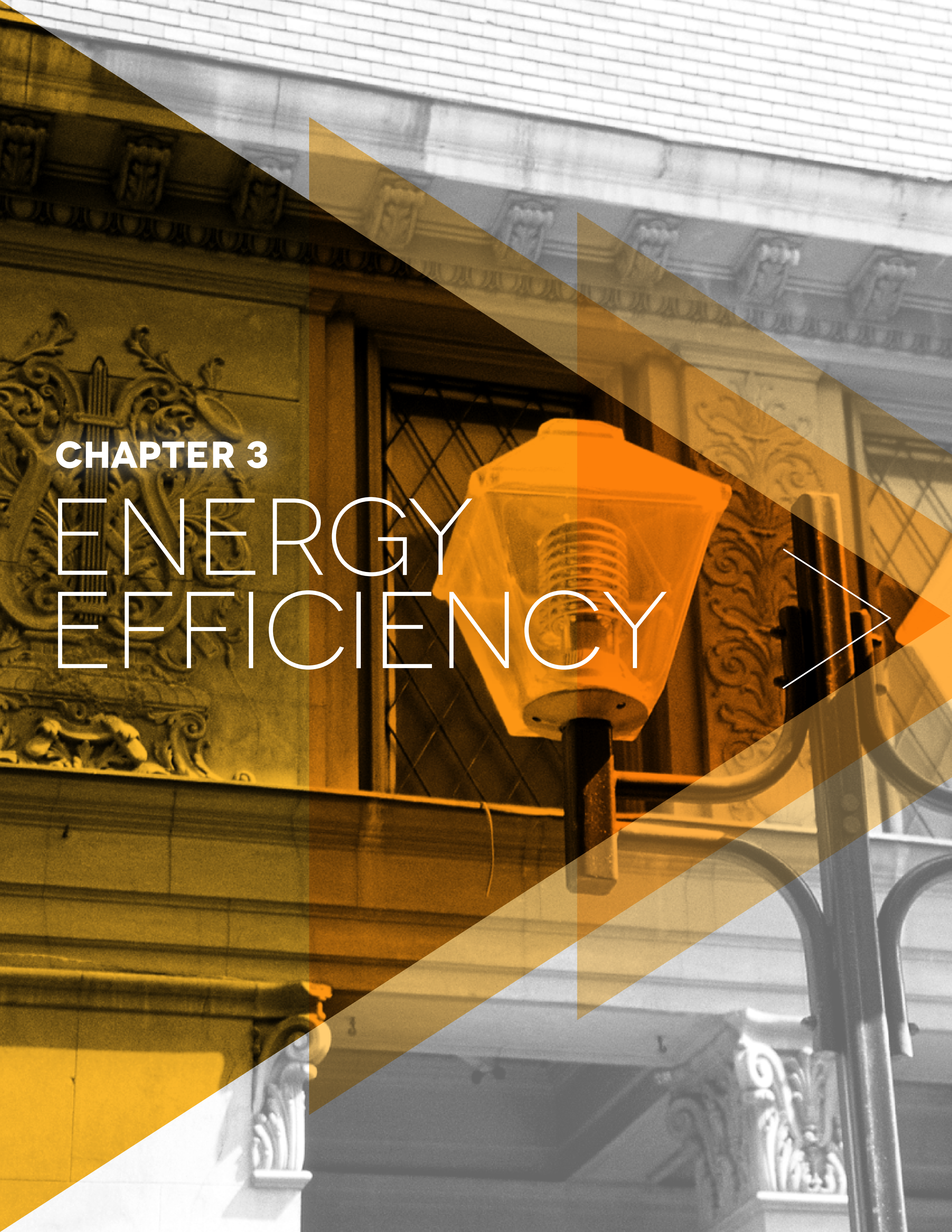


CHAPTER 3

ENERGY EFFICIENCY

CHAPTER 3: ENERGY EFFICIENCY

This chapter proposes a framework for understanding energy efficiency trends, integrating the current approaches to energy efficiency of various international agencies and national institutions, and establishing a methodology to determine the starting point against which future improvements in energy efficiency can be measured at the global and national levels. The chapter begins by identifying the methodological challenges of defining and measuring energy efficiency. After mapping a conceptual framework to address these issues, it goes on to review available global databases and to examine the extent to which those databases can be used to address the methodological issues raised.

Households and industries use energy sources such as electricity to provide goods and so-called end-use services that result in higher levels of economic productivity. Energy efficiency is measured as the ratio between the useful output of the end-use service and the associated energy input. In other words, it is the relationship between how much energy is needed to power a technology (for example, a light bulb, boiler, or motor) and the end-use service (for example, lighting, space heating, or motor power) that the technology provides.

Improving energy efficiency is a means to an end; it is not an end in itself. The value of energy efficiency policies can be measured by the social, economic, and environmental benefits that they bring. Improved efficiency is an important means of addressing the cost, availability constraints, and environmental impacts of energy use and production. Yet the real benefits often come from improved service outcomes: faster journeys, better health from warmer homes, and higher industrial productivity and product performance.

In places where the energy needs of consumers are already met, efficiency improvements primarily translate into reduced demand for energy and reduced costs, which can improve competitiveness. On the other hand, many developing countries cannot meet the energy demands of consumers; in places like these, improvements in energy efficiency are critical to providing more-reliable service and increasing productivity. Both aspects of efficiency—reduced energy demand and improved service value—are essential for wealth creation and social development.

SECTION 1: METHODOLOGICAL CHALLENGES IN DEALING WITH ENERGY EFFICIENCY

Measuring and tracking the rate of improvement of energy efficiency in the global energy mix poses various definitional and methodological challenges—chief among them:

- Finding a single headline measure of energy efficiency despite its multidimensional nature
- Dealing with the fact that headline measures of energy intensity are, at best, imperfect proxies for underlying energy efficiency
- Deciding whether to measure economic output in terms of market exchange rate or purchasing power parity
- Deciding whether to measure energy input in terms of primary or final energy.

Those challenges are considered individually in the four subsections that follow.

Multidimensionality

Energy efficiency is most accurately expressed in terms of the relationship between energy inputs and end-use outputs at the level of individual technologies and processes (as represented by the base of the pyramid in figure 3.1). An example of an indicator of such "process efficiencies" would be units of energy input per ton of steel produced in a particular type of steel mill using a particular quality or type of input material and industrial process.

Operationally, however, such precise indicators present problems as benchmarks for energy efficiency, particularly for comparative analyses across countries. First, few countries, if any, consistently track detailed information across the full spectrum of energy use in their economies, and, even when they do, it is often not possible within a plant to define exactly how much energy is flowing into different processes. (Issues relating to industrial confidentiality pose additional challenges when trying to collect disaggregated data.) Second, even if such data were available, they would comprise a huge number of process-level indicators with different metrics that could not ultimately be aggregated, or, if they could be aggregated, would not be very informative in evaluating a country's overall progress on energy efficiency. In fact, owing to the interactions between energy processes and the different metrics used to measure efficiency, the overall energy efficiency of a country will not necessarily equal the average efficiency of the component processes.

To address this problem, aggregate indicators and methodologies have been developed (represented by the higher tiers of the pyramid shown in figure 3.1). Subsectoral indicators trace the relationship between energy input and physical or service output in an industry or subsector. This is done for energy-intensive products (for example, steel, cement, pulp and paper) regardless of the differences in the process used among factories. For the residential sector, indicators typically track energy used per household and per unit of floor space as well as for each end-use (for example, space heating and cooking). For transport, indicators include energy per traffic unit (such as passenger kilometers and ton kilometers). At an even higher level of aggregation, sectoral indicators measure the relationship between energy input and associated output in one broad sector of the economy, such as industry or agriculture. Finally, the highest level of aggregation measures the relationship between energy input and the output of the economy as a whole.

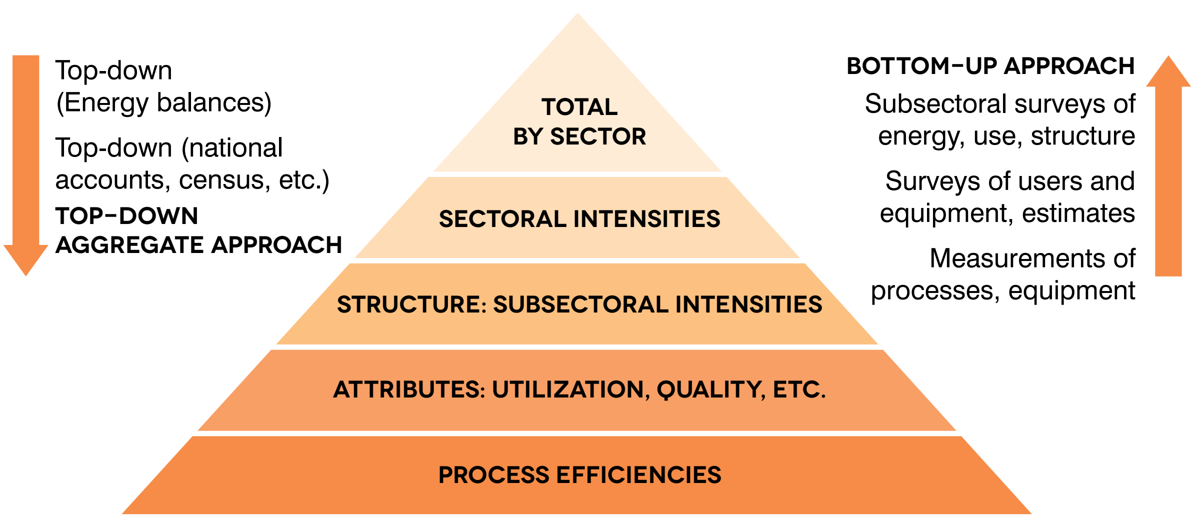


FIGURE 3.1 PYRAMID OF ENERGY EFFICIENCY INDICATORS

SOURCE: MARTIN AND OTHERS 1995; IEA 1997; PHYLIPSEN 2010.

Intensity versus efficiency

As one moves up the pyramid in figure 3.1, the higher degree of aggregation across economic activities makes it increasingly difficult to measure output in physical terms (for example, tons of steel or units of floor space). Instead, output is typically measured in monetary units as the value added of a specific economic sector.

Such value-based measures are typically measured in terms of megajoules (MJ) per U.S. dollar of value added and are technically measures of energy intensity rather than energy efficiency. Energy intensity is at best an imperfect proxy for energy efficiency. This is because energy intensity is affected not only by changes in energy demand but also by shifts in the components that comprise the denominator of that ratio, which may have little to do with energy efficiency. For example, a country that moves rapidly from subsistence agriculture to industrialization would experience a change in the structure of the economy toward more energy-intensive activities rather than a shift in energy efficiency per se.

Energy intensity may also be affected by other factors, such as demographic changes, weather variation, fuel-use shifts, and the overall level of activity in the economy. For example, as national income increases, so does car ownership and car usage,[1] a structural change that has a significant effect on energy intensity even if the fuel consumption of individual automobiles is no higher than before (and may even have improved). Several decomposition methods can help to capture changes in the drivers of energy demand and thus to isolate the changes in energy efficiency (Ang and Choi 1997; Baksi and Green 2007) (box 3.1).

Despite its limitations, energy intensity has traditionally been used as a proxy for energy efficiency when making international comparisons owing to the limited availability of disaggregated data and the multidimensional nature of energy efficiency.

Energy intensity measures are ratios; trends represent the rates of change of those ratios. Therefore, small changes in either the numerator or denominator of energy intensity measures can result in significant shifts in year-to-year trends. The volatility of data trends from one year to the next can make tracking the evolution of energy intensity difficult.

BOX 3.1 Understanding what drives change in aggregate variables

Changes in energy demand in an economy or sector are influenced by multiple driving forces, including changes in:

- Activity or output. Demand for energy rises with increases in industrial output, the number of people needing housing, or the volume of passengers and distances travelled in the transportation sector.
- Structure. Larger houses and sparser occupancies increase household energy intensity independent of changes in population; decreases in steel production or increases in financial services lower the energy intensity of the economy as a whole; shifts in transport modes (for example, from public or nonmotorized transport to private cars, or from trains to trucks) alter transport energy consumption.
- Fuel type. A shift from wood to electricity, for example, alters energy demand.
- External/explanatory factors. Cold weather affects the quantity of energy used for residential space heating; changes in income and lifestyle affect consumer preferences, travel, and the use of appliances.
- Technical efficiency. Managerial or technological changes—such as better insulation, process improvements in industry, or innovations in automotive technology—affect the demand for energy.

[1] There appears to be an upper limit to car ownership and usage. Policy matters, but it does not cancel out the effect of increased car ownership and usage as incomes increase.

A decomposition analysis is typically used to break down the change in an aggregate variable, like energy demand, into its driving factors. Several methodologies can be used for such an analysis, including the Divisia-based and Laspeyres-based methods. Since decomposition is a series expansion truncated at first order, a residual usually remains that captures higher-order terms. Most of the methods based on the Divisia index have the advantage of being "residual free," which comes at the expense of an arbitrary attribution of interaction terms. For the purposes of global tracking, the logarithmic mean Divisia index I (LMDI I) method will be used both because it is practical and because it is already widely used to assess energy efficiency progress.

The Divisia index was devised by François Divisia and first published in the *Revue d'économie politique* in 1925 (Divisia 1925). Divisia initially used the index to determine the variable in the equation of exchange. Its application to energy analysis was pioneered by Boyd, Hanson, and Sterner (1988).

SOURCE: AUTHORS.

Market exchange rate versus purchasing power parity

Another difficulty associated with international comparisons of value-based measures of energy efficiency is that of determining a suitable value measure of output. In particular, value added can be expressed either in terms of market exchange rate (MER) or purchasing power parity (PPP). MER measures simply convert the value of output to a common monetary metric based on standard exchange rates. The drawback to this approach is that price levels vary significantly across countries, and prices of locally produced goods tend to be systematically higher in higher-income countries. As a result, MER measures may undervalue output from lower-income countries and therefore overstate energy intensity. But PPP measures are not as readily available as MER measures because the associated correction factors are updated only every five years (box 3.2).

BOX 3.2 Purchasing power parity

Purchasing power parity (PPP) adjustments are calculated by the International Comparison Program at the World Bank using data from surveys undertaken every five years. A total of 180 countries participate in the surveys.

PPP estimates are developed by interpolation for countries that do not participate in the surveys and for years during which surveys are not conducted. For nonparticipating countries, the PPPs are estimated using a price level index adjustment that computes the relative size of the economies in terms of gross domestic product (GDP), imports, and exports in U.S. dollars. PPP series are updated in years between surveys using the most recent nominal GDP and relative GDP deflators (accounting for the rate of inflation) between the country and the United States since the last PPP value was calculated. The current PPP series in use is from the 2005 survey, and the next update will be released in 2013, based on the survey done in 2011.

In terms of projections, the International Monetary Fund forecasts country-level annual real GDP through 2017 in the *World Economic Outlook*. That report (IMF 2012) uses PPP adjusted values and weights for country comparisons and regional aggregations.

SOURCE: WORLD BANK INTERNATIONAL COMPARISON PROGRAM; IMF 2012; UN 2012.

Primary versus final energy

Just as energy intensity measures are affected by the monetary unit used to capture the value added of output, they are also affected by the way that energy consumption[2] is measured. Specifically, energy consumption can be measured either in terms of primary or final energy.[3] The use of primary energy as a measure requires selecting a method of accounting for nuclear, hydro, and other renewable sources of energy for which there is no distinct process of converting final energy (outputs) to primary energy inputs.[4]

When energy intensity is tracked at the primary energy level, efficiency improvement trends and potential can be analyzed on both the supply side and the demand side. On the supply side, the conversion from primary energy (such as coal) to final energy (such as electricity) can be captured. On the demand side, the conversion from final energy (such as electricity used by appliances) to useful energy (such as light and heat) can be captured. If only final energy is tracked, the analysis will miss the potential for improvements on the supply side, which could be significant for developing countries. Furthermore, analysis at the primary energy level can also capture much of the traditional (that is, noncommercial) energy that accounts for a significant share of energy demand in lower-income countries.

While it may make sense to use primary energy for highly aggregated measures of energy intensity, it is less useful for measuring energy intensity at the sectoral or subsectoral level. For example, it would be difficult to interpret the results of an analysis that uses primary energy measures to gauge the energy intensity of the residential sector, because this would confound the efficiency of energy conversion and transformation in the electricity and heating supply sector (which supplies energy to residential buildings) with the efficiency of energy used within the buildings for end-use services (such as space heating, cooling, and lighting).

[2] Though technically energy cannot be consumed, in this report the term *energy consumption* means "quantity of energy applied", following the definition in ISO 50001:2011 and the future standard ISO 13273-1 Energy efficiency and renewable energy sources - Common international terminology Part 1: Energy Efficiency.

[3] Final energy can also be expressed in primary terms through the use of dynamic and country-specific conversion factors. This approach is proposed in the ISO standard "Energy Efficiency and Savings Calculation for Countries, Regions and Cities," currently under development (ISO/TC257). Given the objectives of the UN SE4ALL Global Tracking Framework, data availability issues, and the arguments presented in this section, final energy in primary terms is not used in this report to calculate sectoral intensities. For further discussion on the use of primary or final energy accounting, see the section on methodological issues in chapter 4.

[4] As explained further in this chapter, primary energy supply data from the International Energy Agency, which employs the physical energy content method, will be used.

Suggested methodology for defining and measuring energy efficiency

While it is not possible to fully resolve all of the challenges outlined in the preceding section, SE4ALL's preferred methodological approach is outlined in table 3.1.

CHALLENGE	PROPOSED APPROACH
The multidimensionality of energy efficiency	Track global performance on energy intensity while also tracking the energy intensity of major economic sectors and the efficiency of the energy industry. Move toward better tracking of targets, policies, institutions, and investments.
Intensity versus efficiency	Track energy intensity for countries and major regions and blocks. Where feasible, complement that tracking with decomposition of changes in energy demand to strip out structural effects.
Market exchange rate versus purchasing power parity	Track energy intensity using the purchasing power parity measure to capture the value-added of economic output.
Primary versus final energy	Track global energy intensity in terms of total primary energy supply and sectoral energy intensity in terms of final energy consumption.
Volatility of efficiency measures	Track a five-year moving average trend.

TABLE 3.1 **ADDRESSING METHODOLOGICAL CHALLENGES IN THE GLOBAL TRACKING OF ENERGY EFFICIENCY**

SOURCE: AUTHORS.

The headline indicator proposed here as a proxy for energy efficiency in global tracking is the compound annual growth rate of energy intensity at the national level. Energy intensity is measured as the ratio of total primary energy supply[5] to the value-added of the economy measured in terms of purchasing power parity to ensure a fairer comparison of energy intensity across developed and developing countries.

To address concerns about the year-to-year volatility of energy efficiency measures, energy intensity is calculated as the compound annual average growth rate for the 20 years between 1990 and 2010, which is the longest time series of data available for this purpose. Going forward, five-year moving averages will be tracked.

To get as close as possible to measuring the underlying changes in energy demand, the headline indicator is accompanied by a decomposition exercise of changes in final energy consumption that distinguishes between activity, structure, and underlying efficiency effects.[6] The proposed methodology uses the logarithmic mean Divisia decomposition (LMDI I) method for each country.

5 Total primary energy supply is defined as "indigenous production + imports – exports – international marine and aviation bunkers +/- stock changes. It is equivalent to total primary energy demand, and represents inland demand only and, except for world energy demand, excludes international marine and aviation bunkers" (IEA). As discussed later, energy statistics used to calculate indicators in this chapter come primarily from the International Energy Agency. Hence, IEA terminology and definitions are generally used for these variables. When referring to final energy consumption, the equivalent IEA indicator is total final consumption (TFC).

6 Decomposition analysis can also isolate fuel-switching effects, mainly electrification. This was not done in the analysis presented here, however, owing to data constraints.

7 Owing to data limitations, this report groups transport, residential, services, and others into "other sectors." The medium- and long-term methodology will consider these sectors separately.

8 For this analysis, transformation losses in oil production are considered negligible and will not be tracked.

9 These include iron and steel, cement, chemicals and petrochemicals, aluminum, pulp and paper, and fertilizers (provided there are sufficient data for tracking).

To give a more nuanced picture of energy efficiency trends, the headline indicators are complemented with indicators of the energy intensity of three end-use sectors (agriculture, industry, and "other sectors"[7]) and two energy supply sectors (electricity and gas[8]) along with the specific energy consumption of select energy-intensive products.[9] In addition, the suggested methodology tracks national targets, policies, institutions, and investments in energy efficiency.

For demand-side sectors, the methodology uses energy intensity measures based on the ratio between final energy consumption (expressed in joules) and a measure of the scale of the sector. Finding a suitable measure for the scale of the sector can be challenging. But its economic value can be captured through global statistics on sectoral value added.

Value added is clearly defined only for industry and agriculture. For "other sectors," a category that includes transport, some activities related to the residential sector, services, and other residuals, value added is less clearly defined. Indeed, grouping transport, which has a high energy intensity, with services, which has a low energy intensity, may not be very meaningful and may complicate the interpretation of results for this category, but the decomposition analysis can at least give some insight into structural changes occurring in better-defined sectors.

Ideally, it would be desirable to report separately on the energy intensity of the residential and transport sectors. In the case of the residential sector, energy consumption would ideally be normalized against the number of households or the size of residential housing units in square meters. Similarly, energy consumption in the transport sector would ideally be normalized against freight and passenger traffic volumes. Unfortunately, because none of these variables is widely available, it is not possible at present to report separate energy intensity measures for the residential and transport sectors.

Overall energy efficiency in the supply sector is captured by the ratio of final energy consumption to total primary energy supply. This is a practical indicator, and the data are typically available in country energy balances. While this indicator can be useful for tracking progress in supply-side energy efficiency within a country, caution is required in a global or regional comparison because the indicator is distorted by resource-endowment factors. In a country with a significant hydroelectric sector, for example, primary energy and delivered energy are more directly related, while a country rich in geothermal energy will have a lower ratio owing to the low thermodynamic quality of the primary resource.

It is very difficult to determine how much primary energy is needed per unit of final energy or end-use output. The electricity system is dynamic, with changing dispatch, outages, and utilization factors. It is not practical to process real-time generator data for indicators, and the use of transformation efficiency assumptions obscures the real changes that occur. Efficiency indicators that focus on the supply system itself are therefore more informative for supply-side decision makers. It is thus more effective to treat the supply side as separate from the demand side for indicator analysis.

Supply-side energy efficiency indicators measure the efficiency of thermal plants in converting primary energy sources—such as coal, gas, and oil—into electricity. They are calculated by dividing gross electricity production from electricity and cogeneration plants by total inputs of fuels into those plants. Whether market-based or privately owned, self-generating plants that do not export their power should be included in the index assessment. In the case of cogeneration plants, fuel inputs are allocated between electricity and heat production in proportion to their shares of the annual output.

Transmission and distribution (T&D) losses measure power lost in the transmission of (high-voltage) electricity from power generators to distributors and in the distribution of (medium- and low-voltage) electricity from distributors to end-users. T&D losses are represented as a percentage of gross electricity production. They include both technical and nontechnical (or commercial) losses. Included in the latter are unmetered, unbilled, and unpaid electricity, including theft, which could be significant in developing countries. Aggregate T&D system indicators may be dominated by factors other than losses. The location of primary energy resources (such as hydro lakes and coal seams) and large loads (cities and industries) may be more significant factors in T&D efficiency indicators than the losses or efficiency of the transmission system itself. Properly

[10] This makes the definition of sectors consistent both in the numerator and the denominator of the intensity calculation. The World Bank's World Development Indicators (WDI) database considers all of the items classified under the International Standard Industrial Classification (ISIC) 3, including the value of energy for own use, as value added in industry. Therefore, own use of energy by industry (as reported by IEA) was added to the sector's consumption. This excludes nonenergy uses (such as feedstocks and methanol production). Similarly, energy use in the WDI sector labeled "services" is calculated by adding the consumption of the EIA sectors listed as "services," "residential," "transportation," and "other nonspecified."

separating true losses (and hence the efficiency potential of transmission systems) from exogenous location and scale factors and nontechnical losses would require detailed studies of system-dynamic interactions and real operating requirements that are not practical for global tracking purposes.

For gas supply, the efficiency indicator is based on the ratio of losses to primary energy supply using data available from national energy balances.

Global databases for setting the tracking framework

A number of agencies have historically collected disaggregated data on sectoral—and sometimes subsectoral—measures of energy intensity and energy efficiency, although these focus primarily on the developed countries of the Organisation for Economic Co-operation and Development (OECD) (box 3.3).

At present, disaggregated data are available for few developed countries. Therefore, when constructing energy intensity indicators for a wide set of countries, it is necessary to analyze base sectoral and end-use energy and activity data.

Table 3.2 summarizes the available databases that are consistent across countries and time, three of which are in the public domain (IEA; the World Bank's World Development Indicators; and UN Energy Statistics). The table also includes ODYSSEE, which, although limited in country coverage, exemplifies the extent to which energy efficiency indicators can be constructed provided that there are sufficient data.

BOX 3.3 Overview of existing data sources for energy efficiency indicators

A number of different agencies are doing important work on developing energy efficiency indicators. In general, these efforts either cover a relatively small number of countries in great depth (e.g. ODYSSEE-MURE) or a large number of countries at a much higher level of aggregation (WEC). While all these sources are relevant and useful for global tracking, none of them are directly suited in their existing form.

The International Energy Agency's (IEA's) energy efficiency indicators start from the top of the energy efficiency indicator pyramid (recall figure 3.1) and cover as many aggregation levels as possible. The IEA makes efforts to deepen the coverage of energy efficiency indicators to lower levels of disaggregation in OECD-IEA member countries. At lower aggregation levels, data availability limits the number of countries for which detailed indicators can be developed to ever-smaller subsets of IEA member countries. The exception is a special effort undertaken for the 2012 World Energy Outlook (WEO), which includes energy efficiency analysis for 25 large countries and global subregions.

The ODYSSEE-MURE Project, under the Intelligent Energy Europe Programme of the European Commission, is one of the most ambitious attempts to produce subsectoral and process-level indicators on energy efficiency. It focuses on the 27 EU member states plus Norway and Croatia.

Through bilateral support—such as the assistance that ADEME (the French Agency for Environment and Energy Management) has provided to several developing countries, and the efforts of individual countries (for example, China, India, Mexico, South Africa, Turkey, and Vietnam)—Enerdata provides relatively good coverage of sectoral-level energy intensity indicators for 184 countries worldwide, but these are proprietary.

The World Energy Council (WEC), with technical support from ADEME/Enerdata, maintains a database of global energy efficiency indicators focusing on a small set of aggregated indicators. The WEC effort covers the entire world at a regional level but provides only relatively aggregated efficiency indicators; this level of aggregation is indicative of what can currently be achieved for most developing countries without substantial additional effort and local involvement. It is important to note that efforts are under way to expand the countries included in the WEC's database.

The Asia Pacific Economic Cooperation, through capacity building activities on energy efficiency indicators organized by its Energy Working Group, has been forging collaboration and information sharing among its member economies.

Additionally, information is collected by various other agencies, including the World Bank, the U.S. Department of Energy's Energy Information Administration (EIA), the UN Industrial Development Organization (UNIDO), and other UN agencies. National energy agencies also collect data as part of their routine work, but these are limited in scope by coverage (either by country or sector) and often are based on differing methodologies. As a result, care must be taken when using these inputs as part of a tracking framework.

ENERGY DEMAND						OTHER VARIABLES		
Source	Primary or secondary	Period covered	Number of countries covered	Sectoral: Sectors (# of countries)	Subsectoral: Subsectors (# of countries)	Sector value added	Transport activities (# of countries)	Household data (# of countries)
International Energy Agency (IEA)	Primary	1971–2010	138	Industry, agriculture, services, residential, transport, fishing, and forestry (138)	13 industry subsectors, 6 transport subsectors for (138)	—	—	Building characteristics (29)
UN Energy Statistics	Primary	1950–2009	Over 200	Industry, agriculture, services, residential, transport (over 200)	3 industry subsectors, 5 transport subsectors (over 200)	—	—	—
World Bank, World Development Indicators (WDI)	Primary	1980–2011	—	—	—	3 sectors (agriculture, industry, services)	Air transport, freight in million ton-km (169); Air transport, passen-gers carried (169); railways, goods transported in million ton-km (88)	Household final consumption (172)
Enerdata	Secondary	1970–2010	184	Industry (181), agriculture (135), services (167), resi-dential (184), transport (184)	13 industry subsectors (16–61) 4 transport subsectors (87–184)	3 sectors (industry, agriculture, services)	—	Private consumption (134)
ODYSSEE	Primary	1990–2010	29	Industry, agriculture, services, residential, transport (29)	16 industrial subsectors, 9 transporta-tion modes, 4 household end-uses, 5 appliances, 6 branches services, 1 agriculture sector (29)	3 sectors (agri-culture, industry, services)	Traffic, annual distance travelled, and stock of vehicles by mode of transporta-tion: road (cars, two-wheelers, bus-es, light vehicles, trucks), rail, water, air (29)	Stock of dwellings, new dwellings, floor area of dwelling, stock of appliances, equipment rate (29)

TABLE 3.2 **COVERAGE OF THE FEW AVAILABLE DATABASES THAT ARE CONSISTENT ACROSS COUNTRIES AND TIME**

SOURCE: AUTHORS.
— = DATA NOT AVAILABLE.

Global and country-level tracking frameworks

Immediate and short term

The immediate approach for global tracking will make use of the most widely available historical data to construct national and sectoral indicators of energy intensity. This will be done by combining two sets of public domain data: (i) data on total primary energy supply and final energy consumption at the national and sectoral levels from the IEA's national energy balances, complemented with UN data on countries for which IEA lacks information; and (ii) data on national and sectoral value added in PPP terms from the World Bank and International Monetary Fund. Indicators will be tracked on a country level and aggregated globally and regionally for reporting by SE4ALL.

The specific energy consumption of selected energy-intensive products will be tracked using a wide range of available studies and databases, including those produced by the IEA, Enerdata, UNIDO, and other relevant stakeholders. In this process, care should be taken to address issues of comparability between different methodologies. Tracking should include national (and regional when applicable) energy efficiency policies, targets, institutional frameworks, and investments. Sources of information for the former include databases and compendiums available from the IEA, the World Energy Council (WEC), the World Bank, the Asia Pacific Energy Research Centre (APERC), and the European Union (EU), as well as country consultations.

At present there is no established methodology or periodic data collection on a global scale for tracking investments in energy efficiency. IEA's recent work for the World Energy Outlook (WEO) 2012 could lay the foundation for this purpose. Data sources include the World Bank and other multilateral development organizations. As mentioned previously, energy intensity indicators should be calculated as five-year moving averages. For monitoring and evaluation, especially in EU countries, the European Commission Directive on energy efficiency and the national energy efficiency action plans may be used.

The question of the entity that should be responsible for tracking, monitoring, and evaluating progress on energy efficiency is still under discussion. Well-established institutions that already collect and analyze the base data, as well as special-purpose entities created under the SE4ALL initiative, are being considered.

Medium term

The development of energy efficiency indicators in many developing countries is limited by the availability and quality of data and by a lack of dedicated resources and expertise to collect, track, and analyze those data. Substantial capacity-building efforts and resources—both human and financial—are needed to strengthen existing programs and institutions. Several countries have already established tracking systems and are collecting data and conducting analysis. In other countries, energy data are limited to supply and demand at the national and sector levels, which makes it difficult both to assess energy efficiency and to target policy interventions.

Efforts to improve data collection are best directed at increasing the availability of sectoral activity indices that can be used to convert into energy intensities detailed data on sectoral energy consumption already available from the national energy balances. In particular, the focus should be on the residential and transport sectors, for which scaling variables are not readily available at present. In the case of the residential sector, data series on floor space, occupancy and the number of households in each country are needed to calculate more meaningful measures of residential energy intensity than are possible today. The same is true for data series on freight and passenger traffic volumes in the transport sector. Improved floor space data could also help to provide more meaningful measures of efficiency in the services sector.

Since SE4ALL envisions the establishment of national tracking systems, there will be opportunities to invest in country-level capacity to collect critical complementary data that can cover the spectrum of economic activity. In addition, at the country level, it may be possible to contemplate more refined and disaggregated data on energy efficiency at the level of subsectors and technology processes.

Annex 1 illustrates the proposed indicators and their limitations. For a country to understand key sector-level factors driving energy efficiency, a bottom-up data collection framework needs to be established. Figure 3.2 illustrates the levels of data needed to monitor energy efficiency and intensity.

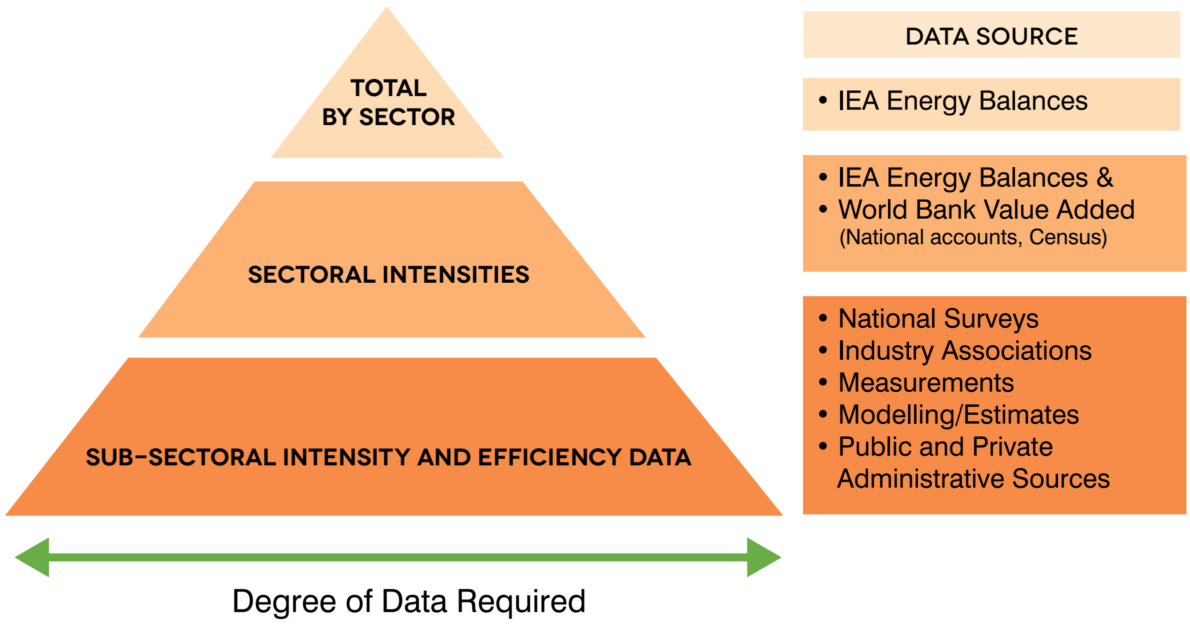


FIGURE 3.2 **ENERGY INDICATORS PYRAMID**

SOURCE: AUTHORS.
NOTE: IEA = INTERNATIONAL ENERGY AGENCY.

There is no single best approach to collecting country-level data; a country could choose from a number of ways to compile bottom-up energy demand data. Data collection could focus on sectors of interest and could include a combination of national surveying, metering, modeling, and collection of administrative data from existing public and private sources. Figure 3.3 illustrates a data collection framework that could be used for each sector based on several different sources. The final—and most important—step of the data collection framework is the bottom-up process of reconciliation and validation with energy balances. This is the step in which analysts ensure that energy and activity data are aligned with activity classification definitions. In addition, energy end-use data (such as for space heating and cooling), or derived data (obtained, for example, by estimating average fuel consumption of vehicles on roads by relating energy data to vehicle registration dates) are produced from the collated data.

Deciding which organization collects, consolidates, and analyzes data can be as important as determining how those data should be handled. This decision can be driven by existing national administrative laws. Some countries task statistical departments to undertake national surveys and carry out analysis; in other countries, final energy end-use analysis and estimates are carried out by ministries responsible for energy and natural resources. Often, different ministries are asked to work together. For example, statistics ministries and ministries tasked with overseeing energy resources and economic output are asked to coordinate to produce a final output together with one national organization taking the lead.

More data are not necessarily better. A country must commit to maintaining ongoing data collection and assessment of efficiency improvements. In order to establish timely and effective analysis of energy efficiency improvements, steps should be taken to ensure that sector-level monitoring of energy use is renewed on an annual basis. Resources should be allocated to monitor sectors that constitute a significant share of the country's absolute energy demand.

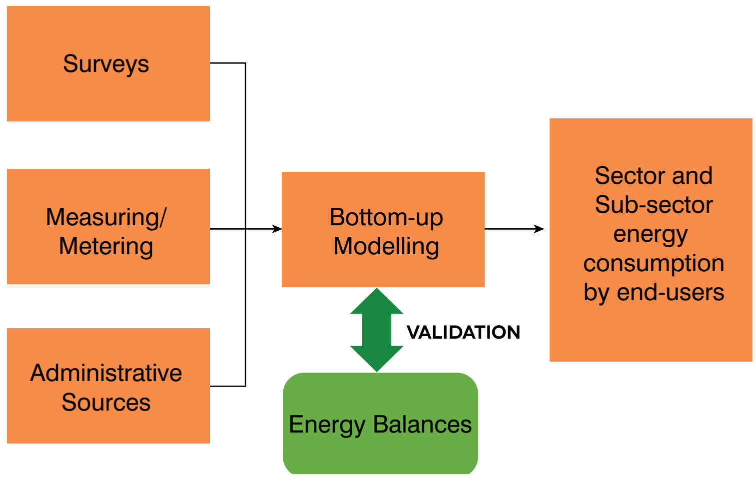


FIGURE 3.3 **DATA COLLECTION FRAMEWORK**

SOURCE: AUTHORS.

IEA's forthcoming *Manual on Statistics for Energy Efficiency Indicators* will be an essential guide for all countries that wish to establish a national framework. It will provide a list of key data elements needed to build energy efficiency indicators and describe how countries collect such data. The manual will feature examples of international practices, such as surveying, metering, modeling, and collecting of administrative sources. Other international guides are also being prepared, including the *Energy Statistics Compilers Manual* by the United Nations Statistics Division, and the *Manual for Statistics on Energy Consumption in Households* by Eurostat.

Figure 3.4 summarizes the proposed framework for the immediate and medium term, both globally and at the country level.

	IMMEDIATE	MEDIUM TERM
Global tracking	National and sectoral energy intensity measures for end-use sectors (industry, agriculture, and other sectors, the latter comprising services, residential and transport) plus an efficiency measure for electricity and gas supply. Apply Divisia decomposition method to track the underlying energy efficiency component of energy intensity.	Improve integration of data systems on energy use and associated output measures (for example, residential floor space and traffic units for transportation). Improve data on specific energy consumption of energy-intensive products.
Country-level Tracking	None	Strengthen country-level information systems and capability to collect data on sectoral intensities (and, ideally, subsectoral process efficiency measures). Improve data on physical activity drivers (traffic volumes—passenger and freight, number of households, floor space, and so on). Improve data on energy efficiency targets, policies, investments and institutional frameworks.

FIGURE 3.4 **IMMEDIATE AND MEDIUM-TERM TRACKING ACROSS GLOBAL AND COUNTRY LEVELS**

SOURCE: AUTHORS.

SECTION 2. GLOBAL, REGIONAL, AND SECTORAL TRENDS IN ENERGY INTENSITY

This section establishes the starting point for improvement in energy intensity using the approach outlined in the previous section. It reviews energy intensity trends over the two decades from 1990 to 2010 at the global, sectoral, and regional levels.

Defining the starting point for improvement

As described earlier, energy intensity measures the amount of energy used to produce a unit of economic activity (GDP). The 20 years between 1990 and 2010 witnessed an unprecedented growth in both GDP and energy demand across the globe. World primary energy supply grew from 367 exajoules (EJ) in 1990 to 534 EJ in 2010, an annual growth rate of 1.9 percent. Global GDP grew at an even higher rate of 3.2 percent per year (from $36 trillion in 1990 to almost $68 trillion in 2010) in PPP terms (constant 2005 U.S. dollars).

Thus, the starting point for the rate of energy efficiency improvement against which future progress will be measured under the SE4ALL initiative is a compound annual growth rate (CAGR) for global energy intensity of –1.3 percent (in PPP terms) for the period 1990–2010. The SE4ALL global objective is a CAGR of –2.6 percent for the period 2010–2030.[12] *For immediate tracking purposes, energy intensity is adopted as an imperfect proxy for energy efficiency that may be subject to improvement over time.*

As figure 3.5 illustrates, improvements in energy intensity were not even across the two decades. Energy intensity decreased more rapidly in the 1990s (–1.6 percent per year) than in the 2000s (–1.0 percent per year). This slowdown is mainly attributable to an increasing share of global economic activity during the 2000s in developing Asian countries, which have energy-intensive industries and coal-fired power generation, and thus relatively high energy intensities.

–1.0%
IS THE COMPOUND ANNUAL REDUCTION
IN GLOBAL ENERGY INTENSITY DURING THE DECADE 2000–2010; SIGNIFICANTLY LOWER THAN THE EQUIVALENT FIGURE OF –1.6% FOR THE DECADE 1990–2000

The magnitude of the deceleration during the decade 2000–2010 differs markedly across the MER and PPP measures. The rate of improvement of energy intensity slowed to only –0.1 percent annually in MER terms, compared to –1.0 percent in PPP terms. This divergence between MER and PPP measures can be attributed to globalization during the 2000s, which led to a large shift in the share of global GDP that was produced in non-OECD countries, where prices tend to be relatively low. As a result, the valuation of global output in PPP terms (to correct for these lower prices) rose steeply relative to MER terms. The rate of improvement in energy intensity thus looks much higher when the true value of increased output is taken into account.

[11] 1 exajoule (EJ) = 10^{18} J; 1 terajoule (TJ) = 10^{12} J; 1 megajoule (MJ) = 10^{6} J.

[12] When measured in final energy terms, the compound annual growth rate is –1.5 percent for the period 1990–2010. Thus the goal is –3.0 percent on average for the next 20 years.

FIGURE 3.5 **RATE OF IMPROVEMENT IN GLOBAL ENERGY INTENSITY (COMPOUND ANNUAL GROWTH RATE)**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A.
NOTE: GDP = GROSS DOMESTIC PRODUCT; MER = MARKET EXCHANGE RATE; OECD = ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT; PPP = PURCHASING POWER PARITY.

In absolute terms, global energy intensity fell from 10.2 MJ/$ in 1990 to 7.9 MJ/$ in 2010 when measured in PPP terms (figure 3.6a). The role of major global economic shocks is evident when examining year-to-year rates of improvement. The impact of steeply rising energy prices is observable in the charts as triggering larger improvements in energy intensity in the 1990s. With the recession of the early 2000s and the global financial crisis of the late 2000s, improvements in energy intensity slowed.

7.9 MJ/US$ IS THE GLOBAL AVERAGE ENERGY

INTENSITY IN 2010; COMPARED WITH 10.2 MEGAJOULES PER US$ IN 1990

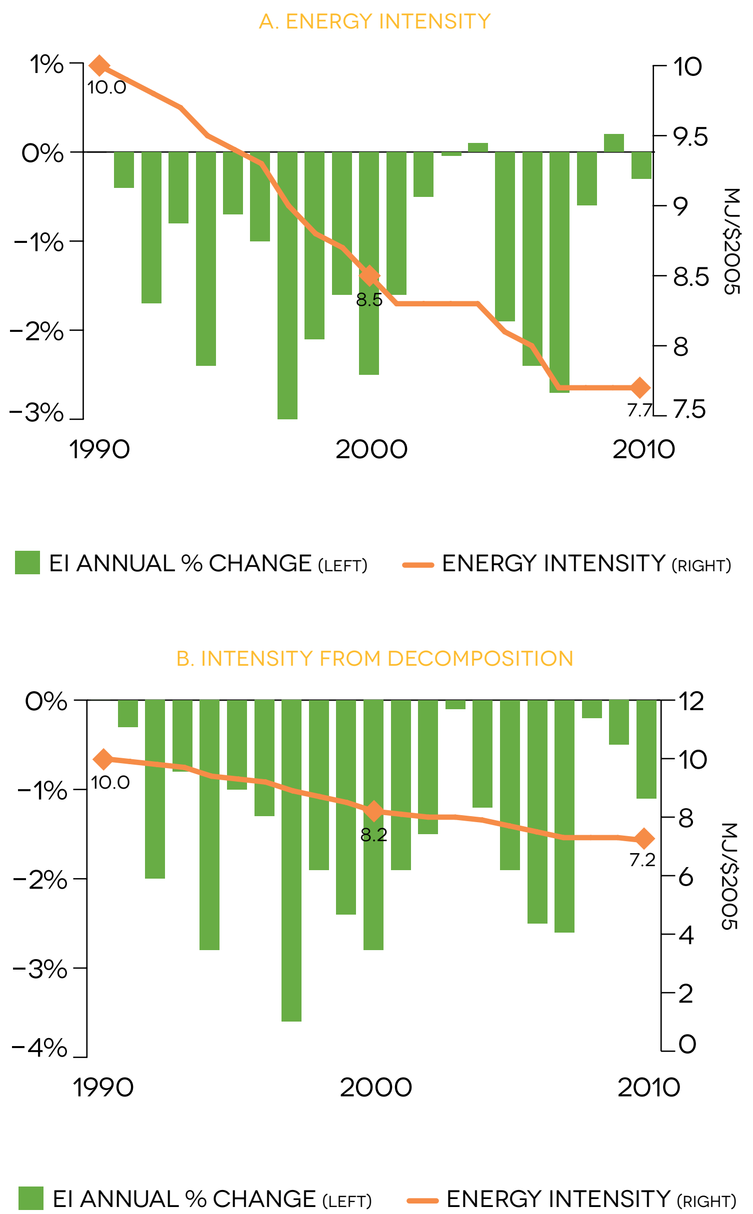


FIGURE 3.6 **EVOLUTION OF GLOBAL ENERGY INTENSITY TRENDS AT PPP**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A.
NOTE: EI = ENERGY INTENSITY; PPP = PURCHASING POWER PARITY.

As noted in the previous section, the decomposition of energy demand trends expressed in final energy consumption by sector makes it possible to distinguish among changes attributable to an expansion in economic activity (the activity effect), changes attributable to a shift in the structure of the economy (the structure effect), and changes attributable to improvements in energy intensity (intensity effect). The latter provides a first-order approximation of underlying energy efficiency (see figure 3.6b). The figure shows that improvements in the decomposed intensity were consistently higher than those in the unadjusted intensity, particularly in the last decade of the period analyzed.

Figure 3.7a shows more clearly the changes in the global energy intensity component of energy consumption for the 20 years since 1990. For the period 1990–2010, the CAGR of energy intensity with the activity and structure effects factored out is –1.6 percent—higher than the CAGR of energy intensity of –1.3 percent for the same time period, illustrating that energy intensity trends underestimate the rate of progress in underlying energy efficiency.[13]

The reason for this difference can be seen in figure 3.7b, which illustrates the variations in each component of energy demand from the base year. As the years progressed, the increase in economic activity in each sector was offset by the increased efficiency in each of the sectors used in the decomposition. The change in the structure component is insignificant at the global level because structural shifts in one country are to some extent offset by those in another, while the level of sector disaggregation is in any case quite coarse.

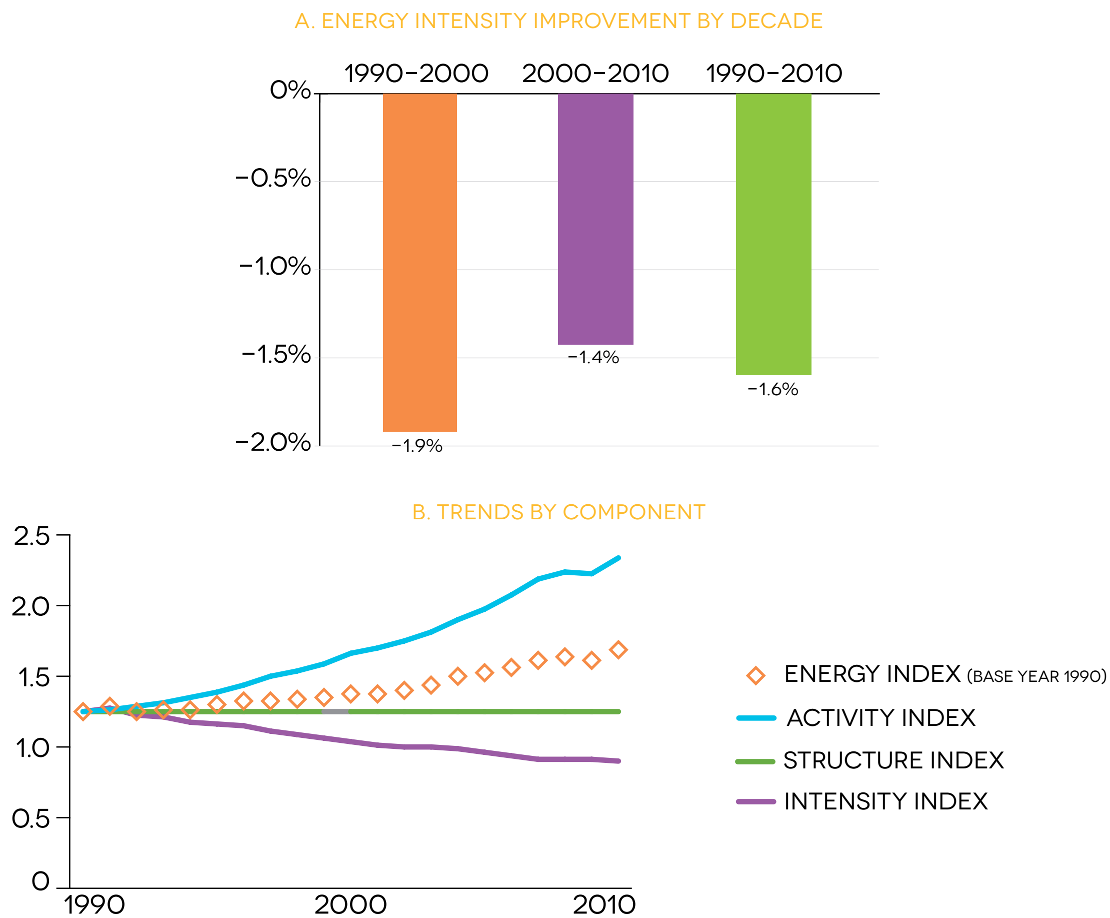


FIGURE 3.7 **GLOBAL RATE OF ENERGY INTENSITY IMPROVEMENT (DECOMPOSITION ANALYSIS)**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A.

[13] The –1.6 percent rate is also a larger improvement than the global compound annual growth rate measured in terms of final energy consumption terms with no decomposition. If taken as a baseline, it would imply average annual growth of –3.2 percent over the next 20 years.

Energy intensity improvements over the two decades 1990–2010 had a dramatic impact on the reduction of primary energy demand[14] globally. As figure 3.8 illustrates, if global energy intensity measured in PPP terms had remained at its 1990 level, world energy demand in 2010 would have been nearly 300 EJ higher. The energy intensity improvement that took place over the past 20 years allowed savings of nearly 2,300 EJ, equivalent to almost one-quarter of cumulative global primary energy demand—or the cumulative primary energy demand of China, Russia, and India combined over the same period.

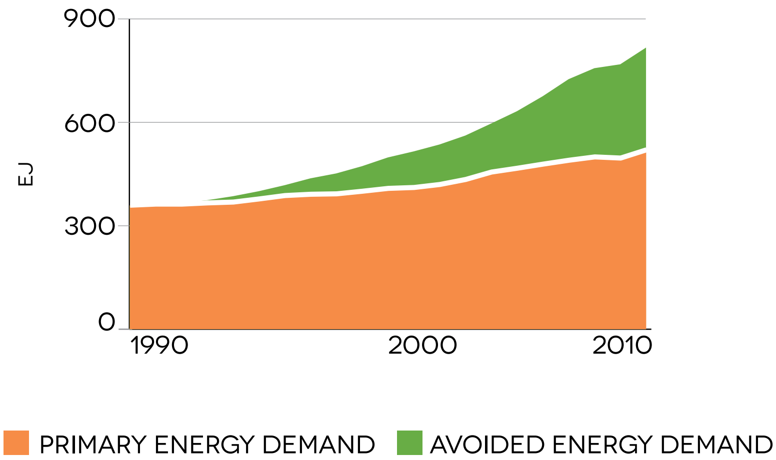


FIGURE 3.8 **ENERGY SAVINGS FROM REALIZED INTENSITY IMPROVEMENTS (EJ)**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A.

Global trends by sector

Further insights can be obtained by examining energy intensity trends at the level of major economic sectors—namely, agriculture, industry and other sectors (including transportation, residential, and services) (figure 3.9). The industrial sector is by far the most energy intensive, despite having improved at a relatively fast rate of –1.4 percent annually in PPP terms. The agricultural sector, which accounts for slightly over 2 percent of global final energy consumption, showed the fastest rate of improvement, at –2.2 percent per annum. Improvement in the other sectors is similar to that in industry, although this is difficult to interpret given the very different activities included under this category, which have markedly different drivers and intensity levels (see box 3.4 for an estimate of the contribution of the transport sector to improvements in energy intensity).

Although the rate of energy intensity improvement in industry and agriculture slowed down in 2000–2010 compared to 1990–2000, the opposite was true in the other sectors; once again, however, this result must be considered cautiously.

2,300 EJ
IS THE CUMULATIVE ENERGY SAVINGS
DUE TO DECREASES IN GLOBAL ENERGY INTENSITY FROM 1990 TO 2010; EQUIVALENT TO THE COMBINED CUMULATIVE PRIMARY ENERGY DEMAND OF CHINA, INDIA AND RUSSIA OVER THE SAME PERIOD

[13] The –1.6 percent rate is also a larger improvement than the global compound annual growth rate measured in terms of final energy consumption terms with no decomposition. If taken as a baseline, it would imply average annual growth of –3.2 percent over the next 20 years.

[14] As indicated previously, primary energy demand is equivalent to primary energy supply.

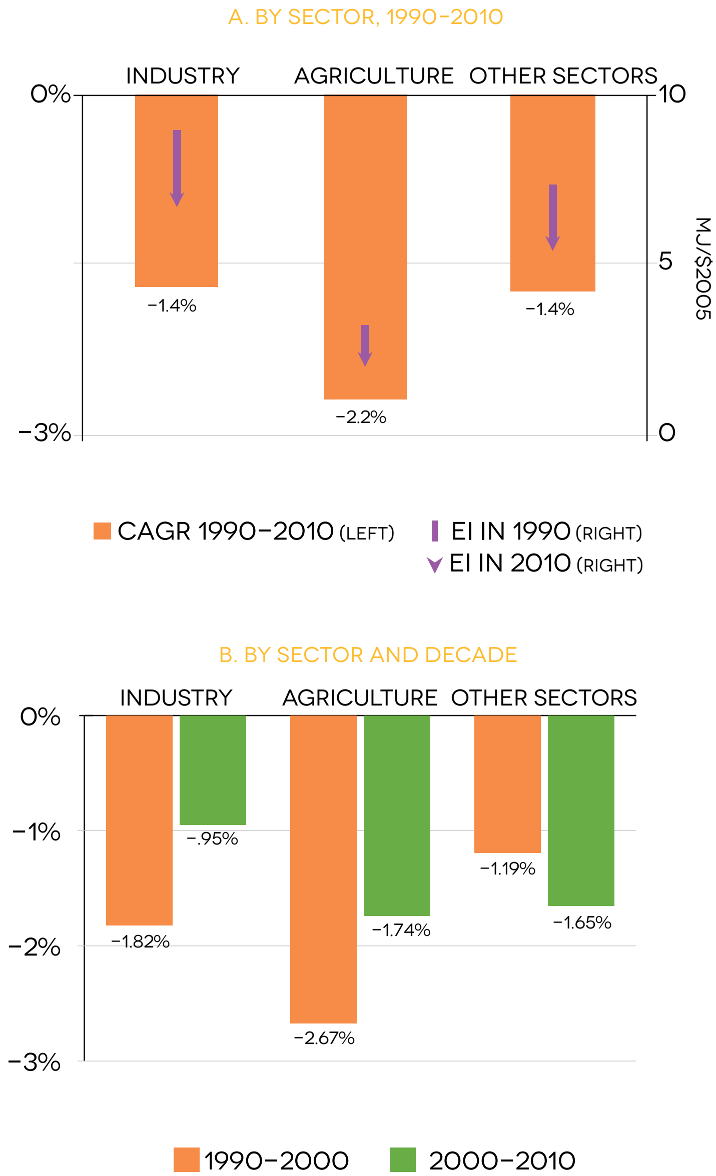


FIGURE 3.9 **SECTORAL ENERGY INTENSITY TRENDS AT PPP**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A.
NOTE: OTHER SECTORS INCLUDE THE TRANSPORTATION, RESIDENTIAL, AND SERVICE SECTORS. CAGR = COMPOUND ANNUAL GROWTH RATE; EI = ENERGY INTENSITY; PPP = PURCHASING POWER PARITY.

When looking at energy savings (that is, the difference between estimated cumulative final energy consumption if energy intensity levels had remained constant at 1990 levels and actual cumulative consumption through 2010), the percentage contribution of each sector (figures 3.10b and 3.10c) matches closely their share of final energy consumption (figure 3.10a).

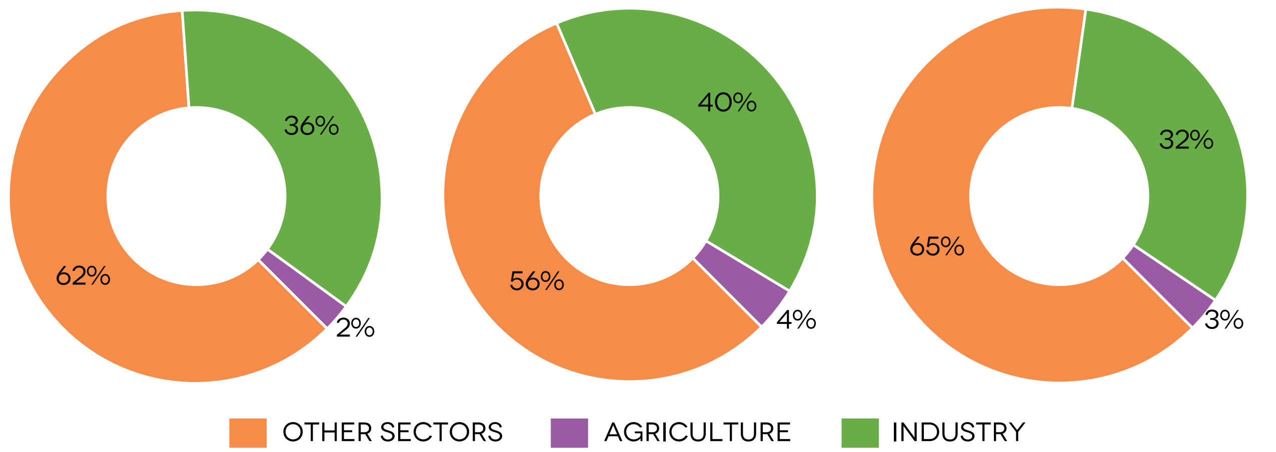


FIGURE 3.10A **FINAL ENERGY CONSUMPTION BY SECTOR, 1990–2010**

FIGURE 3.10B **ENERGY SAVINGS BY SECTOR, 1990–2010**

FIGURE 3.10C **ENERGY SAVINGS BY SECTOR, 1990–2010 (BASED ON INTENSITY FROM DECOMPOSITION)**

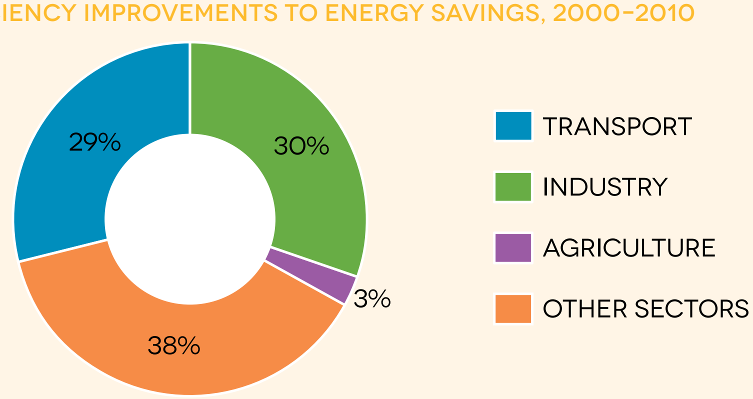
SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A.
NOTE: OTHER SECTORS INCLUDE THE TRANSPORTATION, RESIDENTIAL, AND SERVICE SECTORS.

BOX 3.4 Estimating the contribution of the transport sector to energy intensity improvements

Due to limitations in the availability of data on sectoral value added in the World Development Indicators, the main analysis here treats “other sectors” as a residual after industrial and agricultural output have been subtracted from GDP. As a consequence of this method, a number of disparate subsectors—including transport, residential, and services—are lumped together.

More disaggregated data on value added in the transport sector are available from the United Nations Statistics Division’s National Accounts database, though that database covers 100 countries instead of 116 and only for 2000–10. Despite limitations in data, it is still of interest to explore trends in the transport sector as a supplement to the main analysis. The analysis shows a CAGR of –1.3 percent for the energy intensity of the transport sector in 2000–10. Overall, the transport sector contributed 29 percent of total global energy savings—almost as much as the other service sectors (38 percent) (figure A).

FIGURE A. **ECONOMYWIDE EXTENDED DECOMPOSITION: THE CONTRIBUTION OF SECTORAL ENERGY EFFICIENCY IMPROVEMENTS TO ENERGY SAVINGS, 2000–2010**



SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A; UN ENERGY STATISTICS DATABASE.
NOTE: OTHER SECTORS INCLUDE THE RESIDENTIAL, AND SERVICE SECTORS.

While the sectoral indicators reported above give a good sense of demand-side energy intensity, it is also important to consider the efficiency of conversion and transformation from primary to final energy. Figure 3.11a shows a gradual loss of global total primary energy to final energy transformation efficiency. This ratio decreased from 72 percent in 1990 to 68 percent in 2010. The driving forces behind this include the growth in coal use for electricity generation, and coal, oil, and gas consumption for heat provision relative to other primary resources.

Figure 3.11b shows the impact of improvements made in reducing losses in primary gas extraction and processing. Contributing factors include reduced gas flaring, reduced leakage, and improved efficiency of pipeline pressurization.

Figure 3.11c highlights the inertia in global electricity generation efficiencies, locked in at about 38 percent over many years. New coal-fired power stations dominate recent load growth, keeping overall efficiency relatively low despite the availability of higher-efficiency plants, such as combined-cycle gas generators.

Figure 3.11d highlights that again there is inertia in the dynamics of power transmission and distribution systems. The underlying drivers include the ongoing economic application of transmission efficiency improvements being countered by increasing network length as new generators are added farther from load centers.

The above indicators highlight that it is important to understand the underlying system inertia and dynamics and that disaggregation is key to explaining the status and opportunities of energy systems.

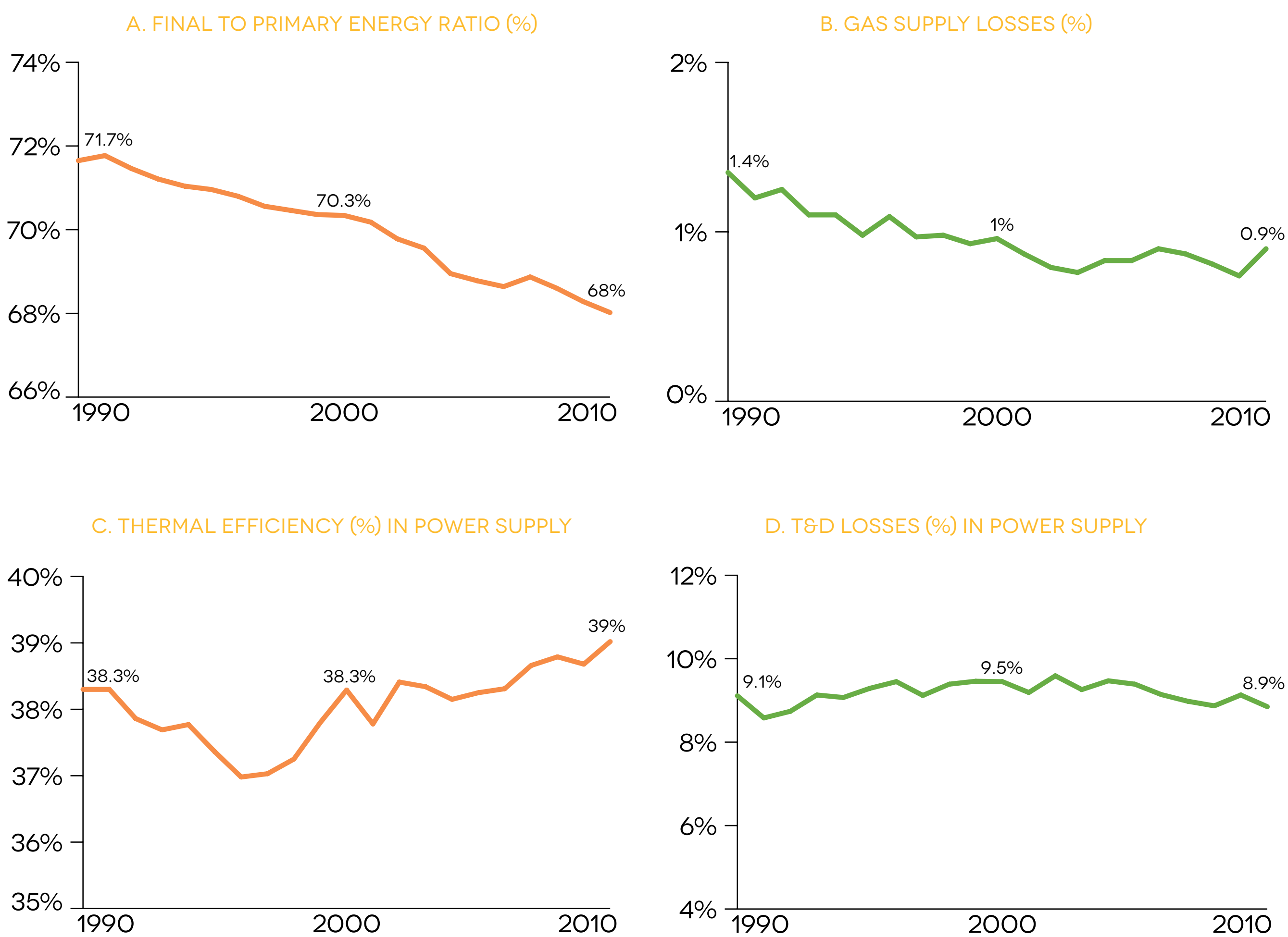


FIGURE 3.11 **SUPPLY-SIDE ENERGY EFFICIENCY INDICATORS**

SOURCE: BASED ON IEA 2012A.
NOTE: T&D = TRANSMISSION AND DISTRIBUTION.

Global trends by region

On a regional level, Eastern Europe and the Caucasus and Central Asia regions exhibited the fastest rate of energy intensity improvement over the past 20 years (figure 3.12). Despite this remarkable improvement, however, Eastern Europe and the Caucasus and Central Asia regions remain among the most energy intensive in the world, alongside Sub-Saharan Africa. Western Asia (which includes countries from the Middle East) is the only region to show a substantial deterioration in energy intensity, particularly in the past decade. Although Latin America and the Caribbean and Northern Africa are among the slowest-performing regions in terms of the rate of energy intensity improvement, they rank second and third, respectively, in terms of the lowest achieved level of energy intensity in 2010. Countries in Europe and North America also steadily improved their energy intensities. Southern and Southeastern Asia achieved similar levels of energy intensity, although the latter showed slower progress, having started from a relatively lower level.

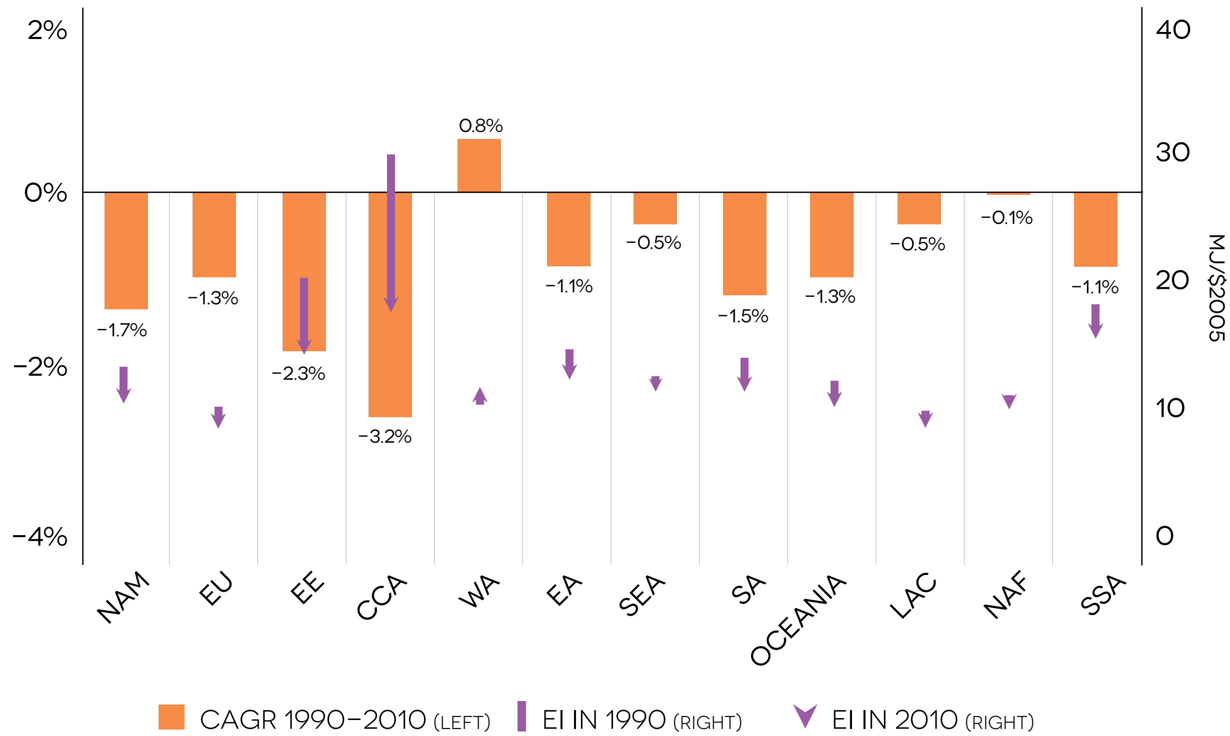


FIGURE 3.12A **RATE OF IMPROVEMENT IN ENERGY INTENSITY AT PPP VS. ENERGY INTENSITY LEVELS IN 1990 AND 2010, BY REGION**

NOTE: NAM = NORTH AMERICA; EU = EUROPE; EE = EASTERN EUROPE; CCA = CAUCASUS AND CENTRAL ASIA; WA = WESTERN ASIA; EA = EASTERN ASIA; SEA = SOUTHEASTERN ASIA; SA = SOUTHERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NAF = NORTHERN AFRICA; SSA = SUB-SAHARAN AFRICA; CAGR = COMPOUND ANNUAL GROWTH RATE; EI = ENERGY INTENSITY; PPP = PURCHASING POWER PARITY.

Eastern Asia, North America, and Europe contributed most to global energy savings over the 20 years between 1990 and 2010 (figure 3.13).[15] Eastern Europe, Southern Asia, and other regions accounted for only 16 percent of energy savings while consuming about 35 percent of global energy. Western Asia and Northern Africa contributed a 0.6 percent decrease in energy savings owing to deterioration or slow progress in energy intensity improvement.

[15] Savings are calculated comparing actual primary energy supply with what it would have been if countries in each region had maintained 1990 energy intensity levels.

FIGURE 3.12B **RATE OF IMPROVEMENT IN ENERGY INTENSITY AT PPP BY REGION AND DECADE**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A; UN ENERGY STATISTICS DATABASE.
NOTE: NAM = NORTH AMERICA; EU = EUROPE; EE = EASTERN EUROPE; CCA = CAUCASUS AND CENTRAL ASIA; WA = WESTERN ASIA; EA = EASTERN ASIA; SEA = SOUTHEASTERN ASIA; SA = SOUTHERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NAF = NORTHERN AFRICA; SSA = SUB-SAHARAN AFRICA; CAGR = COMPOUND ANNUAL GROWTH RATE; EI = ENERGY INTENSITY; PPP = PURCHASING POWER PARITY.

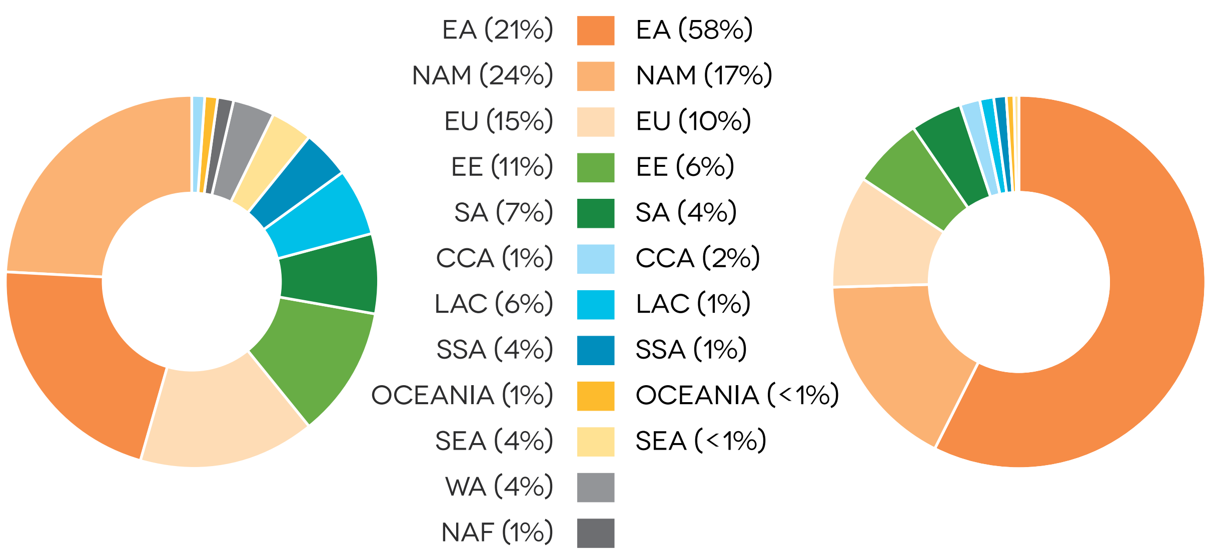


FIGURE 3.13A **PRIMARY ENERGY SUPPLY BY REGION, 1990–2010**

FIGURE 3.13B **ENERGY SAVINGS BY REGION, 1990–2010**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A; UN ENERGY STATISTICS DATABASE.
NOTE: NAM = NORTH AMERICA; EU = EUROPE; EE = EASTERN EUROPE; CCA = CAUCASUS AND CENTRAL ASIA; WA = WESTERN ASIA; EA = EASTERN ASIA; SEA = SOUTHEASTERN ASIA; SA = SOUTHERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NAF = NORTHERN AFRICA; SSA = SUB-SAHARAN AFRICA.

Global trends by income level

Lower-middle-income countries started from the same level of energy intensity as the upper-middle-income countries in 1990 and made the most rapid progress in energy intensity improvement through 2010 (figure 3.14). Even though high-income countries improved their energy intensity at the slowest pace, their absolute level of energy intensity remains the lowest in the world; indeed, even their starting level of energy intensity in 1990 has not yet been matched by countries of other income levels as of 2010. Despite showing solid progress, low-income countries remain by far the most energy-intensive income group. Interestingly, apart from upper-middle-income countries, all income groups—particularly low- and lower-middle-income countries—accelerated their rates of energy intensity improvement in the decade between 2000 and 2010. The deceleration in the global rate of energy intensity improvement in this decade can therefore be attributed to the upper-middle -income countries.

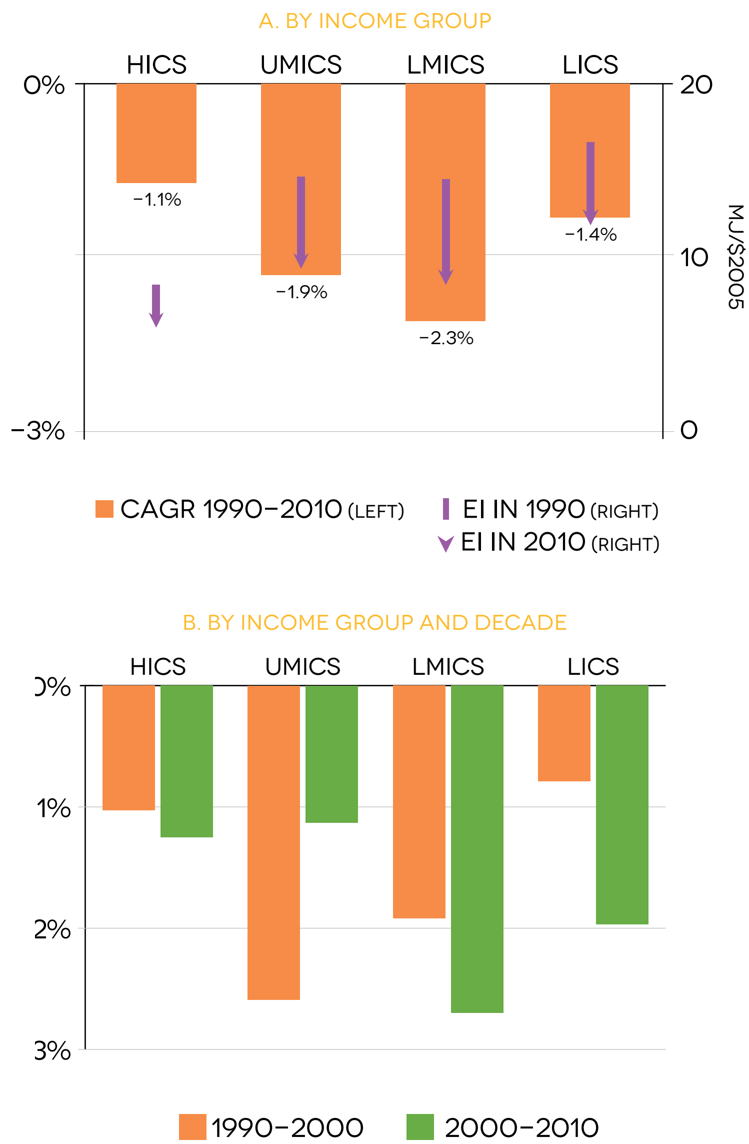
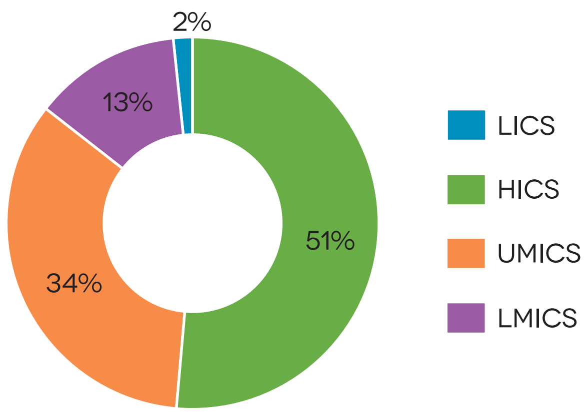


FIGURE 3.14 **RATE OF IMPROVEMENT IN ENERGY INTENSITY AT PPP VS. ENERGY INTENSITY LEVELS IN 1990 AND 2010, BY COUNTRY INCOME GROUP AND DECADE**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A; UN ENERGY STATISTICS DATABASE.
NOTE: CAGR = COMPOUND ANNUAL GROWTH RATE; EI = ENERGY INTENSITY; HICS = HIGH-INCOME COUNTRIES; LICS = LOW-INCOME COUNTRIES; LMICS = LOWER-MIDDLE-INCOME COUNTRIES; PPP = PURCHASING POWER PARITY; UMICS = UPPER-MIDDLE-INCOME COUNTRIES.

Despite the slowdown of energy intensity improvement in 2000s, upper-middle-income countries accounted for more than half of total energy savings over the past 20 years. High-income countries, on the other hand, consumed close to half of global energy but accounted for only one-third of energy savings (figure 3.15). The reason behind this disparity is that the upper-middle-income countries started with an energy intensity twice as high as that of high-income countries, and therefore had more opportunities to introduce energy saving measures.



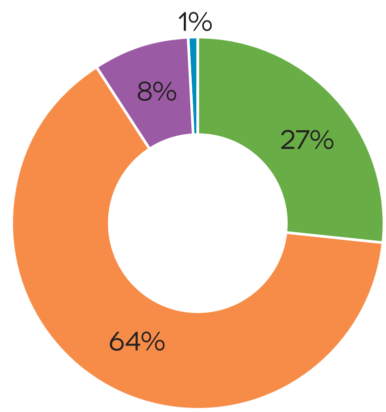


FIGURE 3.15A **PRIMARY ENERGY SUPPLY BY INCOME LEVEL, 1990–2010**

FIGURE 3.15B **ENERGY SAVINGS BY INCOME LEVEL, 1990–2010**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A; UN ENERGY STATISTICS DATABASE.
NOTE: HICS = HIGH–INCOME COUNTRIES; LICS = LOW–INCOME COUNTRIES; LMICS = LOWER–MIDDLE–INCOME COUNTRIES; UMICS = UPPER–MIDDLE–INCOME COUNTRIES.

SECTION 3. COUNTRY PERFORMANCES

Country performances varied greatly within and across regions, ranging from an energy intensity of 1.0 in Macau, China, to almost 60 in Liberia. (All energy intensities in this section are expressed in PPP terms as MJ/$2005.) Overall, 54 out of 181 countries experienced an increase in energy intensity over the past 20 years.

The world can be divided into four country blocks—countries with energy intensities below 5, those between 5 and 7, those between 7 and 10, and those above 10 (figure 3.16). There are 45 countries with energy intensities below 5; most countries in this category are found in Latin America and Caribbean, Europe, Oceania, and Sub-Saharan Africa. In the most energy-intensive category, there are 50 countries, with many of them in Sub-Saharan Africa and Western Asia.

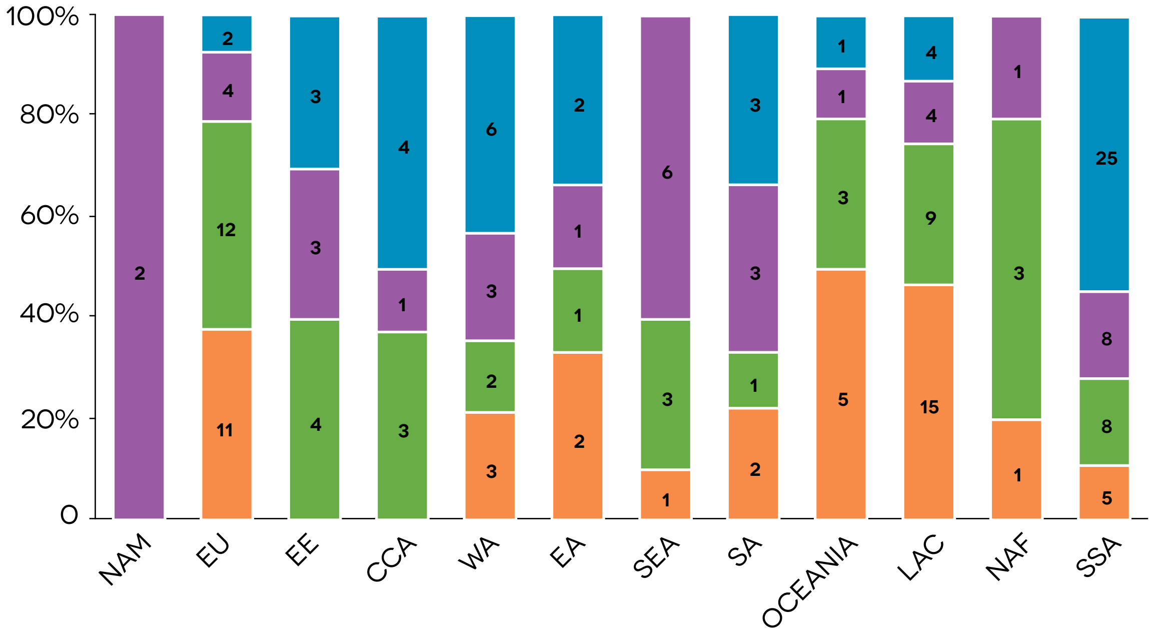


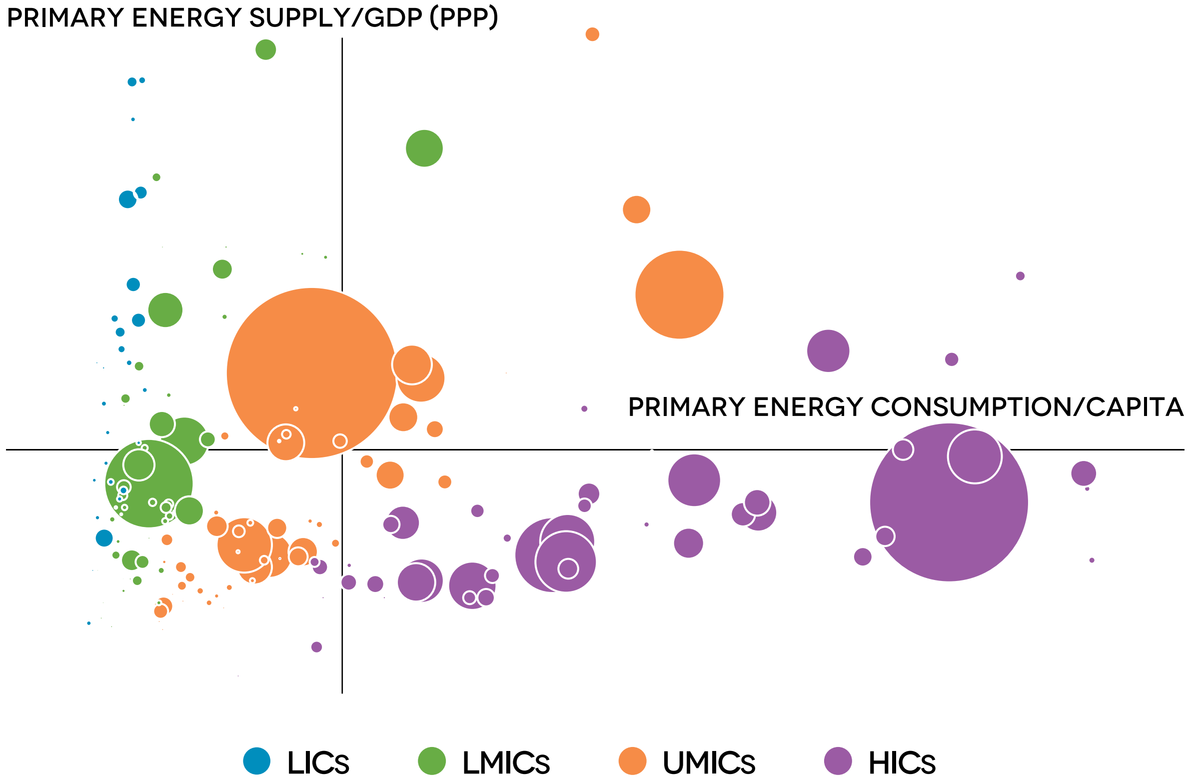
FIGURE 3.16 **ENERGY INTENSITY (MJ/$2005) AT PPP LEVEL BY REGION (NUMBER OF COUNTRIES), 2010**

BELOW 5 BETWEEN 5–7 BETWEEN 7–10 ABOVE 10

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A; UN ENERGY STATISTICS DATABASE.
NOTE: NAM = NORTH AMERICA; EU = EUROPE; EE = EASTERN EUROPE; CCA = CAUCASUS AND CENTRAL ASIA; WA = WESTERN ASIA; EA = EASTERN ASIA; SEA = SOUTHEASTERN ASIA; SA = SOUTHERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NAF = NORTHERN AFRICA; SSA = SUB-SAHARAN AFRICA.

Further insights can be obtained by plotting energy intensity against energy consumption per capita. Low- and lower-middle-income countries show levels of energy consumption per capita that are uniformly below the global average. Yet within these same groups of countries there is great variation in individual energy intensity, from the lowest to the highest energy-intensity ranges observed globally (figure 3.17a). For example, Uzbekistan and Ukraine are two of the most energy-intensive countries in the world, while the Philippines is one of the least (figure 3.17b). High-income countries, on the other hand, show uniformly low levels of energy intensity, but vary hugely in their energy consumption per capita. For example, North America and some of the Gulf states have some of the highest levels of energy consumption per capita, while a number of European countries have some of the lowest. The upper-middle-income countries, by contrast, tend to present either both high energy intensity and consumption per capita, as in the Islamic Republic of Iran and several countries of the former Soviet Union, or both low energy intensity and low consumption per capita, as in Turkey and a number of Latin American countries.

A. BY INCOME GROUP



B. IN LARGEST 40 ENERGY CONSUMERS

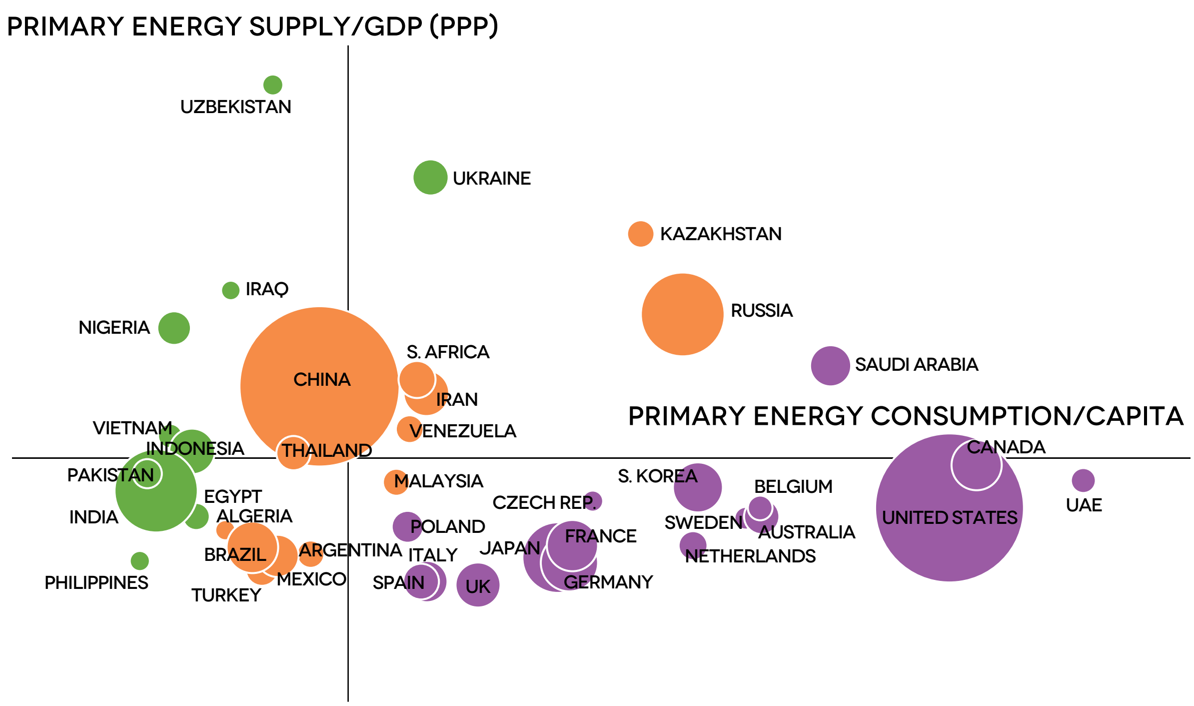


FIGURE 3.17 **ENERGY INTENSITY PPP VS. ENERGY CONSUMPTION PER CAPITA, 2010**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A; UN ENERGY STATISTICS DATABASE.
NOTE: VALUES ARE NORMALIZED ALONG THE AVERAGE. BUBBLE SIZE REPRESENTS VOLUME OF PRIMARY ENERGY SUPPLY.
GDP = GROSS DOMESTIC PRODUCT; HICS = HIGH-INCOME COUNTRIES; LICS = LOW-INCOME COUNTRIES; LMICS = LOWER-MIDDLE-INCOME COUNTRIES; PPP = PURCHASING POWER PARITY; UMICS = UPPER-MIDDLE-INCOME COUNTRIES.

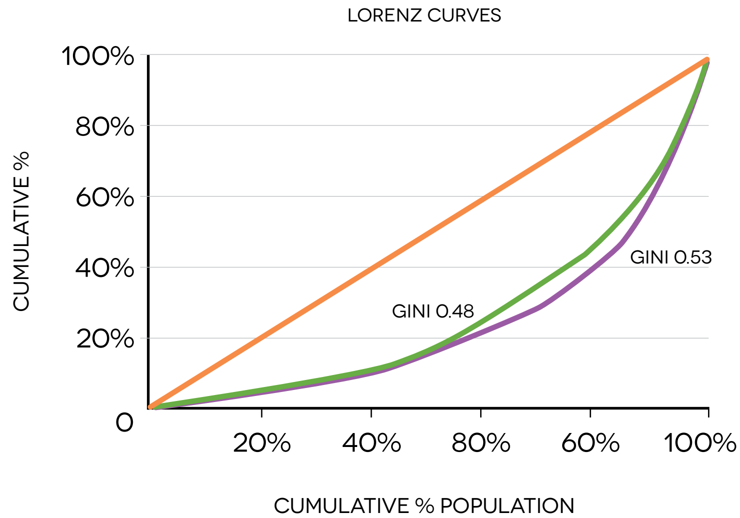


FIGURE 3.18 **DISTRIBUTION OF ENERGY DEMAND AND GDP BY POPULATION**

ENERGY DEMAND GDP

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A; UN ENERGY STATISTICS DATABASE.
NOTE: GDP = GROSS DOMESTIC PRODUCT.

High-impact countries

Global total primary energy supply is heavily concentrated in a relatively small number of high- and middle-income countries. China and the United States alone account for about 40 percent of global primary energy supply. The 20 countries with the highest levels of energy demand together account for 80 percent of the global total, while the top 40 countries account for 90 percent.

One way of capturing the global inequalities in the distribution of energy demand is to calculate a pseudo-Gini coefficient[16] based on the cumulative percentage of global energy demand accounted for by a given cumulative percentage of global population. The resulting Gini coefficient for energy demand is 0.48, which represents a high degree of inequality, just slightly lower than the Gini coefficient of 0.53 for inequality in the global distribution of GDP (figure 3.18).

While improvements in energy efficiency are valuable and important for all countries, achievement of the SE4ALL global objective for energy efficiency will depend on targeting efforts in high-impact countries. The level of a country's impact depends in part on its overall energy demand. Higher energy demand translates into a greater potential impact of a country's efforts on the achievement of the global objective. Many high-consuming countries have already achieved relatively low levels of energy intensity. In identifying high-impact opportunities, it is therefore also relevant to consider a country's starting point in terms of energy intensity. Countries with relatively high energy intensity may have a greater potential for improvement, but as seen previously, the underlying drivers of energy demand must also be considered. For example, a country with a large mining industry or very cold climate may have high energy intensity, but nonetheless be very energy efficient.

In reality, there is very little overlap between those countries with the highest energy demand and the highest energy intensity. The group of 20 countries with the highest energy demand is dominated by high-income countries across Europe, Asia, the Middle East, and North America. India, Indonesia, and Ukraine are the only lower-middle-income countries among the 20 largest energy consumers (figure 3.19a). The group of 20 countries with the highest energy intensity, on the other hand, is dominated by low-income countries from Africa and the former Soviet Union, plus a few smaller countries from Latin America and South Asia and Iceland, which is the only European country in the group (figure 3.19b). Ukraine is the only country that is both one of the largest energy consumers and one of the most energy-intensive economies.

[16] The Gini coefficient is a concept most commonly used in economics to measure inequality of income distribution within a population; a value of zero represents perfect equality, and a value of one represents maximum inequality.

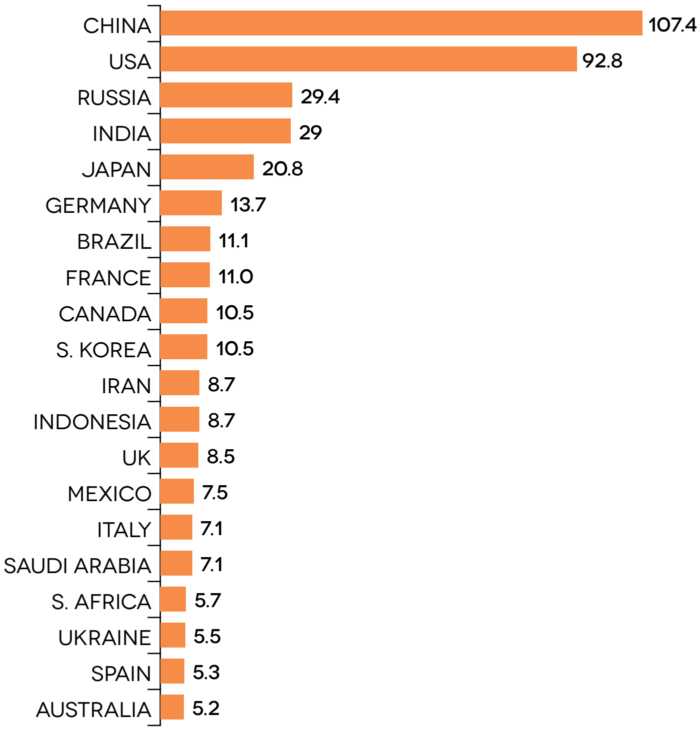


FIGURE 3.19A **COUNTRIES WITH HIGHEST LEVELS OF PRIMARY ENERGY DEMAND, 2010 (EJ)**

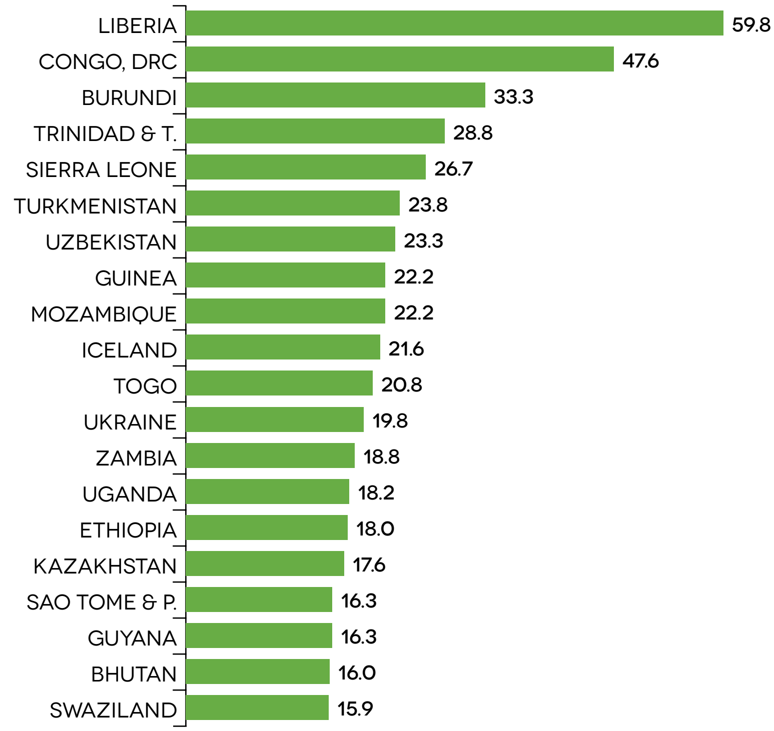


FIGURE 3.19B **COUNTRIES WITH HIGHEST LEVELS OF ENERGY INTENSITY PPP, 2010 (MJ/$2005)**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A; UN ENERGY STATISTICS DATABASE.

A combination of relatively high energy demand and relatively high energy intensity defines where the highest-impact opportunities exist. Table 3.3 lists the countries among the 20 largest energy consumers with the highest energy intensities overall and within each economic sector. When the analysis is done in PPP terms, the highest-impact opportunities can be found in Ukraine, Russia, Saudi Arabia, South Africa, and China. Canada, Iran, Brazil, Indonesia, and the United States also appear when analyzing economic sectors.

X 10 TIMES
– SPAN OF ENERGY INTENSITY AMONG
THE WORLD'S 20 MOST ENERGY INTENSIVE ECONOMIES AT 20–30 MEGAJOULES PER DOLLAR OF GDP AND THE WORLD' LEAST ENERGY INTENSIVE ECONOMIES AT 2–3 MEGAJOULES PER DOLLAR OF GDP

ALL SECTORS		INDUSTRY	AGRICULTURE	OTHER SECTORS
1	Ukraine	Ukraine	Canada	Iran
2	Russia	Russia	South Africa	Ukraine
3	Saudi Arabia	Canada	Russia	Saudi Arabia
4	South Africa	Brazil	United States	Indonesia
5	China	South Africa	Brazil	Russia

TABLE 3.3 **HIGHEST ENERGY INTENSITIES AMONG THE 20 LARGEST ENERGY CONSUMERS, 2010**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A..
NOTE: "OTHER SECTORS" INCLUDE THE TRANSPORTATION, RESIDENTIAL, AND SERVICE SECTORS.

Fast-moving countries

To reap the substantial potential for reducing energy demand, it will be important for countries around the world to learn from one another's experiences and best practices. In that sense, two groups of countries are of particular interest: those who have already achieved low levels of energy intensity and those who have made the most rapid progress in improving their energy intensity over the last decades.

Most of the 20 countries that experienced the most rapid improvement in energy intensity over the 20 years between 1990 and 2010 are from the former Soviet Union and Eastern European, with annual rates of reduction ranging from 4 percent to 12 percent—several times higher than the global average of –1.3 percent (figure 3.20a). Many of these countries started from relatively high levels of energy intensity in 1990 and still remain at above global average levels of energy intensity in 2010. While they therefore cannot be regarded as models for best practice, their experience can help to shed light on where and how to begin the process of accelerating energy efficiency improvements.

–4.0%
IS THE COMPOUND ANNUAL GROWTH
RATE OF ENERGY INTENSITY AMONG THOSE 20 COUNTRIES MAKING THE FASTEST PROGRESS GLOBALLY 1990–2010

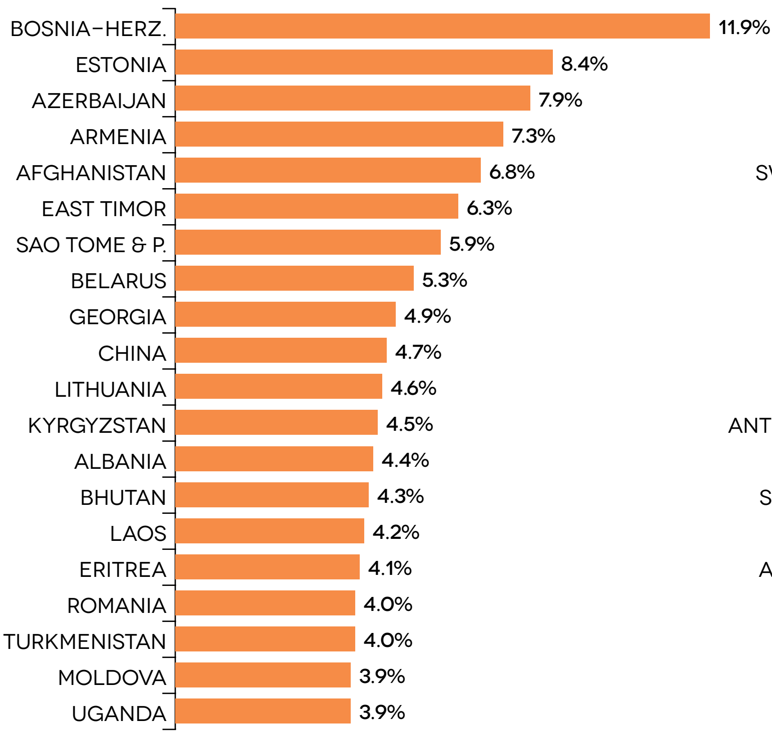


FIGURE 3.20A **FASTEST-MOVING COUNTRIES CAGR 1990–2010 IN PPP TERMS**

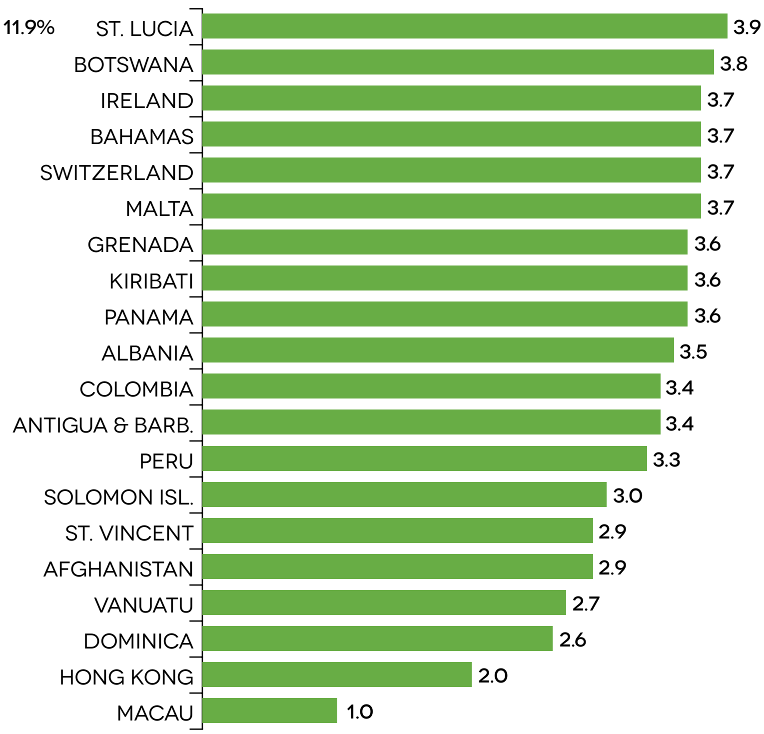


FIGURE 3.20B **FASTEST-MOVING COUNTRIES WITH LOWEST ENERGY INTENSITY IN 2010 IN PPP TERMS (MJ/$2005)**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A; UN ENERGY STATISTICS DATABASE.

The 20 countries exhibiting the lowest energy intensity (less than 3.9 MJ/$2005 GDP PPP) are a heterogeneous group, with a strong presence of small island countries in which energy costs tend to be exceptionally high (figure 3.20b). Confining attention to the least-energy-intensive countries in PPP terms among the 20 largest energy consumers, a handful of Western European countries—the United Kingdom, Spain, Italy, and Germany—and Japan show a strong performance with low energy intensity, both overall and across a number of sectors (table 3.4). Curiously, countries such as China, Indonesia, and Saudi Arabia—which are among the most energy intensive of the large energy consumers—exhibit relatively low energy intensity for agriculture.

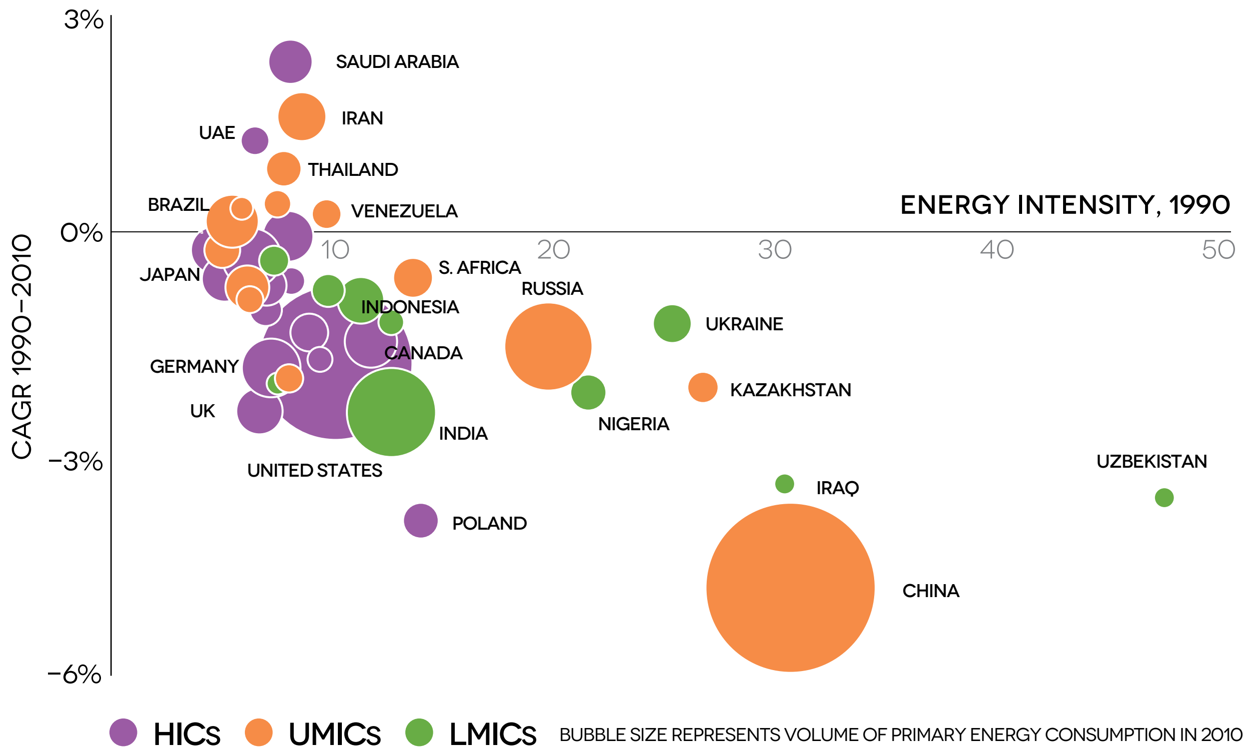
	ALL SECTORS	INDUSTRY	AGRICULTURE	OTHER SECTORS
1	United Kingdom	Japan	Saudi Arabia	Japan
2	Spain	Germany	Indonesia	United Kingdom
3	Italy	United Kingdom	India	Spain
4	Germany	Spain	Germany	Italy
5	Japan	Italy	China	Germany

TABLE 3.4 **LOWEST ENERGY INTENSITIES AMONG THE 20 LARGEST ENERGY CONSUMERS, 2010**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A.
NOTE: "OTHER SECTORS" INCLUDE THE TRANSPORTATION, RESIDENTIAL, AND SERVICE SECTORS.

Perhaps of greater interest is the interaction between a country's starting point in energy intensity and its rate of reduction of energy intensity over the two decades between 1990 and 2010. In principle, those starting out with the highest levels of energy intensity had the greatest opportunities to reduce it. The cross-plots below attempt to depict that. The first chart plots the CAGR of energy intensity during 1990–2010 against initial energy intensity in 1990; the second, against final energy intensity in 2010 (figure 3.21). The negative relationship between the starting point and the annual rate of change is clearly evident in the chart. The country that most clearly stands out is China, which started with one of the highest levels of energy intensity among the largest 40 energy users; despite the huge expansion in its industrial sector that took place over the same period, it also experienced the steepest decline in energy intensity in the last 20 years. Indeed, by 2010, China had reached a level of energy intensity comparable to that of other large, middle-income, emerging economies.

A. ENERGY INTENSITY, 1990 (MJ/$2005 PPP)



B. ENERGY INTENSITY, 2010 (MJ/$2005 PPP)

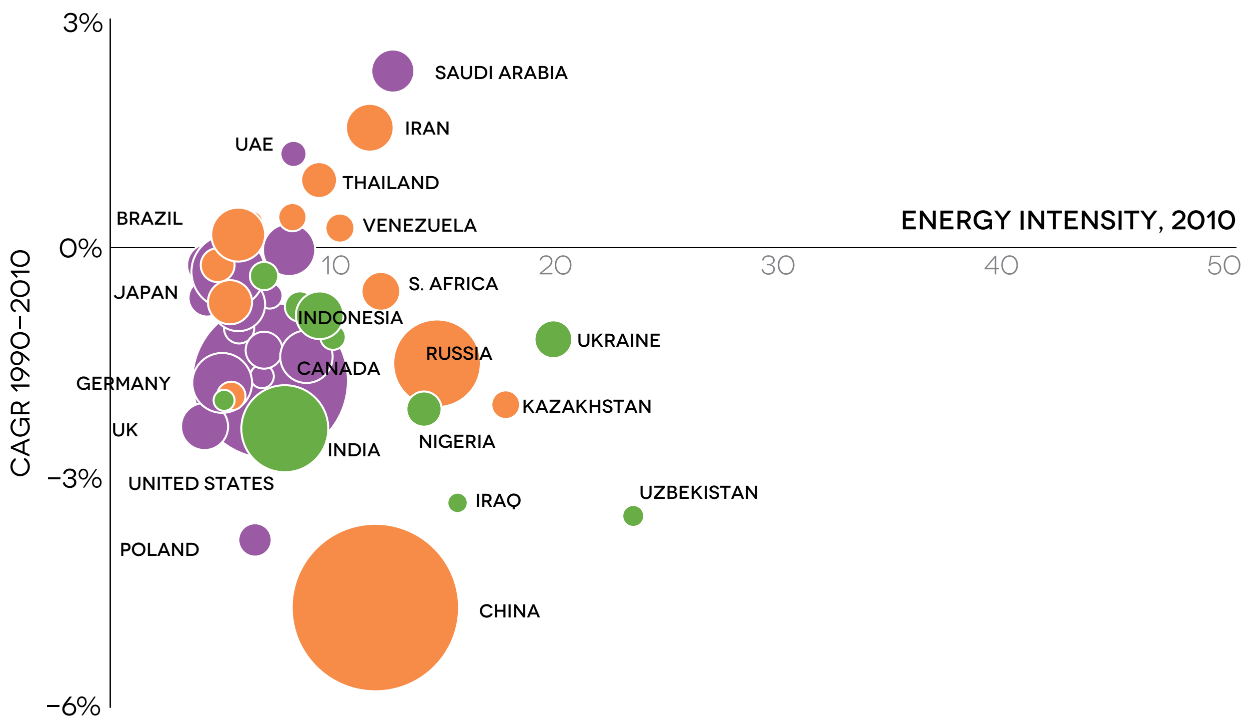


FIGURE 3.21 **ENERGY INTENSITY IN 1990 AND 2010 VS. CAGR 1990–2010**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A.
NOTE: BUBBLE SIZE REPRESENTS THE VOLUME OF PRIMARY ENERGY SUPPLY IN 2010. CAGR = COMPOUND ANNUAL GROWTH RATE; HICS = HIGH-INCOME COUNTRIES; LMICS = LOWER-MIDDLE-INCOME COUNTRIES; UMICS = UPPER-MIDDLE-INCOME COUNTRIES.

The decomposition of energy trends that was undertaken globally above (recall figure 3.7) is also of interest at the country level. Figure 3.22 clearly shows that among the top 20 energy consumers, the underlying energy efficiency effect for China and India after adjusting for activity levels and structural shifts is particularly large at 6 percent and 4 percent respectively, and significantly higher than the trend in overall energy intensity. Such efforts partially offset increases in energy demand due to expanded activity levels and structural changes. By contrast, the reduction in Ukraine´s energy intensity is attributable to reductions in all three factors (mainly activity, and to a lesser degree structure and pure intensity).

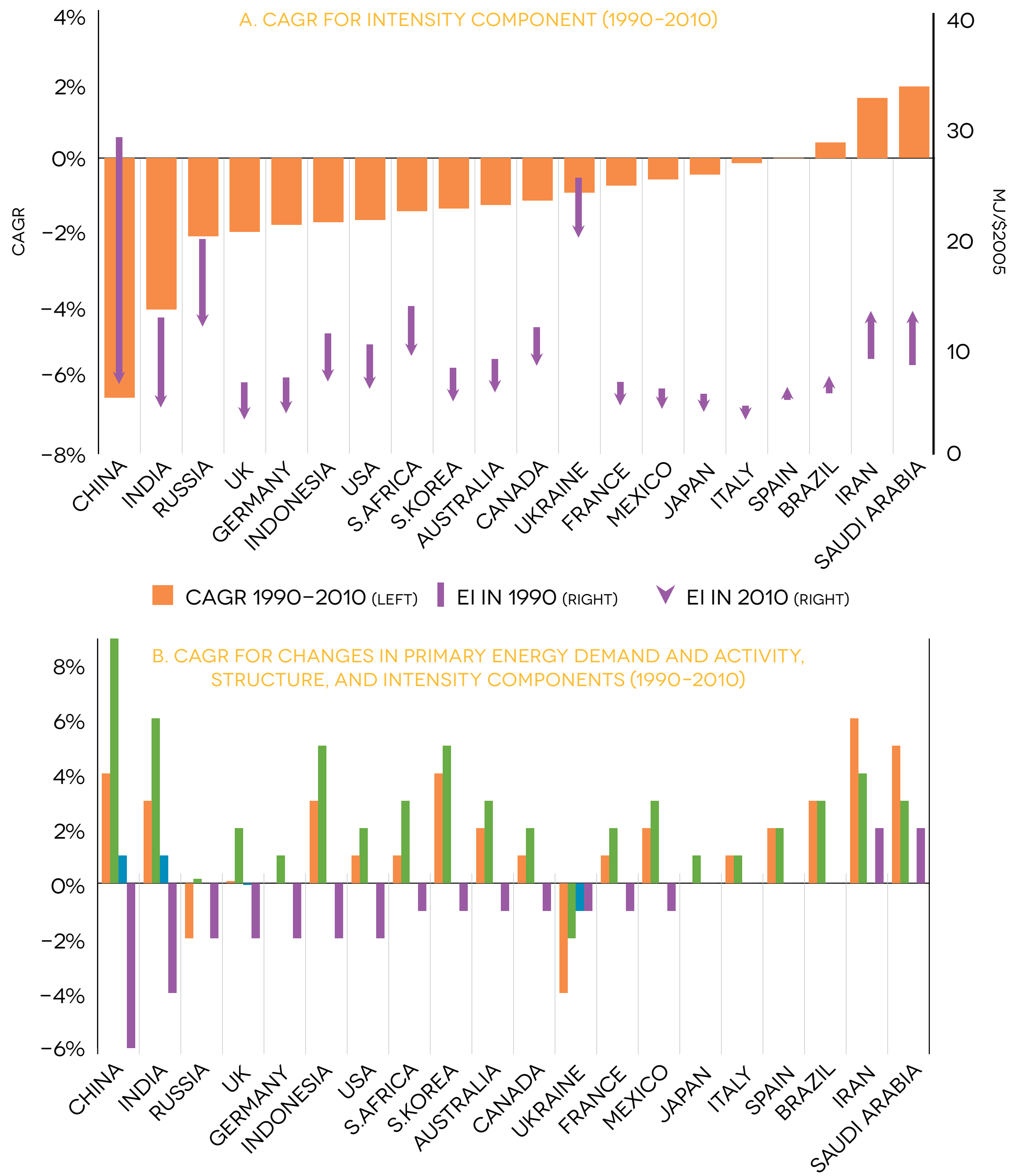


FIGURE 3.22 **DECOMPOSITION ANALYSIS OF ENERGY DEMAND IN 1990 AND 2010 VS CAGR 1990–2010**

TOTAL ENERGY · ACTIVITY · STRUCTURE · INTENSITY

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A.
NOTE: CAGR = COMPOUND ANNUAL GROWTH RATE; PPP = PURCHASING POWER PARITY.

Yet another way of identifying countries that made particularly significant progress in reducing energy consumption is to look at the extra energy these countries would be demanding today if their energy intensity had remained at 1990 levels (figure 3.23). Once again, China stands out as having achieved by far the largest reductions in energy consumption, with cumulative energy savings from 1990 to 2010 exceeding cumulative energy consumption during that same period. Overall, actions taken in China, the United States, Europe, and India accounted for more than 90 percent of the nearly 2,300 EJ of energy saved globally between 1990 and 2010.

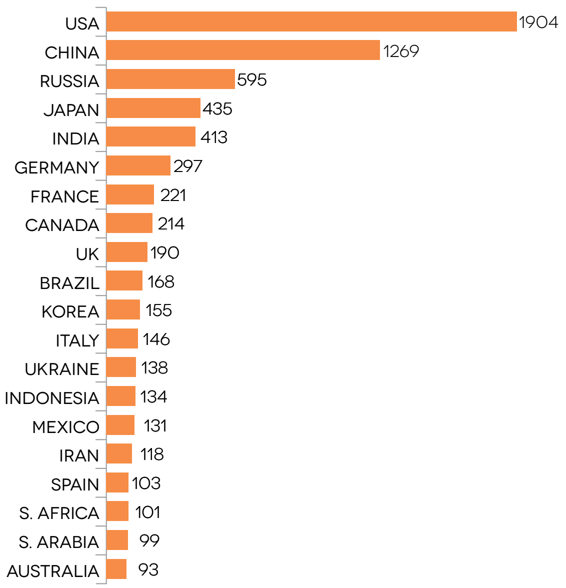


FIGURE 3.23A **LARGEST ENERGY CONSUMERS, CUMULATIVE 1990–2010 (EJ)**

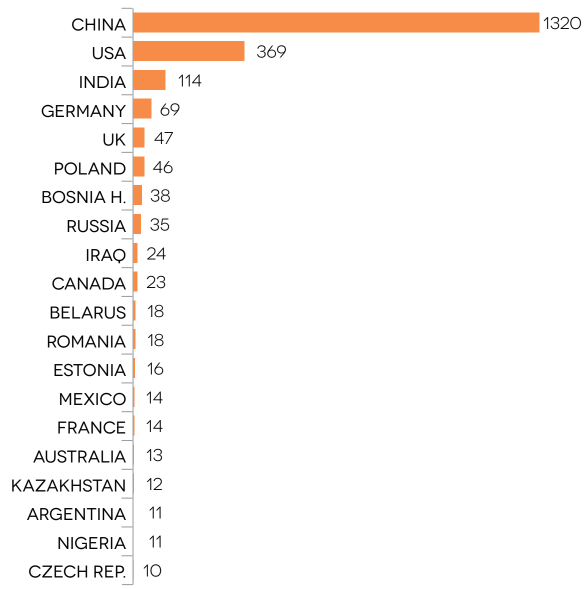


FIGURE 3.23B **LARGEST ENERGY SAVERS, CUMULATIVE 1990–2010 (EJ)**

SOURCE: BASED ON WORLD BANK WORLD DEVELOPMENT INDICATORS; IEA 2012A; UN ENERGY STATISTICS DATABASE.

Policies, targets, technological developments, and investments

There are many underlying factors that explain the trends and figures outlined in the previous section. The framework laid out here proposes to track them through a revision of the policies that affect energy demand, the targets that countries and regions (like the EU) give themselves, the technological developments that reduce specific energy consumption, and the flow of energy efficiency investments.

Though the global and country-level intensity indicators presented may serve to track progress toward the SE4ALL goal, the complementary indicators described above give a more complete picture to policy makers of what actions are being taken—and should be taken—to improve energy efficiency in each country. They also provide a guide of where to direct actions to address needs and reveal opportunities in a given country.

1,320 EJ
IS THE CUMULATIVE ENERGY SAVINGS
OF CHINA DUE TO REDUCTIONS IN ENERGY INTENSITY FROM 1990 TO 2010; EXCEEDING CHINA'S OWN PRIMARY ENERGY DEMAND OVER THE SAME PERIOD.

Policies include a range of instruments—including market-based and financial instruments, regulations, information, and awareness—that can be voluntary or mandatory. Of particular relevance in 1990–2010 have been building codes, labeling, and minimum energy performance standards (MEPS) for appliances and motors, and fuel-efficiency standards and fiscal incentives for vehicles. Countries such as Italy and India have implemented market-based cap and trade mechanisms like the white certificates and the Perform, Achieve, and Trade (PAT) scheme. Box 3.5 summarizes the 25 energy efficiency policies that the IEA is recommending governments to adopt. The same organization is also starting the process of developing a set of governance and policy recommendations for developing countries.

Targets can take several forms. China aims to decrease its energy intensity by 16 percent during the period 2011–15 (its 12th Five-Year Plan). The EU, through its Energy Efficiency Directive, mandates a reduction in primary energy consumption of 20 percent by the year 2020, while Japan and Brazil want to reduce electricity demand by 10 percent by 2030. Recently, the United States announced that it aims to cut in half the energy wasted in homes and businesses in the next 20 years. Meanwhile, India, in its draft 12th Five Year Plan, is proposing to reduce the carbon emissions intensity of its economy by 20–25 percent from 2005 levels by 2020.

Section 4 and annex 2 provide an overview of policies and targets for selected countries,[17] while annex 3 shows the specific energy consumption of selected energy-intensive products, both for current practice and a benchmark of the best available practice.

As noted in section 1, there is no established methodology to track investments in energy efficiency. One will have to be developed for the medium term. This report relies on the work done by IEA'S WEO 2012. The results are presented in the following section.

BOX 3.5 IEA's 25 energy efficiency policy recommendations

To support governments in their implementation of energy efficiency, the International Energy Agency (IEA) recommended the adoption of specific energy efficiency policy measures to the G8 summits in 2006, 2007, and 2008. The consolidated set of recommendations to these summits covers 25 fields of action across seven priority areas: cross-sectoral activity, buildings, appliances, lighting, transport, industry, and power utilities. The fields of action are outlined below.

1. The IEA recommends action on energy efficiency across sectors. In particular, the IEA calls for action on:

- Data collection and indicators
- Strategies and action plans
- Competitive energy markets, with appropriate regulation
- Private investment in energy efficiency
- Monitoring, enforcement, and evaluation

2. Buildings account for about 40 percent of energy used in most countries. To save a significant portion of this energy, the IEA recommends action on:

- Mandatory building codes and minimum energy performance requirements
- Net-zero energy consumption in buildings
- Improved energy efficiency in existing buildings
- Building energy labels or certificates
- Energy performance of building components and systems

[17] Further details are provided in IEA 2012b.

3. Appliances and equipment represent one of the fastest-growing energy loads in most countries. The IEA recommends action on:

- Mandatory minimum energy performance standards and labels
- Test standards and measurement protocols
- Market transformation policies

4. Saving energy by adopting efficient lighting technology is very cost-effective. The IEA recommends action on:

- Phaseout of inefficient lighting products
- Energy-efficient lighting systems

5. To achieve significant savings in the transport sector, the IEA recommends action on:

- Mandatory vehicle fuel-efficiency standards
- Measures to improve vehicle fuel efficiency
- Fuel-efficiency for nonengine components
- Transport system efficiency

6. To improve energy efficiency in industry, action is needed on:

- Energy management
- High-efficiency industrial equipment and systems
- Energy efficiency services for small- and medium-sized enterprises
- Complementary policies to support industrial energy efficiency

7. Energy utilities can play an important role in promoting energy efficiency. Action is needed to promote:

- Utility end-use energy efficiency schemes

SECTION 4. THE SCALE OF THE ENERGY EFFICIENCY CHALLENGE

Doubling the rate of improvement in energy intensity from –1.3 percent to –2.6 percent per annum in the 20 years between 2010 and 2030 will present an immense challenge. Examining the scale of that challenge is the subject of this section. The analysis is based on the scenarios developed by WEO (2012).[18]

The New Policies Scenario is WEO's central scenario. It takes into account broad policy commitments and plans that have already been implemented to address energy- and climate-related challenges, as well as those that have been announced, even where the specific measures to implement these commitments have yet to be introduced. To illustrate the outcome of the current course in energy trends, if unchanged, the Current Policies Scenario embodies the effects of only those government policies and measures that had been enacted or adopted by mid-2012. The Efficient World Scenario is based on the core assumption that all investments capable of improving energy efficiency are made so long as they are economically viable and any market barriers obstructing their realization are removed.

The outlook for efficiency improvements by sector and region

According to the WEO 2012, the SE4ALL objective for energy efficiency can be met only if countries implement policies beyond those in the New Policies Scenario. That conclusion is highly dependent on the chosen reference period. For example, doubling the performance of the last decade, when the pace of improvement in energy intensity was slow, would be only a moderately ambitious goal. In the New Policies Scenario, energy demand is projected to grow from 530 EJ in 2010 to 670 EJ in 2030, equivalent to an increase of nearly 30 percent. That is about 45 EJ, or 6 percent, lower than if only the world's current energy efficiency policies continued, as assumed in the Current Policies Scenario (figure 3.24).

Energy efficiency in end uses and in the supply sectors accounts for almost three-quarters of the total potential for improving energy efficiency by 2030. The New Policies Scenario projects global energy intensity (where GDP is measured at PPP) to decline at a rate of 2.3 percent per year on average over the period 2010–2030, a significant improvement on the trend seen in 1990–2010, when it was –1.3 percent per year.

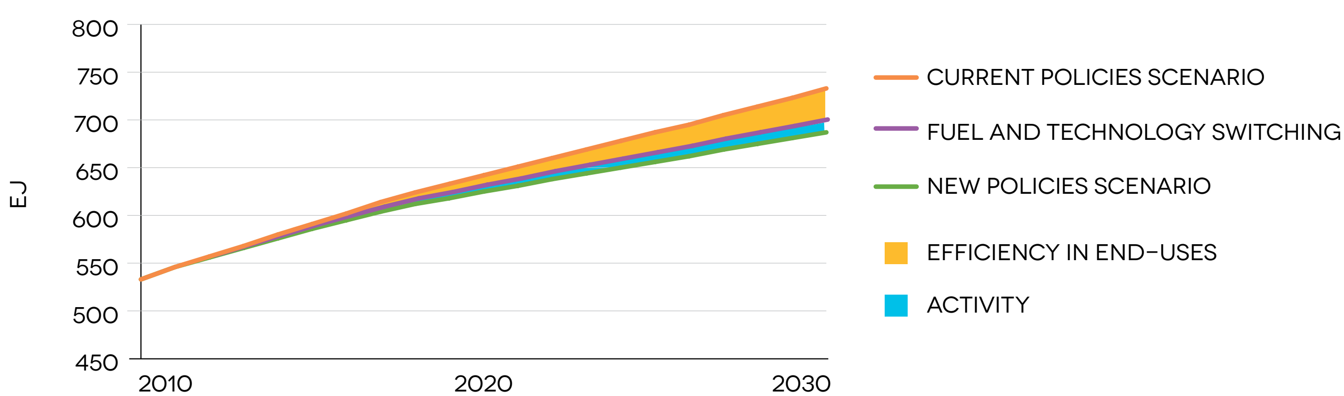


FIGURE 3.24 **CHANGE IN GLOBAL PRIMARY ENERGY DEMAND: CURRENT POLICIES SCENARIO AND NEW POLICIES SCENARIO (EJ)**

SOURCE: IEA 2012B.
NOTE: "ACTIVITY" REFLECTS A CHANGE IN THE DEMAND FOR ENERGY SERVICES DUE TO A CHANGE IN END-USER PRICES.

[18] Figures are also compared to those developed by the International Institute for Applied Systems Analysis (IIASA).

When looking at the economically viable potential of energy efficiency, it becomes apparent that current and planned policies globally would utilize only a third of the economically viable efficiency measures. From a sectoral perspective, industry utilizes most of the potential (44 percent), followed by transport (37 percent), power generation (21 percent), and buildings (18 percent). The uptake of more efficient technologies is strong in industries in OECD countries and China because of the introduction of MEPS and CO_2 pricing, and because rising energy prices strengthen the economic case for improving energy efficiency.

The second-most-important sector in terms of efficiency-related energy savings is transport, where several countries are discussing the introduction of ambitious fuel-economy standards, often with the goal of reducing oil imports or air pollution. Energy savings in the buildings sector are relatively small because of high transaction costs. Most of the savings occur in commercial buildings, where the business case is often stronger and regulation is easier to apply than in residential construction. Some demand reduction also occurs in the residential sector, however, thanks to the assumed reduction in fossil-fuel subsidies in some countries, including India, Russia, and parts of the Caspian region. Depending on the region, some of the key measures applied in the buildings sector include mandatory energy requirements in building codes and energy efficiency labels for appliances.

An increasing number of countries and regions are focusing on energy efficiency and strengthening their respective policies in this area. Annex 2 tabulates current policies in selected countries.

Energy efficiency policies in developing Asia, North America, Europe, and Asia Oceania account for more than three-quarters of the reduction in global primary energy demand under the New Policies Scenario, compared with the Current Policies Scenario. This reflects the sheer size of the energy markets of these regions and their emphasis on energy efficiency. In Europe the EU has established a comprehensive energy efficiency policy framework with targets for 2020, notably a 20 percent reduction in energy demand in 2020 against their reference projection. The energy efficiency directive enlists energy providers in helping consumers—industry and households—to increase their investment in energy efficiency.

In developing Asia China has set a goal of reducing energy intensity by 16 percent between 2011 and 2015. An ongoing restructuring of the national economy is expected to bring about significant savings in energy consumption per unit of GDP. Other key elements of China's strategy include innovation and energy savings in 10,000 energy-intensive enterprises identified by the government, which collectively make up 37 percent of the targeted savings by 2015. The centerpiece of India's efforts to save energy is its innovative PAT scheme, which aims at saving energy in large energy-intensive industries by imposing mandatory energy intensity targets. In addition, it allows trading of excess energy savings with other participants in the form of so-called white certificates for compliance.

In North America, the United States is currently revising its MEPS for appliances and equipment, a policy initially introduced in 1978. Twenty-four states have adopted long-term energy savings targets, which drive utility investments in energy efficiency. Another focus is road transport, with the introduction of a 2025 fuel economy target for passenger cars that would exploit much of the known (but so far unused) technical potential of conventional vehicles.

33%
IS THE SHARE OF ALL ECONOMICALLY
VIABLE ENERGY EFFICIENCY OPPORTUNITIES THAT WILL BE HARNESSED BY CURRENT OR PLANNED POLICIES GLOBALLY

In Asia Oceania Japan's Innovative Strategy for Energy and the Environment, released in 2012, includes a major focus on energy efficiency, with a target to reduce electricity demand by 10 percent in 2030 compared with 2010. This is expected to be backed up by measures to incentivize the introduction of more efficient technologies in the residential sector and, to a lesser extent, in industry.

Because energy resources have been plentiful and prices low, improving energy efficiency has historically not been a key priority throughout much of the Middle East, though in recent years this has begun to change, as fast-increasing domestic demand is restraining oil and gas exports that bring much-needed revenue. Saudi Arabia established an energy efficiency center in 2012, and the United Arab Emirates has launched a national energy efficiency and conservation program to improve efficiency in buildings. With the exception of a few countries, subsidized prices have significantly hampered the uptake of efficient technologies in the power sector, road transport, and buildings. In much of Africa, with the exception of South Africa and a few countries in North Africa, the focus has been on providing access to basic energy services and increasing the availability of energy to boost economic growth rather than on energy efficiency. Improving energy access is fundamental for economic development, but integrating energy efficiency strategies into such programs, ideally from the outset, would make it possible to widen access faster and more economically.

The above-mentioned policy efforts are expected to reduce primary energy demand in 2030 by almost 45 EJ. The biggest contributions come from developing Asia (25 EJ), North America (6 EJ), Europe (4 EJ), Eastern Europe/Eurasia (3 EJ), and the Middle East (2.5 EJ) (figure 3.25).

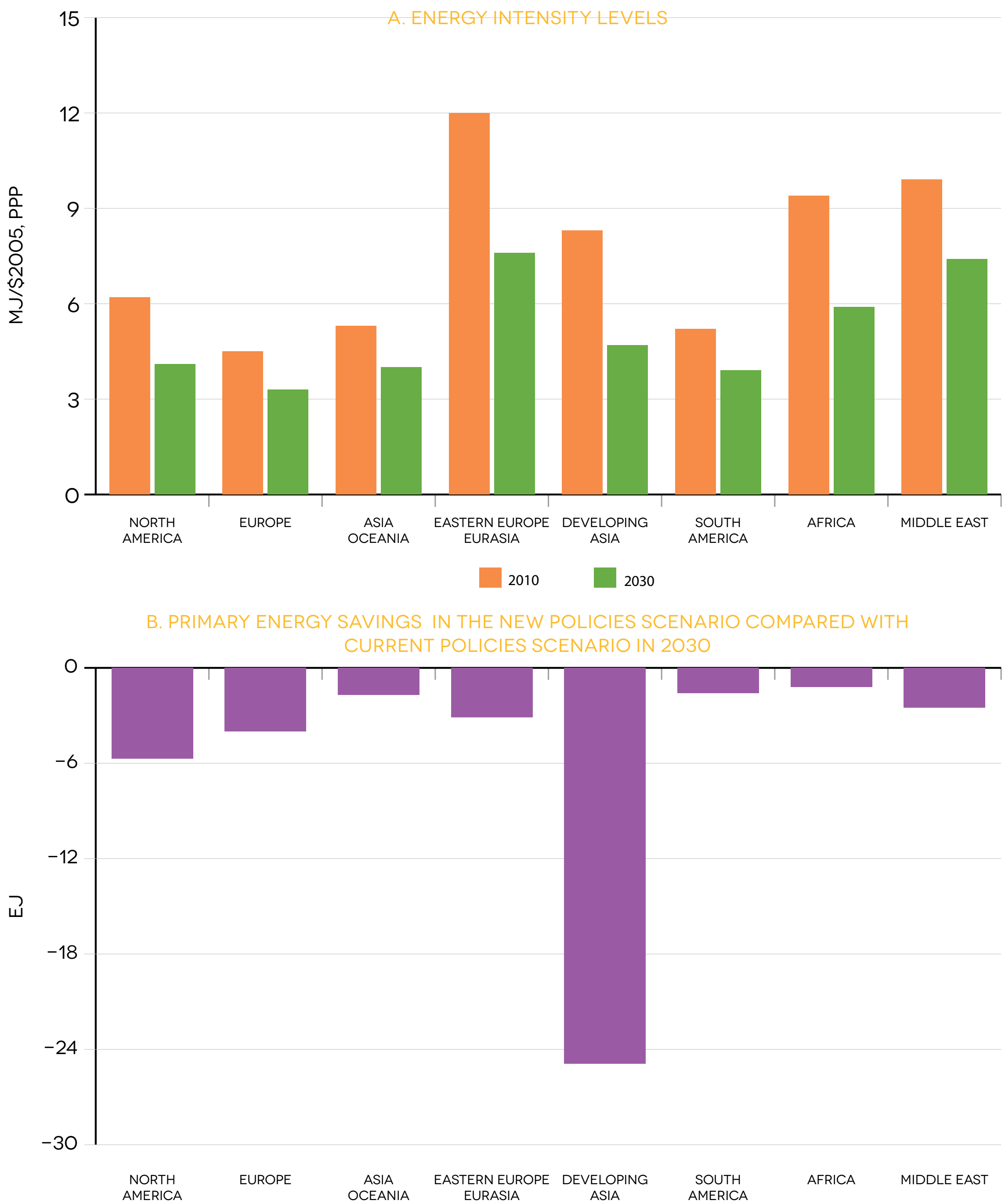


FIGURE 3.25 **RESULTS OF THE NEW POLICIES SCENARIO**

SOURCE: BASED ON DATA/ANALYSIS TAKEN FROM IEA (2012B).

Energy efficiency investments needed to achieve the New Policies Scenario

The current status of energy efficiency investments is difficult to quantify, as investments in energy efficiency are seldom tracked systematically and there is no comprehensive estimate of current global investment in energy efficiency. The lack of an estimate is due to the fact that energy efficiency investments are made by a multitude of agents, households, and firms, often using their own funds. Moreover, there is no standard definition of what constitutes an energy efficiency investment, and while investments in energy efficiency in buildings and industry are tracked in many countries, data for the transport and power sectors are more difficult to obtain. Based on a country-by-country survey, however, it is estimated that current global investment in projects aimed principally at improving energy efficiency amounted to about $180 billion in 2011—significantly lower than the investment in expanding or maintaining the fossil-fuel supply (nearly $600 billion in the same year). About two-thirds of the estimated investment in energy efficiency in 2011 was undertaken in OECD countries.

To achieve the savings from energy efficiency laid out in the New Policies Scenario, cumulative additional investments of $2.3 trillion are needed through 2030 (or $128 billion per year, on average, above current levels of investment in transport, residential, industry, and services) (figure 3.26).[19] Investment in transport increases by $0.9 trillion (almost 40 percent of the total additional investment for all sectors worldwide), largely to improve fuel economy. Residential and service-sector buildings account for another $1.1 trillion from 2012 to 2030, in the form of investments in retrofits, insulation, and thermal efficiency, as well as for electrical equipment (appliances and lighting). Additional investment in industry amounts to $340 billion between 2012 and 2030, about two-thirds of which is to improve the efficiency of heat systems, where much unrealized potential exists. The remainder of the investment is in electrical equipment, mostly industrial motors.

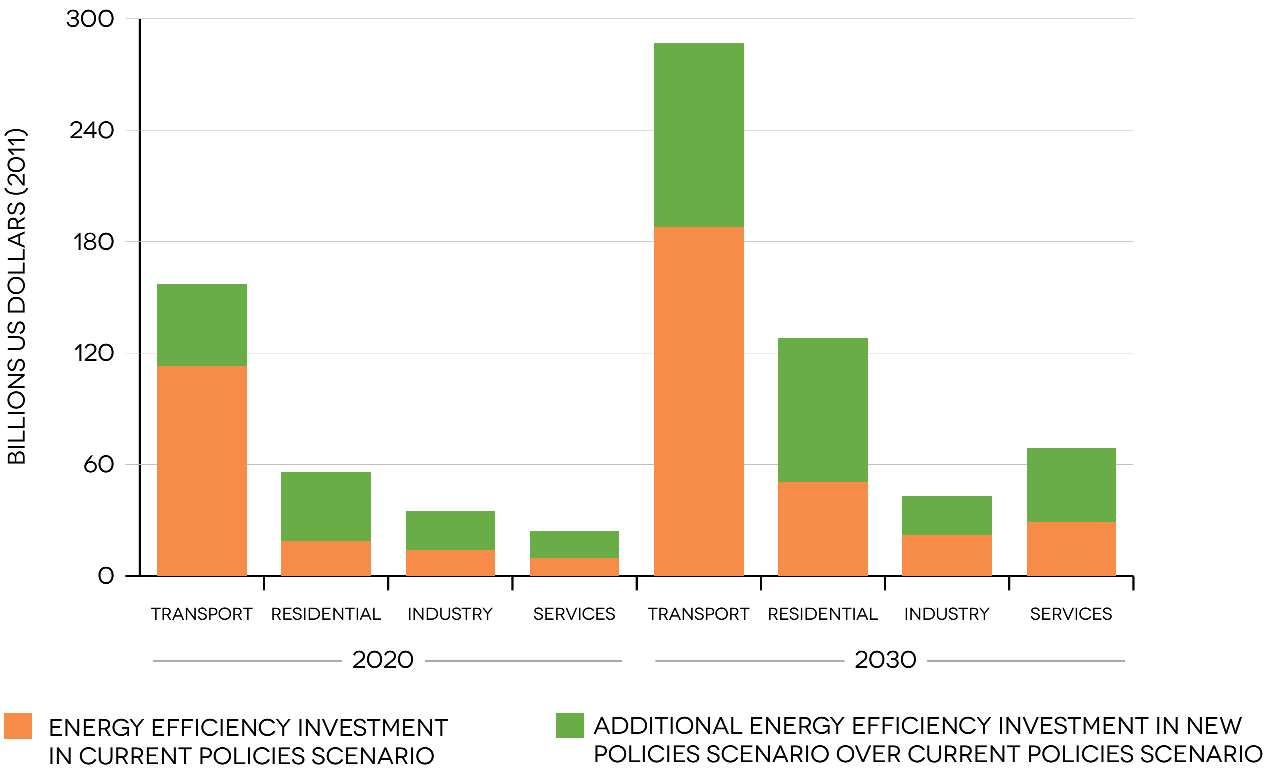


FIGURE 3.26 **AVERAGE ANNUAL INCREASE IN ENERGY EFFICIENCY INVESTMENT: NEW POLICIES SCENARIO VERSUS CURRENT POLICIES SCENARIO**

SOURCE: BASED ON DATA/ANALYSIS TAKEN FROM IEA (2012B).

The IEA Efficient World Scenario

The New Policies Scenario does not fully exploit the potential for cost-effective energy efficiency improvements or achieve the SE4ALL energy efficiency objective. Under the Efficient World Scenario, however, it is possible to improve energy intensity by 2.8 percent per year, on average, through 2030, compared with the annual rate of –1.3 percent achieved from 1990 to 2010. The central assumption of the Efficient World Scenario is that policies are put in place to allow the market to realize the full potential of all economically viable energy efficiency measures. Projections for energy savings under the Efficient World Scenario, compared with the Current Policies Scenario and New Policies Scenario, are presented in figure 3.27.

In the Efficient World Scenario, oil demand peaks at 91 million barrels per day (mb/d) before 2020 and then declines to 88.7 mb/d in 2030. Global coal demand also peaks before 2020, at around 5,400 million tons of coal equivalent (Mtce), before dropping to about 4,800 Mtce in 2030—19 percent lower than under the New Policies Scenario. Unlike for the other fossil fuels, global demand for natural gas still increases under the Efficient World Scenario, as it remains an important fuel in the power, industry, and buildings sectors. Total demand reaches 3,700 billion cubic metres (bcm) in 2020 and almost 4,100 bcm in 2030.

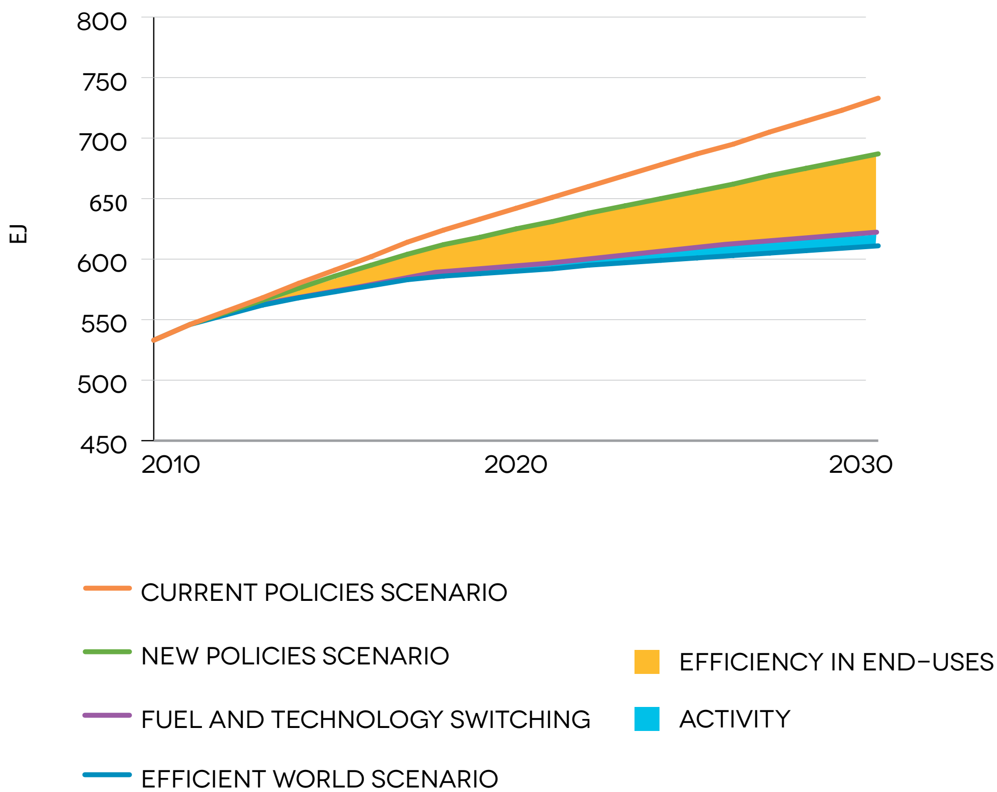


FIGURE 3.27 **CHANGE IN GLOBAL PRIMARY ENERGY DEMAND: EFFICIENT WORLD SCENARIO VERSUS OTHER SCENARIOS (EJ)**

SOURCE: IEA (2012B)

Two steps were taken to calculate the economic potential of the Efficient World Scenario, which varies by sector and region.

First, technical potentials were determined, identifying key technologies and measures to improve energy efficiency by sector. This process involved analysis of a substantial amount of data and information from varied sources pertaining to a variety of subsectors and technologies. The Efficient World Scenario assumes no major or unexpected technological breakthroughs. Nor does it assume the application of holistic concepts such as prioritizing energy efficiency at all levels of urban planning or changes in consumer behavior (except where induced by lower energy prices). The scenario is, rather, based on a bottom-up analysis of currently available technologies and practices, and considers incremental changes in the level of energy efficiency deployed.

A second step identified those energy efficiency measures that are economically viable. The criterion adopted was the amount of time an investor might reasonably be willing to wait to recover the cost of an energy efficiency investment (or the additional cost, where appropriate) through the value of undiscounted fuel savings. Acceptable payback periods were calculated as averages over the 2012–2035 projection period and take account of regional and sector-specific considerations (see also figure 10.2 in IEA 2012b). In countries with carbon pricing, these prices are lower than in the New Policies Scenario, as energy efficiency measures are assumed to contribute to targeted emissions reductions. In the Efficient World Scenario, no additional carbon pricing beyond the New Policies Scenario is assumed. Fossil-fuel subsidies are phased out by 2035 at the latest in all regions except the Middle East, where they are reduced to a maximum rate of 20 percent by 2035. Additional efforts toward energy efficiency lead to a lower energy demand and thereby to lower international energy prices. This again causes a rebound in energy consumption, offsetting roughly 9 percent of the energy savings.

On a regional level, the implemented energy efficiency measures lead to different conclusions. While the largest relative savings potential in terms of energy intensity exist in developing Asia, Eastern Europe/Eurasia, and North America, it is developing Asia, North America, and Europe that save the most primary energy by 2030 under the Efficient World Scenario (figure 3.28).

The energy savings in the Efficient World Scenario are achieved by a raft of policy measures across different end-use energy demand sectors,[20] leading to a significant improvement in energy intensity (table 3.5).

[20] For more detail on policy measures in each sector see chapter 11 in IEA (2012b).

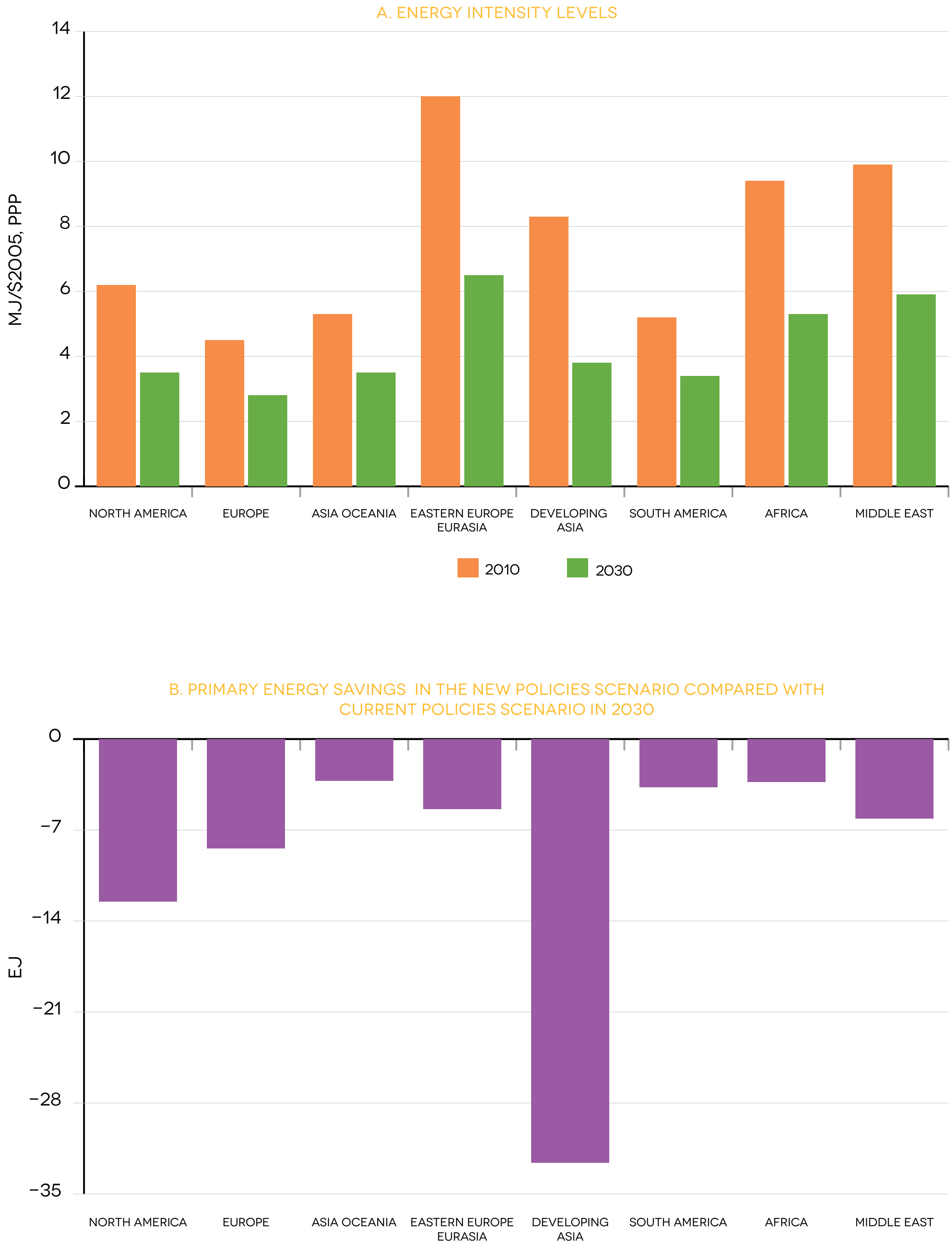


FIGURE 3.28 **CHANGES IN ENERGY INTENSITY AND PRIMARY ENERGY SAVINGS UNDER THE EFFICIENT WORLD SCENARIO, BY REGION**

SOURCE: BASED ON DATA/ANALYSIS TAKEN FROM IEA (2012B).

	WORLD		NORTH AMERICA		EUROPE		ASIA OCEANIA		EASTERN EUROPE/ EURASIA	
	2010	2030	2010	2030	2010	2030	2010	2030	2010	2030
Energy intensity (MJ/dollar, PPP)	7.0	3.9	6.2	3.5	4.6	2.8	5.3	3.5	12.0	6.5
Energy demand per capita (GJ/capita)	77.9	74.1	242.4	191.3	137.3	115.1	183.4	172.9	141.9	152.8
Residential energy intensity (2010 = 100)	100	75	100	73	100	74	100	73	100	82
Service energy intensity (2010 = 100)	100	62	100	61	100	72	100	69	100	52
Fuel consumption, new PLDVs, test cycle (l/100 km)	7.6	4.1	8.7	4.3	6.2	3.6	6.8	3.7	7.1	3.8
Fuel consumption, new heavy trucks on-road (l/100 km)	36	22	38	21	31	19	27	16	33	19
Energy intensity of industries (TJ/$1,000 VA industry)	4.3	2.6	3.8	2.6	2.9	2.2	3.3	2.6	6.2	3.6
Fossil-fuel power plant efficiency (%)	43%	48%	42%	49%	51%	59%	43%	50%	60%	68%

	DEVELOPING ASIA		SOUTH AMERICA		AFRICA		MIDDLE EAST	
	2010	2030	2010	2030	2010	2030	2010	2030
Energy intensity (MJ/dollar, PPP)	8.3	3.8	5.2	3.4	9.4	5.3	9.9	5.9
Energy demand per capita (GJ/capita)	46.1	55.7	54.4	61.1	28.1	22.6	131.5	119.7
Residential energy intensity (2010 = 100)	100	73	100	93	100	70	100	81
Service energy intensity (2010 = 100)	100	48	100	72	100	64	100	58
Fuel consumption, new PLDVs, test cycle (l/100 km)	7.7	4.0	8.1	4.5	7.4	4.4	11.7	6.4
Fuel consumption, new heavy trucks on-road (l/100 km)	40	24	36	21	41	25	40	25
Energy intensity of industries (TJ/$1,000 VA industry)	5.6	2.7	4.1	2.9	3.2	1.9	3.5	2.2
Fossil-fuel power plant efficiency (%)	38%	43%	39%	47%	37%	43%	33%	42%

TABLE 3.5 **KEY ENERGY EFFICIENCY INDICATORS FOR SELECTED REGIONS**

SOURCE: = IEA.

NOTE: FOR THE DEFINITION OF REGIONS AND ADDITIONAL DETAIL ON INDICATORS, SEE ANNEX 2. GJ = GIGAJOULES; MJ = MEGAJOULES; PPP = PURCHASING POWER PARITY; PLDV = PASSENGER LIGHT DUTY VEHICLE; TJ = TERAJOULES; VA = VALUE ADDED.

Why do we want to achieve the Efficient World Scenario?

The Efficient World Scenario requires cumulative additional investments in energy efficiency of $8 trillion over the investments already realized under the New Policies Scenario from 2012 to 2030 (figure 3.29). The additional investment level for the Efficient World Scenario is about three-and-a-half times higher than for the New Policies Scenario. The majority of the additional investments under the Efficient World Scenario accrue in the transport sector ($3.0 trillion). The remaining investments are split among the residential sector ($2.7 trillion), services sector ($1.4 trillion), and industry ($1.1 trillion).

Achieving the Efficient World Scenario brings many regional and global benefits, including fuel savings, improved energy security, health improvements, environmental benefits, and reduced energy import bills. For example, the required investment of $8.2 trillion in energy efficiency is more than offset by fuel expenditure savings of $10.6 trillion, freeing up economic resources and stimulating additional demand for efficient goods and services. Achieving the Efficient World Scenario would give a $11.4 trillion boost to the global economy from 2012 to 2030. Countries that have a competitive advantage in producing less energy-intensive goods would see their economy grow the most. This is the case for China, India, the EU, and the United States. The particularly high growth in China and India is stimulated both by domestic demand and exports.

$400 BILLION IS THE ANNUAL INVESTMENT

REQUIREMENT TO MEET SE4ALL OBJECTIVE FOR ENERGY EFFICIENCY; AROUND TRIPLE HISTORICAL LEVELS

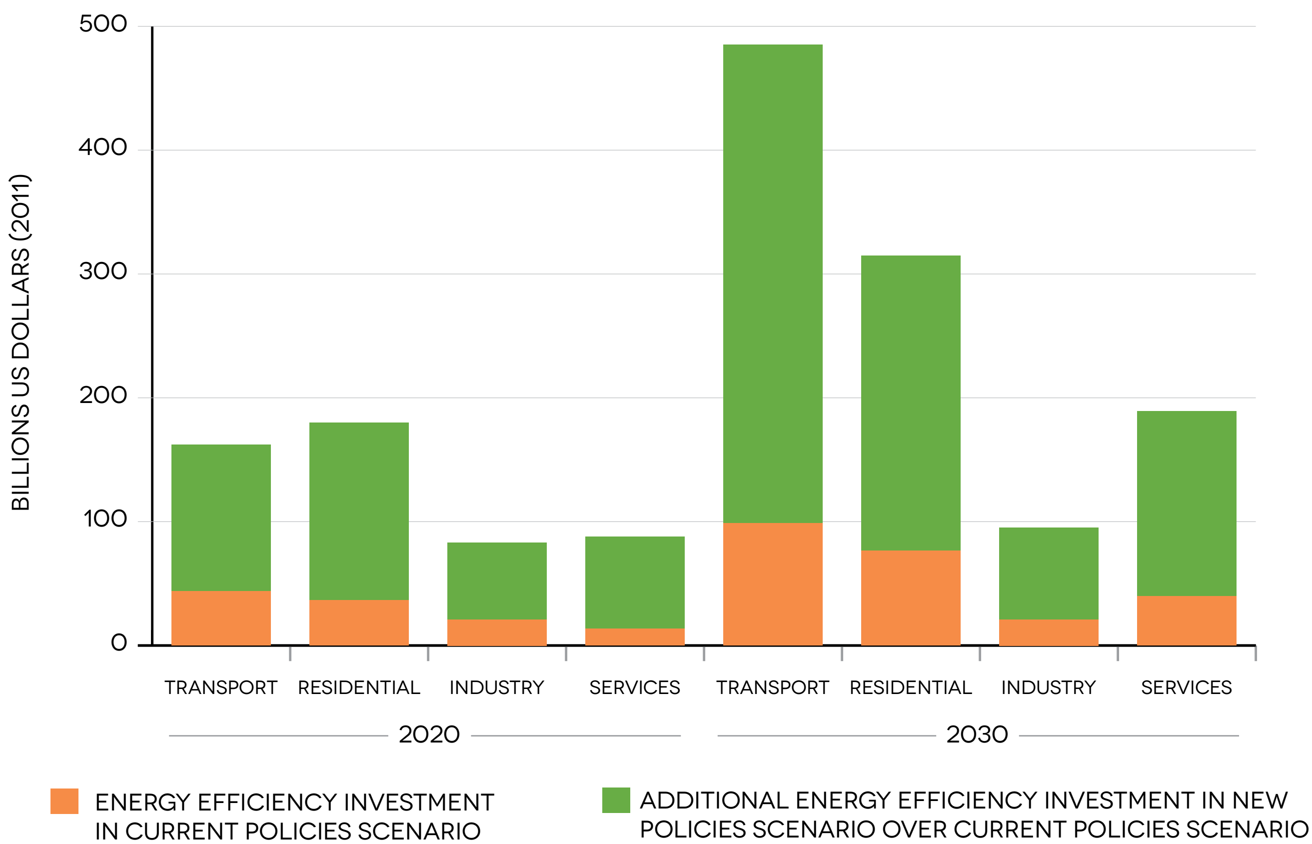


FIGURE 3.29 **AVERAGE ANNUAL INCREASE IN ENERGY EFFICIENCY INVESTMENT: EFFICIENT WORLD SCENARIO VERSUS NEW POLICIES SCENARIO**

SOURCE: BASED ON DATA/ANALYSIS TAKEN FROM IEA (2012B).

From the perspective of mitigating climate change, a rapid and widespread adoption of energy-efficient technologies can reduce CO_2 emissions in the short term. Energy-related CO_2 emissions under the Efficient World Scenario peak before 2020 at 32.4 gigatons (Gt) before beginning a steady decline to 31.0 Gt in 2030. Owing to the faster development of energy-efficient technologies, emissions in 2030 are 5.2 Gt lower than under the New Policies Scenario.

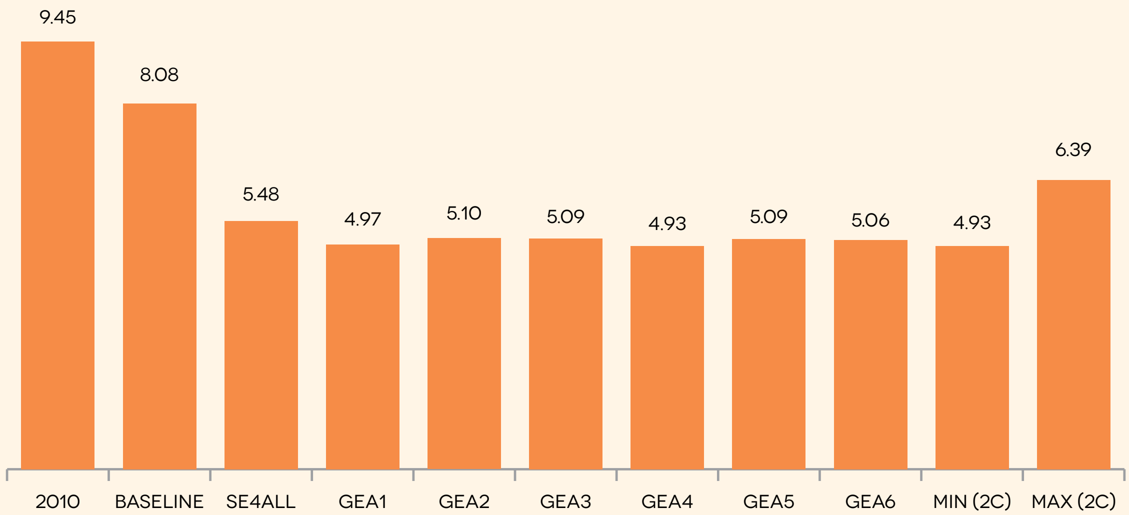
An analysis of the global capital stock in place in all energy sectors shows that the infrastructure that either exists today or is under construction emits, in normal use, about 80 percent of the cumulative emissions allowed over the period to 2035 in a 2°C world. If infrastructure investments continue in line with the New Policies Scenario and are operated as projected in that scenario, infrastructure in existence in 2017 would emit 100 percent of the allowed cumulative emissions. Energy efficiency can delay by five years (to 2022) the complete locking in of all CO_2 emissions allowed in a 2°C world. This additional time is crucial in the immediate future, because a new climate agreement is expected to be reached by 2015 and to take effect by 2020.

BOX 3.6 Overview of the energy intensity projections of the Global Energy Assessment

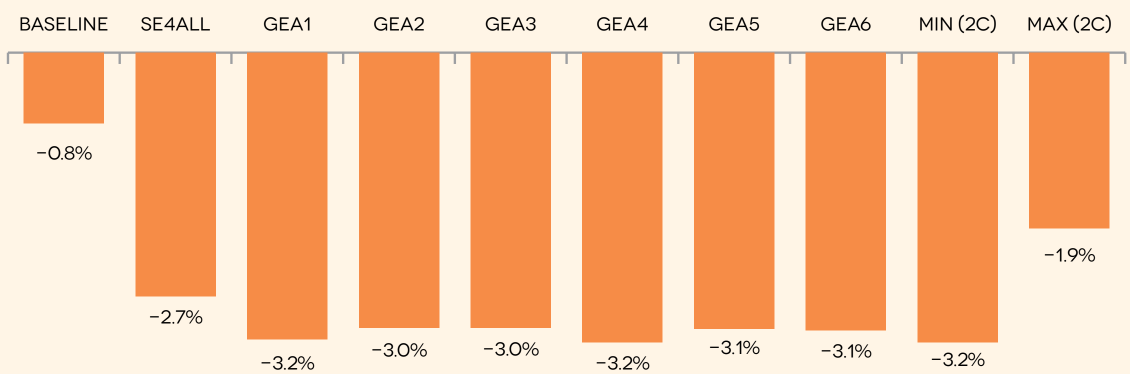
The figures below present the main energy intensity projections from the Global Energy Assessment (GEA) developed by the International Institute for Applied Systems Analysis (IIASA). The bases and regional groupings on which the IIASA scenarios are constructed are different from those of the International Energy Agency (IEA). It is outside the scope of this report to make them compatible.

The baseline scenario is consistent with the annual rate of improvement of energy intensity observed over the last 20 years (–0.8 percent). The SE4ALL scenario—a scenario that meets the access, renewables, and efficiency targets—assumes an annual improvement in energy intensity of –2.7 percent, which is actually greater than the needed rate of improvement of –1.5 percent if measured at market exchange rate (MER). The six GEA "pathways"—each of which assumes the future availability of various key technologies—do not differ much in actual energy intensity or in the rate of improvement. All meet the SE4ALL energy efficiency target and assume faster energy intensity improvement as compared to SE4ALL.

PROJECTIONS OF GLOBAL PRIMARY ENERGY INTENSITY BY SCENARIO, 2010 VS. 2030 (MJ/$2005), MER



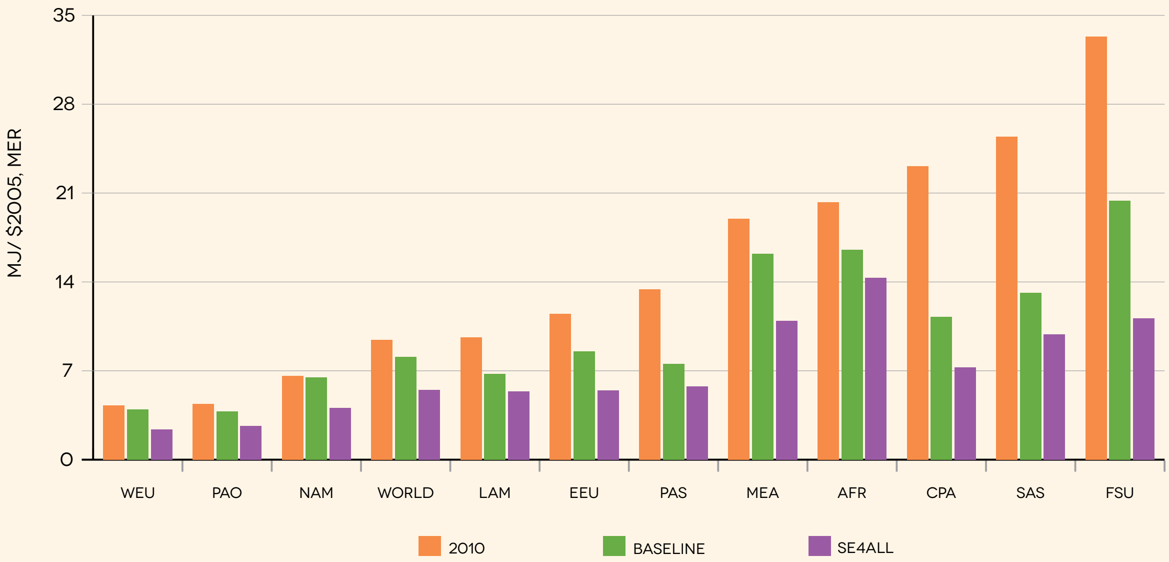
PROJECTED ANNUAL RATE OF IMPROVEMENT IN GLOBAL PRIMARY ENERGY INTENSITY BY 2030, BY SCENARIO (MER)



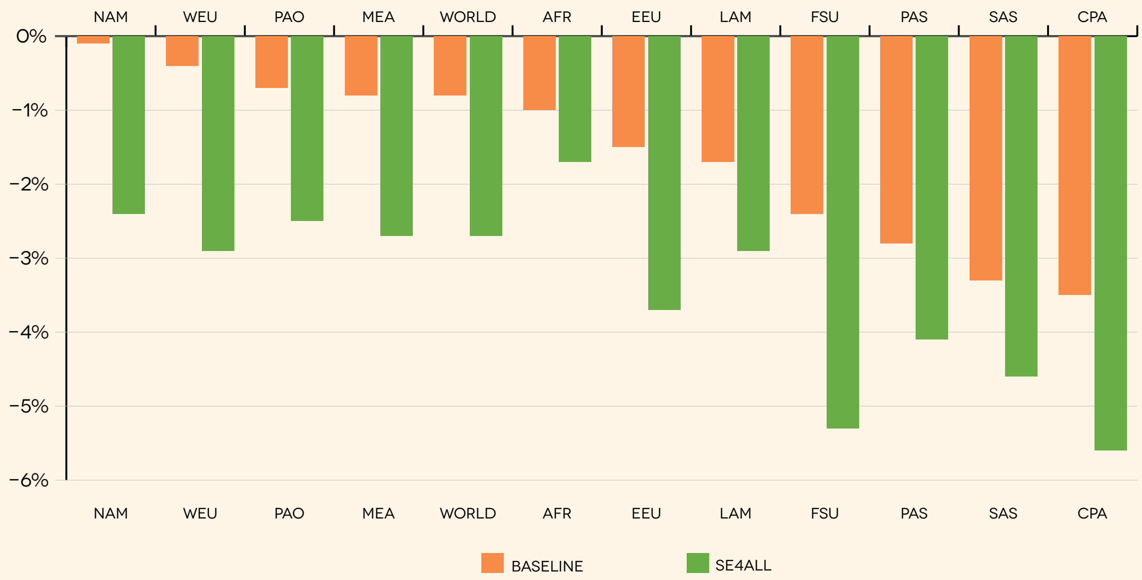
Looking at the world's regions, substantial reductions in the absolute level of energy intensity are expected from the former Soviet Union, centrally planned Asia (including China), and South Asia. These regions are projected to decrease their current energy intensity levels by more than 60 percent and to meet the SE4ALL target—reflecting that the SE4ALL target is not that far off from the business-as-usual, or IIASA's baseline, scenario in these regions.

By contrast, an effort far beyond that of the baseline scenario would be needed from those regions that have already achieved low levels of energy intensity, such as North America and Western Europe. Substantial effort would also be required in the former Soviet Union and Middle East. Some improvements are expected in Africa, but they do not go far beyond the business-as-usual projection.

PRIMARY ENERGY INTENSITY: 2010 VERSUS 2030 BASELINE AND SE4ALL SCENARIOS (MJ/$2005), MER



PRIMARY ENERGY INTENSITY ANNUAL RATE OF IMPROVEMENT: BASELINE VERSUS SE4ALL SCENARIO (CAGR 2010–30), MER



SOURCE: INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS (IIASA).

NOTE: PRIMARY ENERGY PRESENTED ON THE CHARTS ABOVE IS MEASURED USING DIRECT EQUIVALENT METHOD AS OPPOSED TO THE PHYSICAL CONTENT METHOD USED IN THE REST OF THE REPORT. AFR = SUB-SAHARAN AFRICA; CPA = CENTRALLY PLANNED ASIA AND CHINA; EEU = CENTRAL AND EASTERN EUROPE; FSU = FORMER SOVIET UNION; LAM = LATIN AMERICA AND CARIBBEAN; MEA = MIDDLE EAST AND NORTH AFRICA; NAM = NORTH AMERICA; PAO = PACIFIC OECD; PAS = OTHER PACIFIC ASIA SAS = SOUTH ASIA; WEU = WESTERN EUROPE.

Overcoming the barriers

The energy savings identified in the Efficient World Scenario will not be realized if market actors are left to their own devices. For that reason, the Efficient World Scenario rests on a raft of policy measures taken to overcome market barriers. Various countries have successfully implemented policies that were effective in saving energy. It is important to learn from those experiences and the approaches used.

Because the nature of the barriers to energy efficiency differs by the end use and economy considered, a portfolio of measures is needed. But, whatever the specifics of the sector or economy being addressed, certain key principles need to be adhered to.

Make it visible. The energy performance of each energy end-use and service needs to be made visible to the market. Governments need to ensure that the energy performance of all major energy services and end-uses is measured and reported to consumers, clients, and statistical agencies in a consistent, accessible, timely, and reliable manner. Increased visibility lowers information costs, an important element of transaction costs.

Make it a priority. The profile and importance of energy efficiency needs to be raised. Visibility stimulates market actors to consider energy efficiency, but is often not enough to motivate them to demand it. Governments need to take additional steps to ensure that the full value of higher energy efficiency is made clear to individuals and to society at large and integrated into decision-making processes in government, industry, and society.

Make it affordable. It is essential to identify and support business models, financing vehicles, and incentives that provide those who invest in energy efficiency an appropriate share of the rewards that flow from efficiency improvements. Tailored economic instruments such as tax policies, loans, grants, trading schemes, white certificates, public procurement, and investment in R&D or infrastructure are needed to address the various principal–agent barriers and other split incentives where investors may not directly reap the return on investments to energy efficiency, including short asset-ownership periods vis-à-vis payback periods for building retrofits (Hilke and Ryan 2012). Perception of financial risk is another barrier to energy efficiency investment and can be overcome by lowering the risk premiums applied to lending for energy efficiency projects and by providing risk guarantees, credit lines, mechanisms to standardize and bundle project types, and awareness and capacity-building efforts among the finance community.

Make it standard. Energy efficiency needs to be standardized if it is to endure. Once a high-efficiency technology or service solution has been widely adopted, there is rarely a step backwards: the less-efficient technology or approach is rapidly forgotten, and the cost differentials for higher-efficiency technologies decline substantially as adoption rates increase. Under the Efficient World Scenario, a mix of regulations is deployed to prohibit the least-efficient approaches and to impose MEPS for equipment, vehicles, buildings, and power plants.

Make it real. Monitoring, verification, and enforcement activities are needed to verify claimed energy efficiencies. Without such efforts, experience has shown that savings will turn out to be less than expected, undermining policy objectives. Under the Efficient World Scenario, there is a substantial increase in the scale of such activities.

Make it realizable. Achieving the supply and widespread adoption of energy-efficient goods and services depends on an adequate body of skilled practitioners in government and industry and requires improved energy efficiency governance, including legislative frameworks, funding mechanisms, institutional arrangements, and coordination bodies that work together to support the implementation of energy efficiency strategies, policies, and programs (IEA 2010).

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ANNEX 1: Proposed energy efficiency indicators for the medium term

SECTOR	ENERGY INTENSITY INDICATOR PROPOSED IN THIS BASELINE REPORT	CHALLENGES ASSOCIATED WITH ENERGY EFFICIENCY MONITORING, USING THE PROPOSED ENERGY INTENSITY INDICATORS	MEDIUM –TERM AND PREFERRED ENERGY INDICATORS TO TRACK ENERGY EFFICIENCY	RATIONALE FOR INCREASING THE SCOPE OF MONITORING AND DATA COLLECTION	DATA SOURCES
Residential	Included under other sectors	Does not permit tracking of the sector, as it also includes transport, residential, and others.	MJ/floor area MJ/number of households MJ/total population MJ/end use (for example space heating, cooking, cooling, appliances)	Floor area is a better proxy to identify changes in the residential sector. Household number can be informative, but size of each household may also be relevant. End-use energy consumption such as for space heating, cooling, and cooking needs is of importance to the residential sector main activities.	Activity data such as floor area and number of households can be obtained from existing national census. Floor area measurements should follow UN census guidelines. National household surveys also track total floor area on a more frequent basis. These surveys are essential to capture physical building and equipment characteristics and total annual energy consumption. Energy consumption by end use can be estimated by combining output from household surveys, metering/measuring of household activity, and modeling techniques. The final breakdown needs to be validated against total residential energy consumption from energy balances.

SECTOR	ENERGY INTENSITY INDICATOR PROPOSED IN THIS BASELINE REPORT	CHALLENGES ASSOCIATED WITH ENERGY EFFICIENCY MONITORING, USING THE PROPOSED ENERGY INTENSITY INDICATORS	MEDIUM-TERM AND PREFERRED ENERGY INDICATORS TO TRACK ENERGY EFFICIENCY	RATIONALE FOR INCREASING THE SCOPE OF MONITORING AND DATA COLLECTION	DATA SOURCES
Services	MJ/service sector GDP	There has been little evidence that the two variables are directly linked (that is, correlated). Because of data disaggregation limitations, services value added includes residential, transport, and others. Therefore, the indicator combines sectors with very different intensities and drivers. Using physical parameters is a better indicator of energy efficiency improvements.	MJ/floor area MJ/floor area by type of service	Total floor area is one of the key physical variables essential to track overall improvement in the service sector efficiency. Long-term monitoring of the service sector by type of service (or type of building where service is provided) such as government and public buildings, education, hospitals, lodging, and so on. In some sectors such as hospitals, number of hospital beds may be a better indicator of the activity in the building. Challenge will remain as some countries may choose to cut off surveying of small entities and only focus on large institutions.	Services sector floor area can be derived from a number of sources such as national building surveys and business tax offices. Some monitoring may be essential to capture the behavioral aspect of energy consumption in buildings. Finally, bottom-up modeling and estimation techniques will be needed as the sector is highly heterogeneous and some assumptions need to be made.
Industry	Total industry MJ/GDP	The variable is highly aggregated, missing the information at subsector level. Literature points to poor correlation in monitoring energy efficiency improvements industry based on value added alone.	Industry subsector MJ/value added of industry subsector GDP MJ/output volume	Where possible use physical output in the following sectors: aluminum, cement, iron and steel, pulp and paper, fertilizers, and others.	The existing IEA energy balances structure provides industry subsector information according to the UN ISIC code definitions. National energy consumption industry surveys. Physical activity data exist in international organizations. Bottom-up modeling validated at the aggregate level against energy balances.

SECTOR	ENERGY INTENSITY INDICATOR PROPOSED IN THIS BASELINE REPORT	CHALLENGES ASSOCIATED WITH ENERGY EFFICIENCY MONITORING, USING THE PROPOSED ENERGY INTENSITY INDICATORS	MEDIUM-TERM AND PREFERRED ENERGY INDICATORS TO TRACK ENERGY EFFICIENCY	RATIONALE FOR INCREASING THE SCOPE OF MONITORING AND DATA COLLECTION	DATA SOURCES
Transport	Included under other sectors	Does not permit tracking of the sector, as it also includes services, residential, and others.	MJ/vehicle-kilometers MJ/passenger-kilometers MJ/freight kilometers MJ/total passenger vehicles MJ/total freight vehicles	The need to split passenger and freight transport energy consumption in MJ. Currently there are no publicly available global data that properly split passenger and freight transportation energy consumption. Within domestic boundaries, the IEA energy balances reports these data in aggregate form by road, rail, marine, and domestic aviation. Age of vehicles would be another important parameter to capture, especially in countries where used vehicles are imported.	National mobility surveys. Tax offices where actively used vehicles are registered with data such as vehicle kilometers and age of vehicle. Monitoring using the latest GPS data logger technology. Modeling to estimate mode split and average fuel consumption of existing vehicle stock by mode type. Bottom-up modeling validated at the aggregate level against energy balances.

SOURCE: AUTHORS.
NOTE: GDP = GROSS DOMESTIC PRODUCT; GPS = GLOBAL POSITIONING SYSTEM; IEA = INTERNATIONAL ENERGY AGENCY; ISIC = INTERNATIONAL STANDARD INDUSTRIAL CLASSIFICATION; MJ = MEGAJOULE.

ANNEX 2: Overview of energy efficiency policies and targets by country and sector

	AUSTRALIA	CANADA	EU MEMBER STATES	JAPAN	KOREA	NEW ZEALAND	UNITED STATES
Cross-sectoral							
Energy efficiency strategy or target	Clean Energy Future Plan National Strategy on Energy Efficiency (NSEE)	Moving Forward on Energy Efficiency in Canada: Achieving Results to 2020 and Beyond	National Energy Efficiency Action Plans	Innovative Energy Savings Plan September 2012	The National Energy Master Plan and Energy Use Rationalization Master Plan	New Zealand Energy Efficiency and Conservation Strategy	Target: Cut in half the energy wasted in homes and businesses over the next 20 years. Energy efficiency action plans at state level.
Buildings and appliances							
Building energy codes	Mandatory for new and existing residential and commercial buildings. Codes updated in 2011.	Voluntary national Energy Code for new and existing residential and commercial buildings, published in 2011 for adoption by subnational regulators.	Mandatory for new and existing buildings when renovation is undertaken.	Voluntary guidelines.	Mandatory for residential buildings and commercial buildings 500–300 m^2. Codes updated in 2010.	Mandatory for new residential and commercial buildings.	Mandatory for new residential and commercial buildings, and major renovations, with some exceptions. Variation of stringency across states.
Energy labeling	National framework replacing seven state and territory legislative frameworks. Seven appliances covered by the mandatory Energy Rating Labeling Scheme. Mandatory disclosure of commercial building energy efficiency.	Mandatory EnergyGuide label for eight major household appliances and light bulbs. International ENERGY STAR symbol promoted in Canada.	Energy performance certificates mandatory for all new buildings. Labeling in place for household appliances.	Voluntary building labeling program and Energy Star for office equipment.	Labeling system expanded from 26 products in 2011 to 35 products in 2012.	Eight products covered.	Mandatory EnergyGuide labeling for most household appliances. Voluntary energy star labeling for over 60 categories of appliances, equipment, and buildings.

	AUSTRALIA	CANADA	EU MEMBER STATES	JAPAN	KOREA	NEW ZEALAND	UNITED STATES
Buildings and appliances (continued)							
Appliance, equipment and lighting MEPS	20 products covered.	47 products covered.	15 product groups covered by EcoDesign Directive.	Top Runner: 23 products covered.	26 products covered.	16 products covered.	45 products covered.
Transport							
Fuel-efficiency standards	LDV: Implementation from 2015. HDV: Included in carbon price mechanism from 2014.	LDV: published October 2010 for model years 2011–2016. HDV: under consideration.	LDV: 130 g/CO2 per km by 2015.* 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 by 2015; 140 g/CO2 per km by 2015. HDV: starting after 2015	None	LDV: 34.1 mpg by 2016 (6.90 l/100 km); large increases by 2025. HDV: starting MY 2014.
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 EVs.	Most countries align vehicle taxes with CO2 emissions.	Registration taxes according to CO2 emissions and fuel economy.	None	None	Tax at federal level; 20 states plus DC offer tax incentives, rebates, or voucher programs for advanced vehicles (EVs, PHEVs, HEVs, and/or fuel cell vehicles)

	AUSTRALIA	CANADA	EU MEMBER STATES	JAPAN	KOREA	NEW ZEALAND	UNITED STATES
industry							
Energy man-agement programs	Energy Efficiency Opportunities (EEO) Program mandatory for corporations using more than 0.5 PJ of energy per year. Expan-sion of program announced.	ecoEnergy Efficiency for Industry program, which supports the early implemen-tation of the new ISO 50001 Energy Manage-ment Systems standard.	Voluntary agreements in place in Belgium (Flanders), Denmark, Finland, Ireland, Netherlands, Sweden.	Energy managers required for large industries.	Voluntary Energy Saving through Partnership program.	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.	IE3 (premium efficiency). MEPS for three-phase induction motors <7.5kW by 2015; all IE3 (IE2+Variable Speed Drive) in 2017.	Adding three-phase induction MEPS to Top Runner program.	IE2 (high efficiency) three-phase electric motors.	MEPS are in place at level II Standards. Investigation under way to advance to level III.	IE3 (premium-efficiency) MEPS for three-phase induction motors.

	RUSSIA	CHINA	INDIA	BRAZIL	SOUTH AFRICA	MEXICO
Cross-sectoral						
	2009 Federal Law No. 261-FZ on energy saving and improving energy efficiency; reduce energy intensity by 40 percent by 2020.	12th Five Year Plan (2011–2015): target to reduce energy intensity by 16 percent by 2015.	11th Five-Year plan (2007–2012): target to improve energy efficiency by 20 percent. An "Approach to the 12th Five-Year" has been published.	2011 National Energy Efficiency Plan: reduce projected power consumption by 10 percent by 2030.	Energy Efficiency Strategy of the Republic of South Africa: sets a national target of energy efficiency improvement of 12 percent by 2015.	2008 Law on Sustainable Energy Use Goal: reduce electricity demand 12 percent by 2020 and 18 percent by 2030.
Buildings and appliances						
Building energy codes	Mandatory building codes (but not yet fully implemented).	Mandatory codes for all new large residential buildings in big cities.	Energy Conservation Building Code (2007), with voluntary guidelines for commercial and residential 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.	Voluntary for residential and commercial buildings.	Voluntary Green Star South Africa label.	Green Building Labeling System.
Appliance, equipment and lighting MEPS	Phaseout of incandescent >100 watt bulbs.	46 products covered by labeling schemes.	Mandatory S&L for room air conditioners and refrigerators, voluntary for 5 other products.	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.

	RUSSIA	CHINA	INDIA	BRAZIL	SOUTH AFRICA	MEXICO
Transport						
Fuel-efficiency standards	None	PLDV: 6.9l/100 km by 2015, 5.0 l/100 km by 2020; trucks: proposed MY 2015. HDV: None	LDV: Under development HDV: None	None	None	LDV: Average new car fleet average fuel economy of 14.9 km/l (35 mpg) in 2016 HDV: None
Fuel-efficiency labeling	None	LDV: Yes HDV: None	None	None	None	None
Fiscal incentives for new efficient vehicles	None	Acquisition tax based on	Registration taxes by vehicle and engine size, sales incentives for advanced vehicles.	None	None	None
Industry						
Energy man-agement programs	Periodic energy audits required for some industries.	Top 10,000 program setting energy savings targets by 2015 for the largest 10,000 industrial consum-ers.	PAT in force since 2011. Audits mandated for designated consumers.	None.	Voluntary "Energy Efficiency and Energy Demand Management Flagship Programme" involving 24 major indus-trial energy users and associations.	
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

SOURCE: IEA.
NOTE: CAN/CSA = CANADIAN STANDARDS ASSOCIATION; CO2 = CARBON DIOXIDE; EV = ELECTRIC VEHICLE; HDV = HEAVY-DUTY VEHICLE; HEV = HYBRID-ELECTRIC VEHICLE; IE2 = HIGH-EFFICIENCY MOTOR; IE3 = PREMIUM EFFICIENCY MOTOR; MEPS = MINIMUM ENERGY PERFORMANCE STANDARDS; ISO = INTERNATIONAL ORGANIZATION FOR STANDARDIZATION; KW = KILOWATTS; LDV = LIGHT-DUTY VEHICLE; MPG = MILES PER GALLON; PAT = PERFORM, ACHIEVE, TRADE; PHEVS = PLUG-IN HYBRID ELECTRIC VEHICLE; PJ = PETAJOULE; PLDV = PASSENGER LIGHT-DUTY VEHICLE; S&L = STANDARDS AND LABELING; SME = SMALL AND MEDIUM ENTERPRISE.

ANNEX 3: Specific energy consumption of energy-intensive products

The tables below list the status of energy consumption in major industries, along with the existing best practices and their savings potential.

SECTOR OR PROCESS	CURRENT PRACTICE	BEST AVAILABLE PRACTICE BENCHMARKS
Iron and steel	90 percent of the production of crude steel is in the range of 14–30 GJ final energy/ton. Includes total energy consumption for steel production—from coke making to furnace firing to steel finishing—and refers to crude steel production. Electricity consumption is not corrected for the efficiency of power generation.	Practical minimum energy consumption for a blast furnace is 10.4 GJ/t iron.
Cement		Dry-process kilns thermal energy consumption: 2.9–3.3 GJ/t clinker. Dry-process kilns electricity consumption: 95–100 kWh/t cement.
Chemicals and petrochemicals		Olefin production from steam cracking: 12 GJ/t olefin (excluding feedstocks). Ammonia production from natural gas: 11 GJ/t ammonia (excluding feedstocks). Methanol production from natural gas: 9 GJ/t methanol (excluding feedstocks).
Aluminum		Total fuel and electricity consumption of Bayer process: 9.5–10 GJ/t alumina. The current best practice of Hall–Heroult electrolysis cells (using currents of 300–315 kA) is estimated at 12.9–13 MWh/t aluminum.
Pulp and paper	Large modern chemical pulp mills are largely self-sufficient in energy terms, using only biomass and delivering surplus electricity to the grid. Steam consumption of 10.4 GJ/ adt and an excess of electricity production of 2 GJ/adt.	Mechanical pulping 7.5 GJ elec/t. Chemical pulping 12.5 GJ/t + 2.08 GJ elec/t. Waste paper pulp 0.5GJ/t + 0.36 GJ elec/t. De-inked waste paper pulp 2.0 GJ/t + 1.6 GJ elec/t. Depending on final paper quality energy intensities vary from 3.7 –5.3 GJ/t + 1.8–3.6 GJ elec/t.

SOURCE: : IEA.
NOTE: GJ/ADT = GIGAJOULE/AIR DRY TON PULP; KA = KILO AMPERE; KWH = KILOWATT-HOUR; MWH/T = MEGAWATT-HOUR/TON.

Comparison of estimated short-term potential for industrial energy savings in industrialized and developing countries, 2007

	IMPROVEMENT POTENTIAL (%)		TOTAL SAVINGS POTENTIAL (EJ/YEAR)		SHARE OF ENERGY COSTS (%)
Sectors and products	Industrializing countries	Developed countries (including economies in transition)	Industrializing countries	Developed countries (including economies in transition)	Industrializing and developing countries (including economies in transition)
Petroleum refineries	10–25	40–45	0.7	2.9	50–60
Chemical and petrochemical			0.5	1.8	
Steam cracking (excl. feedstock)	20–25	25–30	0.4	0.3	50–85
Ammonia	11	25	0.1	0.3	
Methanol	9	14	0.0	0.1	
Nonferrous			0.3	0.7	30
Alumina production	35	50	0.1	0.5	35–50
Aluminum smelters	5–10	5	0.1	0.15	—
Copper smelters		45–50	0.0	0.1	—
Zinc	16	46	0.0	0.1	10–30
Iron and steel	10	30	0.7	5.4	
Nonmetallic minerals			0.8	2.0	25–50
Cement	20	25	0.4	1.8	40
Lime					7–20
Glass	30–35	40	0.4	0.2	30–50
Ceramics					15–35
Pulp and paper	25	20	1.3	0.3	5–25
Textile					5–25
Spinning	10	20	0.1	0.3	5–15
Weaving					
Food and beverages	25	40	0.7	1.4	1–10
Total of all sectors (excl. feedstock)	15	30–35	7.6	23	–

SOURCE: UNIDO 2010.