	UN[c]	—	—	—	34.8	34.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	—	6
Dominica	UN[c]	23.6	11.3	9.1	11.9	4.0	0.0	7.9	0.0	0.0	0.0	0.0	0.0	39.4	37.4	2
Dominican Republic	IEA	34.3	22.3	25.9	13.2	5.9	4.8	2.5	0.0	0.0	0.0	0.0	0.0	18.5	10.7	220

Country	Source	Share in total final energy consumption (%): Renewable energy				Solid biofuels, traditional	Solid biofuels, modern	Hydro	Liquid biofuels	Wind	Solar	Geothermal	Others (biogas, renewable waste, marine)	Renewable energy as share of (%): Electricity capacity	Electricity generation	Total final energy consumption[b] (petajoules)
		1990	2000	2010	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
Ecuador	IEA	23.2	19.6	12.4	13.4	2.2	2.4	8.7	0.0	0.0	0.0	0.0	0.0	42.7	54.9	430
Egypt	IEA	8.6	8.2	6.1	5.5	1.6	1.7	2.0	0.0	0.2	0.0	0.0	0.0	12.3	9.0	2,044
El Salvador	IEA	67.1	50.9	34.8	34.0	15.5	8.4	5.5	0.0	0.0	0.0	4.6	0.0	46.8	64.0	111
Equatorial Guinea	UN[c]	82.0	53.2	15.4	29.2	29.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	5.6	6.3	13
Eritrea[d]	IEA	88.3	71.2	77.2	80.4	76.7	3.7	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.6	22
Estonia	IEA	3.3	19.9	25.1	24.9	0.0	23.9	0.1	0.1	0.8	0.0	0.0	0.1	15.2	12.3	119
Ethiopia	IEA	95.6	94.3	94.5	93.5	91.6	0.8	1.1	0.0	0.0	0.0	0.0	0.0	91.7	99.4	1,547
Falkland Islands (Malvinas)	UN[c]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fiji	UN[c]	16.4	13.0	15.5	13.0	1.7	0.0	11.3	0.0	0.0	0.0	0.0	0.0	53.7	55.2	16
Finland	IEA	24.6	31.7	33.5	39.1	0.0	30.0	6.9	1.2	0.2	0.0	0.0	0.8	38.4	40.5	1,009
France	IEA	10.4	9.3	12.3	12.6	0.0	6.4	2.7	1.9	0.7	0.2	0.1	0.5	55.6	14.9	5,987
French Guiana	UN[c]	12.5	8.0	34.4	—									89.6	—	—
French Polynesia	UN[c]	100.0	9.2	8.6	9.1	0.4	0.0	8.8	0.0	0.0	0.0	0.0	0.0	21.0	26.8	8
Gabon	IEA	78.3	74.5	63.0	69.6	53.4	13.0	3.2	0.0	0.0	0.0	0.0	0.0	41.0	41.7	77
Gambia	UN[c]	58.9	50.3	41.0	49.7	49.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	11
Georgia	IEA	12.8	47.3	39.9	28.7	8.8	1.7	17.9	0.0	0.0	0.0	0.3	0.0	60.8	74.5	123
Germany	IEA	2.1	3.8	10.8	12.4	0.0	4.8	0.8	1.6	1.8	1.3	0.0	2.1	48.9	22.9	8,339
Ghana	IEA	80.6	74.7	66.5	49.5	33.1	9.1	7.3	0.0	0.0	0.0	0.0	0.0	54.6	67.1	284
Gibraltar	IEA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Greece	IEA	7.8	7.5	11.1	13.9	0.0	7.2	2.0	0.8	1.7	1.9	0.1	0.2	27.4	16.7	685
Grenada	UN[c]	6.4	7.0	8.8	10.2	9.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	2.0	—	3
Guadeloupe	UN[c]	7.8	0.6	5.5	—									13.2	—	—
Guatemala	IEA	75.0	62.7	67.0	66.2	59.3	3.0	3.7	0.0	0.0	0.0	0.2	0.0	43.0	66.9	357
Guinea	UN[c]	92.6	89.6	88.9	74.1	72.8	0.5	0.8	0.0	0.0	0.0	0.0	0.0	32.2	28.4	139
Guinea-Bissau	UN[c]	70.8	50.1	37.4	88.5	80.8	7.7	0.0	0.0	0.0	0.0	0.0	0.0	—	—	26
Guyana	UN[c]	28.1	41.5	46.7	35.4	4.7	30.7	0.0	0.0	0.0	0.0	0.0	0.0	3.7	—	27
Haiti	IEA	81.1	76.0	70.5	83.1	78.7	4.2	0.2	0.0	0.0	0.0	0.0	0.0	22.8	13.9	123
Honduras	IEA	70.1	55.1	49.8	53.4	37.5	11.5	3.9	0.0	0.5	0.0	0.0	0.0	39.1	43.7	182
Hungary	IEA	3.9	5.2	9.1	10.2	0.0	7.5	0.1	1.1	0.4	0.0	0.7	0.3	9.4	7.6	602

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		1990	2000	2010	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
Iceland	IEA	62.2	66.1	76.7	78.1	0.0	0.0	36.9	0.0	0.0	0.0	41.2	0.1	95.7	100.0	112
India	IEA	57.5	52.6	42.4	39.0	28.7	7.9	1.8	0.0	0.4	0.1	0.0	0.0	26.4	15.6	19,925
Indonesia	IEA	58.7	44.7	37.4	37.1	31.2	4.3	0.7	0.4	0.0	0.0	0.5	0.0	16.8	11.4	6,211
Iran, Islamic Republic of	IEA	1.3	0.4	0.7	—									17.8	—	—
Iraq	IEA	1.6	0.3	1.6	1.6	0.0	0.1	1.5	0.0	0.0	0.0	0.0	0.0	20.2	8.8	1,003
Ireland	IEA	2.3	2.0	5.2	7.0	0.0	1.9	0.6	0.8	3.0	0.1	0.0	0.5	26.6	19.2	420
Israel	IEA	5.8	6.0	8.5	8.7	0.0	0.1	0.0	0.0	0.0	8.5	0.0	0.0	2.1	0.8	553
Italy	IEA	3.8	5.1	10.0	12.1	0.0	3.8	3.1	1.4	1.0	1.5	0.5	0.7	37.2	31.0	4,805
Jamaica	IEA	7.6	11.5	12.1	14.7	9.4	4.5	0.5	0.0	0.3	0.0	0.0	0.0	8.3	8.8	81
Japan	IEA	4.4	3.9	4.2	4.5	0.0	1.6	2.2	0.0	0.1	0.3	0.1	0.1	15.0	12.0	11,339
Jordan	IEA	2.8	2.1	3.0	3.1	0.1	0.0	0.1	0.0	0.0	2.9	0.0	0.0	0.6	0.4	204
Kazakhstan	IEA	1.4	2.5	1.2	1.4	0.1	0.0	1.2	0.0	0.0	0.0	0.0	0.0	12.7	8.4	1,720
Kenya	IEA	77.7	81.8	77.1	78.5	75.2	0.2	2.3	0.0	0.0	0.0	0.8	0.0	57.6	75.2	556
Kiribati	UN[c]	39.5	30.9	1.1	3.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	1
Korea, Dem. People's Rep. of	IEA	7.7	9.8	12.0	16.0	0.0	8.8	7.1	0.0	0.0	0.0	0.0	0.0	—	70.2	509
Korea, Republic of	IEA	1.6	0.7	1.3	1.6	0.0	0.5	0.3	0.2	0.1	0.1	0.1	0.4	3.4	1.3	5,148
Kuwait	IEA	0.2	—	—	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	514
Kyrgyzstan	IEA	7.9	37.3	22.5	22.5	0.0	0.1	22.4	0.0	0.0	0.0	0.0	0.0	78.9	93.5	144
Lao People's Dem. Rep.	UN[c]	96.7	91.3	90.1	86.5	73.5	0.0	12.2	0.0	0.0	0.7	0.0	0.0	93.4	67.8	72
Latvia	IEA	17.6	35.8	35.3	40.4	17.0	12.5	9.0	0.6	0.3	0.0	0.0	1.0	73.7	66.6	164
Lebanon	IEA	11.5	5.0	5.0	5.0	2.3	0.3	1.9	0.0	0.0	0.5	0.0	0.0	9.8	6.8	180
Lesotho	UN[c]	—	100.0	100.0	40.5	35.2	0.0	5.3	0.0	0.0	0.0	0.0	0.0	100.0	—	47
Liberia	UN[c]	95.4	90.5	92.5	84.4	84.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	85
Libya	IEA	3.1	2.1	2.1	1.7									—	—	413
Lithuania	IEA	3.1	17.6	22.6	24.3	11.8	7.5	1.5	1.3	1.9	0.0	0.0	0.2	13.5	26.1	199
Luxembourg	IEA	1.7	6.8	3.7	4.1	0.0	1.1	0.5	1.3	0.4	0.2	0.0	0.6	28.6	11.0	160
Macedonia, Former Yugoslav Rep. of	IEA	2.4	19.4	23.0	16.5	9.4	1.0	5.5	0.0	0.0	0.0	0.5	0.0	35.9	16.7	76
Madagascar	UN[c]	86.4	78.5	82.8	78.4	43.7	33.1	1.5	0.0	0.0	0.0	0.0	0.0	30.3	32.6	119

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		1990	2000	2010	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
Malawi	UN[c]	86.1	76.9	81.3	78.7	35.1	36.6	6.9	0.1	0.0	0.0	0.0	0.0	99.3	57.4	63
Malaysia	IEA	14.0	8.6	6.2	6.8	4.5	0.2	1.8	0.3	0.0	0.0	0.0	0.0	12.4	7.4	1,625
Maldives	UN[c]	—	—	—	3.1	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	4
Mali	UN[c]	91.6	88.9	88.3	83.5	78.9	1.5	3.1	0.0	0.0	0.0	0.0	0.0	51.6	28.2	58
Malta	IEA	—	—	0.3	2.6	0.2	0.0	0.0	1.3	0.0	0.6	0.0	0.5	2.7	1.1	14
Martinique	UN[c]	2.3	1.6	1.6	—	—	—	—	—	—	—	—	—	0.3	—	—
Mauritania	UN[c]	40.9	42.6	35.1	32.2	32.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.1	—	39
Mauritius	UN[c]	51.9	14.6	6.9	34.0	1.3	15.1	1.3	0.0	0.1	0.0	0.0	0.2	24.5	22.2	67
Mexico	IEA	14.3	12.5	10.0	9.4	0.0	6.7	2.0	0.0	0.2	0.1	0.4	0.0	23.9	15.0	4,582
Moldova, Republic of	IEA	0.8	4.6	4.3	4.7	3.2	0.6	0.9	0.0	0.0	0.0	0.0	0.0	11.6	4.6	92
Mongolia	IEA	1.8	4.9	3.7	3.2	2.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	—	123
Montenegro[d]	IEA	n.a	n.a	48.9	46.2	23.4	2.3	20.4	0.0	0.0	0.0	0.0	0.0	75.8	51.9	29
Montserrat	UN[c]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Morocco	IEA	8.5	6.7	7.2	11.3	4.6	5.2	1.0	0.0	0.5	0.0	0.0	0.0	25.9	8.6	577
Mozambique	IEA	93.1	92.5	89.6	88.4	66.7	9.1	12.6	0.0	0.0	0.0	0.0	0.0	89.8	99.9	312
Myanmar	IEA	90.9	80.2	84.9	78.7	72.7	2.4	3.6	0.0	0.0	0.0	0.0	0.0		72.4	596
Namibia[d]	IEA	38.9	38.2	30.2	32.9	13.2	0.0	19.6	0.0	0.0	0.1	0.0	0.0	67.1	97.8	65
Nepal	IEA	95.1	88.3	88.3	84.7	79.3	1.0	2.8	0.0	0.0	0.0	0.0	1.6	92.5	99.5	418
Netherlands	IEA	1.2	1.5	3.6	4.7	0.0	1.7	0.0	0.7	1.0	0.1	0.0	1.1	14.9	12.2	1,942
Netherlands Antilles	IEA	—	—	—		—	—	—	—	—	—	—	—	—	—	—
New Caledonia	UN[c]	40.2	15.9	8.0	3.7	0.0	0.0	3.3	0.0	0.4	0.0	0.0	0.0	23.2	15.2	43
New Zealand	IEA	29.2	28.9	31.5	30.8	0.0	8.9	14.4	0.0	1.3	0.1	5.9	0.2	71.0	71.8	500
Nicaragua	IEA	70.4	62.4	53.8	53.1	41.6	7.7	1.2	0.0	1.0	0.0	1.5	0.0	38.1	42.8	89
Niger	UN[c]	86.8	93.9	73.7	79.7	78.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	—	0.0	70
Nigeria	IEA	88.4	86.9	88.8	86.5	77.1	9.0	0.4	0.0	0.0	0.0	0.0	0.0	35.0	19.7	4,829
Norway	IEA	59.3	60.3	56.9	58.0	0.0	6.0	50.1	0.7	0.5	0.0	0.0	0.7	95.5	98.0	756
Oman	IEA	—	—	—	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	717
Pakistan	IEA	57.5	51.1	46.0	45.5	37.8	4.7	3.0	0.0	0.0	0.0	0.0	0.0	30.9	31.1	2,886
Palau	UN[c]	—	—	6.8	2.6	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	n.a.	15.0	2

Country	Source	Renewable energy				Solid biofuels, traditional	Solid biofuels, modern	Hydro	Liquid biofuels	Wind	Solar	Geothermal	Others (biogas, renewable waste, marine)	Renewable energy as share of (%) Electricity capacity	Electricity generation	Total final energy consumption[b] (petajoules)
		Share in total final energy consumption (%)														
		1990	2000	2010	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
Panama	IEA	43.7	34.4	24.1	22.9	8.4	2.9	11.6	0.0	0.0	0.0	0.0	0.0	61.3	62.9	140
Papua New Guinea	UN[c]	70.4	66.4	66.7	52.5	43.9	5.2	3.3	0.0	0.0	0.0	0.0	0.0	38.9	30.2	115
Paraguay	IEA	78.5	70.4	64.1	62.7	21.1	23.9	15.9	1.8	0.0	0.0	0.0	0.0	99.9	100.0	186
Peru	IEA	39.4	32.2	30.2	28.2	13.6	1.7	10.6	2.2	0.0	0.1	0.0	0.0	36.8	55.2	651
Philippines	IEA	51.0	34.9	28.8	29.4	14.2	8.0	3.0	1.2	0.0	0.0	3.0	0.0	32.0	28.4	999
Poland	IEA	2.5	6.9	9.5	11.1	0.0	8.7	0.2	1.3	0.5	0.0	0.0	0.2	10.9	10.4	2,596
Portugal	IEA	27.1	20.0	27.9	25.6	0.0	13.5	3.2	1.9	5.9	0.7	0.1	0.3	52.8	42.5	636
Puerto Rico	UN[c]	1.8	0.7	0.7	1.1	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	3.6	0.9	64
Qatar	IEA	—	—	—	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	—	479
Reunion	UN[c]	38.9	16.5	17.6	—	—	—	—	—	—	—	—	—	30.8	—	—
Romania	IEA	3.4	16.5	24.0	21.7	14.7	1.7	3.4	1.0	0.7	0.0	0.1	0.1	40.5	25.4	933
Russian Federation	IEA	3.8	3.5	3.3	3.2	0.3	0.4	2.5	0.0	0.0	0.0	0.0	0.0	20.5	15.6	16,524
Rwanda	UN[c]	84.4	89.4	87.9	86.3	75.3	9.7	1.2	0.0	0.0	0.0	0.0	0.0	65.7	42.3	54
Saint Kitts and Nevis	UN[c]	67.4	23.3	—	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	—	2
Saint Lucia	UN[c]	—	—	—	2.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	4
Saint Pierre and Miquelon	UN[c]	—	—	1.7	—	—	—	—	—	—	—	—	—	3.7	—	—
Saint Vincent and the Grenadines	UN[c]	18.0	10.6	7.9	5.0	2.2	0.0	2.9	0.0	0.0	0.0	0.0	0.0		14.9	3
Samoa	UN[c]	100.0	49.6	44.5	22.2	18.0	1.7	2.5	0.0	0.0	0.0	0.0	0.0	28.6	21.7	4
Sao Tome and Principe	UN[c]	62.2	35.7	35.4	42.4	41.6	0.0	0.8	0.0	0.0	0.0	0.0	0.0	25.0	6.4	2
Saudi Arabia	IEA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	3,315
Senegal	IEA	55.6	47.7	42.5	51.4	49.2	1.4	0.7	0.0	0.0	0.0	0.0	0.0	0.3	9.8	113
Serbia	IEA	15.5	23.5	20.3	19.6	11.3	1.0	7.2	0.0	0.0	0.0	0.1	0.0	32.7	25.7	348
Seychelles	UN[c]	—	—	—	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	5
Sierra Leone	UN[c]	95.6	90.6	71.2	80.4	56.3	22.9	1.2	0.0	0.0	0.0	0.0	0.0	66.7	36.0	53
Singapore	IEA	0.2	0.3	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.5	1.4	419
Slovakia	IEA	2.2	3.7	10.9	10.5	—	—	—	—	—	—	—	—	42.5	19.3	388
Slovenia	IEA	12.4	15.9	18.8	19.3	0.0	11.2	5.6	1.1	0.0	0.4	0.6	0.4	51.5	27.8	202
Solomon Islands	UN[c]	68.4	87.0	75.3	65.1	65.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	5

Country	Source	Renewable energy				Share in total final energy consumption (%) Solid biofuels, traditional	Solid biofuels, modern	Hydro	Liquid biofuels	Wind	Solar	Geothermal	Others (biogas, renewable waste, marine)	Renewable energy as share of (%) Electricity capacity	Electricity generation	Total final energy consumption[b] (petajoules)
		1990	2000	2010	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
Somalia	UN[c]	100.0	96.3	94.8	94.3	65.8	28.6	0.0	0.0	0.0	0.0	0.0	0.0	—	—	97
South Africa	IEA	16.6	18.2	18.7	16.9	13.7	2.9	0.2	0.0	0.0	0.1	0.0	0.0	2.7	1.0	2,777
Spain	IEA	10.5	8.0	14.8	15.7	0.0	5.2	1.8	2.7	4.4	1.3	0.0	0.2	47.4	29.6	3,293
Sri Lanka	IEA	78.1	64.2	62.0	60.9	39.8	18.4	2.6	0.0	0.1	0.0	0.0	0.0	48.9	29.2	402
Sudan	IEA	73.3	81.6	66.6	64.0	41.2	18.7	4.1	0.0	0.0	0.0	0.0	0.0	69.3	70.1	472
Suriname	UN[c]	36.0	17.1	18.3	20.2	3.6	1.5	15.1	0.0	0.0	0.0	0.0	0.0	45.9	49.2	23
Swaziland	UN[c]	84.3	46.8	35.7	39.9	24.4	8.5	7.0	0.0	0.0	0.0	0.0	0.0	40.3	—	37
Sweden	IEA	34.1	40.9	47.4	49.9	0.0	27.3	16.7	2.0	1.5	0.0	0.0	2.3	87.6	59.1	1,303
Switzerland	IEA	16.9	18.5	21.2	22.7	0.0	4.5	14.6	0.1	0.0	0.3	1.5	1.6	96.6	59.5	821
Syrian Arab Republic	IEA	2.4	1.9	1.4	2.4	0.0	0.1	2.3	0.0	0.0	0.0	0.0	0.0		10.4	367
Tajikistan	IEA	29.6	62.4	57.3	58.0	0.0	0.0	58.0	0.0	0.0	0.0	0.0	0.0	92.4	99.6	86
Tanzania, United Republic of	IEA	94.8	94.3	90.7	88.2	68.4	19.2	0.6	0.0	0.0	0.0	0.0	0.0	66.8	29.1	800
Thailand	IEA	33.6	22.0	22.8	23.0	8.7	11.2	1.0	1.3	0.0	0.1	0.0	0.7	9.8	8.3	3,050
Timor-Leste	UN[c]	—	—	43.1	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	—
Togo	IEA	78.7	77.1	76.1	72.7	60.3	9.1	3.4	0.0	0.0	0.0	0.0	0.0	78.3	84.7	83
Tonga	UN[c]	—	0.4	2.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	1
Trinidad and Tobago	IEA	1.2	0.5	0.2	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	—	156
Tunisia	IEA	14.5	14.2	14.6	13.0	12.1	0.2	0.1	0.0	0.2	0.5	0.0	0.0	4.1	1.7	298
Turkey	IEA	24.6	17.3	14.2	12.8	0.0	4.3	5.0	0.1	0.5	1.0	1.9	0.1	39.0	27.2	3,359
Turkmenistan	IEA	0.3	0.0	0.0	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	702
Turks and Caicos Islands	UN[c]	—	—	—	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—	1
Uganda	UN[c]	96.1	94.6	88.8	90.0	86.2	2.7	1.1	0.0	0.0	0.0	0.0	0.0	91.2	42.9	403
Ukraine	IEA	0.7	1.3	2.9	2.8	1.4	0.4	0.9	0.0	0.0	0.0	0.0	0.0	14.7	5.7	2,805
United Arab Emirates	IEA	—	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	—	2,060
United Kingdom of Great Britain and Northern Ireland	IEA	0.7	1.0	3.2	4.4	0.0	1.2	0.3	0.8	1.2	0.2	0.0	0.6	10.0	11.4	5,053
United States of America	IEA	4.2	5.4	7.6	7.9	0.0	2.8	1.6	2.0	0.8	0.2	0.1	0.4	12.9	12.0	55,615
Uruguay	IEA	44.8	38.8	52.3	46.4	7.9	26.0	11.5	0.8	0.2	0.0	0.0	0.0	55.5	61.7	155
Uzbekistan	IEA	1.3	1.2	2.6	2.4	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	13.8	21.4	1,409

Country	Source	Renewable energy				Share in total final energy consumption (%): Solid biofuels, traditional	Solid biofuels, modern	Hydro	Liquid biofuels	Wind	Solar	Geothermal	Others (biogas, renewable waste, marine)	Renewable energy as share of (%): Electricity capacity	Electricity generation	Total final energy consumption[b] (petajoules)
		1990	2000	2010	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
Vanuatu	UN[c]	100.0	68.9	41.6	28.8	27.9	0.0	0.8	0.0	0.0	0.0	0.0	0.0	10.7	13.6	3
Venezuela, Bolivarian Rep. of	IEA	11.8	14.1	12.5	11.2	0.5	1.0	9.7	0.0	0.0	0.0	0.0	0.0	61.5	64.8	2,112
Viet Nam	IEA	76.1	58.0	34.8	35.6	22.4	5.2	8.0	0.0	0.0	0.0	0.0	0.0	36.4	43.6	2,144
Western Sahara	UN[c]	—	—	—		—	—	—	—	—	—	—	—	—	—	—
Yemen	IEA	2.1	1.2	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	—	225
Zambia	IEA	82.9	89.9	90.7	88.2	66.4	11.7	10.0	0.0	0.0	0.0	0.0	0.0	99.6	99.7	292
Zimbabwe	IEA	64.1	70.2	80.8	75.6	66.0	5.0	4.6	0.0	0.0	0.0	0.0	0.0	36.8	60.0	363

Aggregated by region

Country	Source	Renewable energy				Share in total final energy consumption (%): Solid biofuels, traditional	Solid biofuels, modern	Hydro	Liquid biofuels	Wind	Solar	Geothermal	Others (biogas, renewable waste, marine)	Renewable energy as share of (%): Electricity capacity	Electricity generation	Total final energy consumption[b] (petajoules)
		1990	2000	2010	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
Northern America	IEA/WDI	6.0	7.1	9.0	9.4	—	3.1	3.1	1.9	0.8	0.1	0.1	0.3	18.2	18.6	63,224
Europe	IEA/WDI	8.1	9.4	14.1	15.6	0.3	6.4	4.0	1.4	1.6	0.7	0.2	1.0	33.6	29.8	39,917
Eastern Europe	IEA/WDI	3.0	4.2	5.4	4.9	0.6	2.0	1.9	0.2	0.1	0.0	0.0	0.1	17.5	13.0	25,083
Caucasian and Central Asia	IEA/WDI	3.1	5.2	4.4	3.4	0.0	0.0	3.4	—	0.0	—	—	—	28.6	25.8	4,062
Western Asia	IEA/WDI	8.2	5.8	4.3	4.2	0.1	1.1	1.7	0.0	0.1	0.6	0.5	0.0	11.4	8.7	13,728
Eastern Asia	IEA/WDI	22.2	19.1	15.3	15.0	9.4	0.4	3.4	0.1	0.4	0.7	0.2	0.4	20.8	17.4	84,953
South Eastern Asia	IEA/WDI	52.2	37.9	31.1	31.7	22.9	5.5	2.2	0.5	0.0	0.0	0.4	0.2	15.9	17.5	15,304
Southern Asia	IEA/WDI	50.9	43.4	34.8	33.1	25.2	5.9	1.7	0.0	0.3	0.1	—	0.0	24.4	14.9	30,784
Oceania	IEA/WDI	15.0	15.6	15.1	13.1	1.5	5.9	3.3	0.4	0.7	0.4	0.8	0.2	24.2	19.2	3,688

Country	Source	Share in total final energy consumption (%)												Renewable energy as share of (%)		Total final energy consumption[b] (petajoules)
		Renewable energy				Solid biofuels, traditional	Solid biofuels, modern	Hydro	Liquid biofuels	Wind	Solar	Geothermal	Others (biogas, renewable waste, marine)	Electricity capacity	Electricity generation	
		1990	2000	2010	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
Latin America and Caribbean	IEA/WDI	32.3	28.2	29.0	27.7	4.4	11.4	9.1	2.4	0.1	0.1	0.1	0.0	52.5	55.7	23,293
Northern Africa	IEA/WDI	6.5	6.2	5.0	10.6	6.0	3.1	1.4	—	0.1	0.0	—	—	9.6	8.0	4,982
Sub-Saharan Africa	IEA/WDI	72.5	74.6	75.4	71.2	62.7	6.8	1.6	0.0	0.0	0.0	0.0	0.0	26.0	20.9	14,772
World[e]	IEA/WDI	16.6	17.4	17.8	18.1	9.3	3.6	3.2	0.8	0.5	0.3	0.2	0.3	28.5	20.9	342,105

Aggregated by income group

Country	Source	Share in total final energy consumption (%)												Renewable energy as share of (%)		Total final energy consumption[b] (petajoules)
		Renewable energy				Solid biofuels, traditional	Solid biofuels, modern	Hydro	Liquid biofuels	Wind	Solar	Geothermal	Others (biogas, renewable waste, marine)	Electricity capacity	Electricity generation	
		1990	2000	2010	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
High-income economies	IEA/WDI	5.9	6.8	8.9	9.5	0.1	3.7	2.9	1.2	0.8	0.3	0.1	0.4	22.7	18.8	152,968
Upper-middle-income	IEA/WDI	25.2	23.4	18.5	17.8	8.7	2.7	4.4	0.6	0.3	0.6	0.2	0.3	30.0	23.9	140,564
Lower-middle-income	IEA/WDI	43.4	45.8	40.1	39.5	30.5	6.4	2.2	0.1	0.2	0.1	0.1	0.0	27.2	21.2	48,817
Low-income	IEA/WDI	70.3	77.6	75.4	75.0	65.2	6.8	2.9	0.0	0.0	0.0	0.1	0.1	53.8	55.1	9,255

Source: IEA World Energy Statistics and Balances (2014), UN Energy Statistics.

Note: — indicates that data are not available.

a. See annex 3 of chapter 5 for the method used to calculate share of renewable energy consumption in total final energy consumption.

b. Derived by subtracting non-energy use from total final consumption.

c. The latest available UN data are for 2009.

d. First available data were used for countries for which 1990 data were unavailable: Cambodia (1995), Eritrea (1992), Montenegro (2005), and Namibia (1991).

e. World values are greater than the sum of values for countries because world values include marine and aviation bunkers.

SUSTAINABLE ENERGY FOR ALL

The SE4All *Global Tracking Framework* full report, summary report, key findings, PowerPoint presentation, and associated datasets can be downloaded from the following website:

http://trackingenergy4all.worldbank.org
#endenergypoverty

The Sustainable Energy for All indicators can also be found at World Development Indicators:
http://data.worldbank.org/wdi

COORDINATORS

ESMAP Energy Sector Management Assistance Program
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iea International Energy Agency