International Energy Agency

Energy Efficiency Indicators: Essentials for Policy Making

residential
services
industry
transport

Energy Efficiency Indicators: Essentials for Policy Making

Energy efficiency is a growing policy priority for many countries around the world. It is widely recognised as the most cost-effective and readily available means to address numerous energy-related issues, including energy security, the social and economic impacts of high energy prices, and concerns about climate change. At the same time, energy efficiency increases competitiveness and promotes consumer welfare.

In this context, it is important to develop and maintain well-founded indicators to better inform policy making and help decision makers formulate policies that are best suited to domestic and/or international objectives. Yet, choosing and developing appropriate indicators to support the development of policies is not straightforward.

This publication should enable energy analysts and policy makers to:

- Identify priority areas for the development of energy efficiency indicators
- Define which sector(s) offer the greatest potential to further improve energy efficiency
- Select the data and indicators that best support policy development in these sectors
- Develop a strategy to advance policy development through the improved use of indicators to track progress of energy efficiency policies.

This publication and its companion document, *Energy Efficiency Indicators: Fundamentals on Statistics*, are intended to provide the necessary tools to initiate and/or further develop in-depth indicators to support the decision-making process.

International Energy Agency

Energy Efficiency Indicators: Essentials for Policy Making

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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Foreword

The International Energy Agency (IEA) has published reports on the impact of improved energy efficiency trends in end-use energy consumption, otherwise known as energy efficiency indicators, since 1997. Over this period, the IEA together with other energy efficiency experts have been leading the development of energy efficiency indicators, as well as working closely with countries and other key stakeholders to improve the collection of energy and related end-use data. The IEA *Energy Statistics Manual* (IEA, 2005), *Oil Crises & Climate Challenges: 30 Years of Energy Use in IEA Countries* (IEA, 2004) and *Energy Use in the New Millennium* (IEA, 2007) are examples of the results of this collaboration.

As an energy resource, energy efficiency has the unique potential to simultaneously contribute to long-term energy security, economic growth, and even improved health and well-being; in particular it is a key means to reduce greenhouse gas emissions. By reducing or limiting energy demand, energy efficiency measures can increase resilience against a variety of risks, such as energy price rises and volatility, stress on energy infrastructure, and disruptions to energy supply systems.

The *Energy Efficiency Market Report* (IEA, 2013) highlights energy efficiency's place as a major energy resource and the critical role it plays in the global energy market. It concluded that energy efficiency investments delivered reductions in energy demand that exceed the output of any other fuel source in many IEA countries. This points to energy efficiency being not just a hidden fuel, but in fact, the "first fuel". Energy efficiency indicators are used to quantify just how big this hidden or first fuel is. To better understand the drivers and potential for energy efficiency, it is important to develop and maintain well-founded energy efficiency indicators to better inform the policy process and help decision-makers develop policies that are best suited to meet domestic and/or international policy objectives. Yet choosing and developing appropriate indicators to support the development of policies is not straight forward.

The *Energy Efficiency Indicators: Essentials for Policy Making* and its companion document *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014) aim to provide the necessary tools to initiate or further develop in-depth indicators to support the development of effective energy efficiency policies. T*he Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014) is intended for statisticians and energy analysts collecting the needed information for the development of energy efficiency indicators.

The *Energy Efficiency Indicators: Essentials for Policy Making* is aimed at providing energy analysts with tools needed to determine the priority areas for the development of energy efficiency indicators (EEI) and how to select and develop the data and indicators that will best support energy efficiency policy. The information gained from these indicators will help policy makers to set energy efficiency targets and track progress towards these targets.

This report is published under my authority as Executive Director of the IEA.

Maria van der Hoeven

Executive Director
International Energy Agency

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Introductíon

Countries around the world are increasingly aware of the urgent need to transform the way they use energy. Concern over energy security, the social and economic impacts of high energy prices, and growing awareness of climate change have led many countries to put greater emphasis on developing policies and measures that promote energy efficiency. Two things have become increasingly clear:

- Ensuring better use of global energy resources will require policies that encompass a wide range of options. There is a growing recognition that improving energy efficiency is often the most economic, proven and readily available means of achieving this goal.
- Establishing and maintaining sound policies requires the availability of good-quality, timely, comparable and detailed data that go well beyond those currently included in energy balances, and which reflect the distinct characteristics of economic activity and resources available in each country.

For decades, countries have used the data contained in energy balances as a means of tracking energy consumption according to type of energy source and by major sector, and as a way to develop aggregate indicators (such as total energy per capita). Aggregate indicators have the advantage that they are often readily and widely available: thus, they reveal high-level developments in energy consumption in simple terms. However, their usefulness is limited and can generate misleading results when used inappropriately. For example, it would be incorrect to rank energy performance according to a country's total final consumption per gross domestic product (GDP) or per capita given the many factors (e.g. climate, wealth, economic structure) influencing this indicator.

As each main sector is influenced by varying underlying factors, different explanatory data will be needed depending on the sector analysed. Such data are not reported in energy balances and are currently available for only a few countries. Thus, in order to develop estimates of overall energy efficiency, detailed data are required for end-use sectors.

Development of state-of-the-art indicators is not straightforward and requires financial and human resources to collect detailed data, and analyse the information. Recent efforts by several countries to collect more detailed end-use data have helped to develop energy efficiency indicators that provide important information for understanding past trends, assessing potential for energy savings and enhancing energy efficiency policies. However, much more still needs to be done. The full spectrum of detailed indicators cannot be developed within a few years. It is important for countries to prioritise which sectors – or which segments of a sector will be prioritised – and then build on the expertise that will be gained.

The goal of this publication is to provide the necessary tools for analysts and policy makers to prioritise the development of energy efficiency indicators, and build

meaningful indicators to support policy development and implementation. This publication is complementary to the *Energy Efficiency Indicators: Fundamentals on Statistics* (International Energy Agency [IEA], 2014), which provides guidance to developing a data collection programme to support the development of energy efficiency indicators. This manual dedicates individual chapters to each of the end-use sectors, namely residential, services, industry, and passenger and freight transport. The chapter "The IEA methodology for analysing trends in energy consumption" provides an overview of the analysis methodologies recommended, and associated benefits and caveats that will apply to all end-use sectors in conjunction with each individual end-use chapter.

The IEA Methodology for Analysing Trends in Energy Consumption

1 Energy efficiency indicators

Energy indicators are an important tool for analysing interactions among economic and human activity, energy consumption and carbon dioxide (CO_2) emissions. These indicators show policy makers where energy savings can be made. In addition to providing information on trends in past energy consumption, energy efficiency indicators can also be used to help model and forecast future energy demand.

One of the most important issues to understand from an energy policy perspective is to what extent improvements in energy efficiency have been responsible for the changes in final energy intensity in different countries. To understand the impact of energy efficiency, it is necessary to separate the impact of changes in activity, economic structure and other exogenous factors that influence the demand for energy from changes in energy intensities (which are a proxy for energy efficiency). This is done using a decomposition approach that separates and quantifies the impacts of the individual factors of changes in activity, structure and energy intensities on final energy consumption in each sector and country.

The IEA indicators approach is based on a conceptual structure of an indicators pyramid, which portrays a hierarchy of energy indicators from most detailed, at the bottom of the pyramid, to least detailed at the top (Figure 2.1).

Questions and Answers

Q 1. What is the difference between energy intensity and energy efficiency?

Something is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input. Energy intensity is defined as the amount of energy consumed per activity or output for sub-sectors and end uses. Generally energy intensity is calculated as energy consumed divided by an economic indicator (e.g. gross domestic product [GDP] or value-added by sector). Energy intensity is determined by many factors not just energy efficiency. Such factors can include the structure of the economy, the type of industry base, the exchange rate, the affordability of energy services, the size of a country, climate and behaviour. Efficiency impacts can be masked by variation in these non-energy-related factors, so using energy intensity as a proxy for energy efficiency can generate misleading results.

Q2. What is the difference between energy efficiency and energy conservation?

Energy conservation refers to limiting or reducing energy consumption through change in lifestyle or behaviour (e.g. turning off light in unoccupied rooms), while energy efficiency refers to limiting or reducing energy consumption through the adoption of more efficient devices (e.g. use of compact fluorescent light bulbs instead of incandescent light bulbs). In decomposition analysis, where an intensity effect based on actual energy consumption is used as a proxy for energy efficiency, both technical energy efficiency and energy conservation are included in the energy intensity improvement.

Q3. Should indicators be developed using primary energy supply or final energy demand?

Energy efficiency is realised in specific sectors and end uses; therefore, indicators should be developed using final energy demand. Indicators should be calculated at the most disaggregated end-use level possible in order to accurately represent energy efficiency improvements.

In general, individuals cannot impact the efficiency of conversion of primary energy sources into useful energy for consumers, including sectors such as refining or electricity generation. Therefore, energy efficiency indicators focus on final energy demand. There is value in developing primary energy efficiency indicators, if the data and resources are available to do so, in order to calculate overall energy system efficiency. This is particularly the case where there is electrification of end uses.

Energy-related CO_2 emissions indicators can similarly be developed for both primary and final energy consumption. For each level where energy consumption information is available by energy source, it is possible to develop CO_2 indicators. The purpose and limitations identified for the indicators also apply to CO_2 indicators.

Q4. What is decomposition analysis and why is it useful?

In isolation, energy efficiency indicators provide only part of the picture of the drivers of energy consumption in a particular sector or sub-sector. Decomposition analysis is used to disentangle the impact of various factors on total energy consumption. The International Energy Agency (IEA) methodology for analysing end-use trends usually distinguishes among three main components that affect energy consumption: activity levels; structure (the mix

of activities within a sector); and energy intensity. The influence of each individual factor is quantified in the decomposition analysis, so factors that relate to energy policy can be isolated from changes in the structural and activity components of energy consumption.

Q5. Which sector should be prioritised?

Each country should prioritise its highest-energy-using sectors for developing energy efficiency indicators or choose indicators that will help to address specific policy priorities. If there are not enough data available for the highest-energy end-use sector, the sector for which meaningful energy end-use indicators can be calculated should be prioritised.

Q6. Is waste carbon neutral?

Only waste produced from biomass should be considered carbon neutral. For example, the carbon dioxide (CO_2) content of tyres burnt in cement kilns will depend on the share of natural rubber versus petroleum-based rubber.

The top row of the pyramid (the most aggregate indicator) is defined as the ratio of energy consumption to GDP. Alternatively, it could be defined as the ratio of energy consumption to another macro-economic variable, such as population. It is useful to consider both GDP and population-based indicators simultaneously to observe the two key drivers of energy consumption.

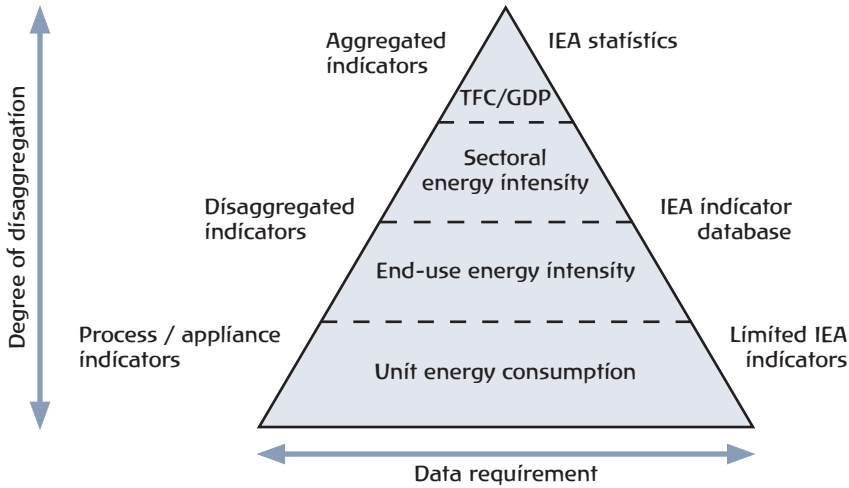
The second row of elements can be defined as the energy intensity of each major sector, as measured by energy consumption per unit of activity in each sector. Again, it is useful to consider energy consumption by denominators of both physical and monetary units, according to the key drivers of the sector.

Lower rows represent the sub-sectors or end uses that make up each sector and progressively provide more detail e.g. characterising particular energy services, physical processes or key end-use appliances.

Aggregate indicators provide a general idea of the reasons behind trends in energy consumption in a sector. However, more detailed information is required to understand the key drivers of energy consumption and to provide policy-relevant analysis on how to influence these trends.

This hierarchy is important because it shows how detailed changes at the lowest level (which may be the result of policies [e.g. appliances minimum energy performance standards], technological progress [e.g. more efficient blast furnaces], structural reform [e.g. increased or improved rail infrastructure], or behavioural change [e.g. energy management]) can be linked to a higher order showing how the former affects the latter. With this hierarchy, one can better explain more aggregate changes in energy consumption in terms of components and more carefully choose the depth of analysis required. That choice depends on the questions that need to be answered.

Figure 2.1 • The IEA energy indicators pyramid



Notes: unless otherwise indicated, all tables and figures in this publication are derived from IEA data and analysis. TFC = total final consumption.

Descending lower down the pyramid requires more data and more complex analysis to re-aggregate back up to a higher level. However, each descent also provides a better measure of energy efficiency defined for a specific sector, end use, process and/or technology. Associated with each level of intensities in the pyramid are activity and structural variables. The structural variables are used for weighting the intensities when forming an aggregate parameter of intensity or use.

In its current work, the IEA draws on detailed end-use information about the patterns of energy consumption in more than 20 end uses covering the residential, services, industry and transport sectors (Figure 2.2). This information, coupled with economic and demographic data, is used to identify the factors behind increasing energy consumption as well as those that restrain it. IEA energy indicators typically reflect ratios or quantities and, at a disaggregated level, can describe the links between energy consumption, and human and economic activities. The indicators include measures of activity (such as industry output or volume of freight haulage), measures of developments in structure (such as changes in industry output mix or modal shares in transport) and measures of energy intensity (defined as energy consumption per unit of activity).

Given that not all indicators are relevant to all countries, and that resources are often limited for developing these indicators and collecting the necessary data, it is important to determine which indicators should be given priority. This selection is based on information available to the country, the resources available and the policy question that needs to be answered.

Selecting and developing indicators is only the first step in analysing the energy situation in a particular sector and drawing initial conclusions on how to interpret its past trends and influence future development. Each indicator has its own purpose, but also limitations in what it can explain. Providing an accurate picture requires a set of several indicators, which when analysed jointly will provide a strong basis for policy making. It is also possible to develop CO_2 indicators; the purpose and any limitations identified for the energy efficiency indicators also apply to associated CO_2 indicators.

Box 2.1 • Impacts of behaviour on energy efficiency

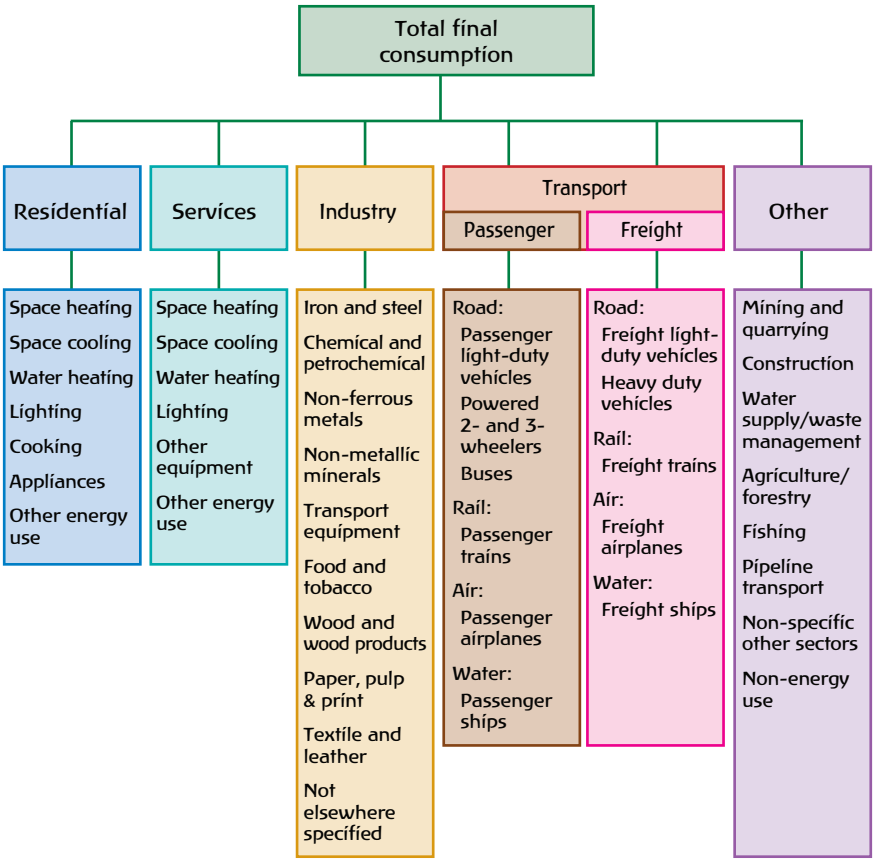
An understanding of the human dimensions of energy consumption can catalyse and amplify technology-based energy savings. This refers to the many social, cultural and psychological factors that shape patterns of human behaviour associated with technology choice, adoption, use and maintenance. Energy-smart behaviours, choices and practices play a key role in unlocking additional sources of energy savings while ensuring the persistence of these savings into the future. These human dimensions account in part for the breadth of the well-known gap that exists between potential and actual levels of efficiency, and they are the key to understanding and reducing the even larger gap between consumer attitudes and behaviours. Conversely, energy savings achieved from technical energy efficiency improvements can be cancelled out by negative behavioural factors.

Research efforts that have attempted to quantify the potential for behaviour-related energy savings and to characterise the nature of the behavioural changes that might contribute to these savings indicate a conservative estimate of behaviour-related energy and greenhouse gas savings in the range of 20% to 30% over the course of the next five to ten years. It is estimated that approximately 22% of household energy consumption in the United States (around 9.1 exajoules [EJ]) could potentially be saved if people were to adopt cost-effective energy conservation and efficiency behaviours (Laitner, Ehrhardt-Martinez and McKinney, 2009). Among the other notable findings, the study concludes that more than half of the potential energy savings (57%) could be achieved through low-cost or no-cost behavioural changes, rather than requiring more complex investment decisions.

Studies on the impact of efficiency labels show that when informed about appliance efficiency, consumers quickly adopt the most efficient technology. In particular, this is true where the link between energy efficiency savings and monetary savings is explicit.

A human dimensions approach attempts to understand energy consumption in the context of individual and organisational needs, abilities, resources and motivations, as well as the social and cultural constraints and opportunities that impede behaviour change and result in specific energy service demands. Consumers may include residential, industrial and commercial energy consumers, although most studies of energy-related behaviours have focused on individuals and households rather than the actions of industrial or commercial groups. Importantly, a human dimensions perspective can greatly complement and expand on the traditional and most commonly used techno-economic model of human behaviour.

Figure 2.2 • Disaggregation of sectors, sub-sectors, and end uses in IEA energy indicators approach



Note: Services include the commercial and public service sectors.

2 Policy information and evaluation

Policy makers are increasingly seeking forward-looking indicators in order to identify issues, to explain what is possible and why it deserves special policy consideration. Energy efficiency policy and programme development requires detailed data at end-use levels to allow programme-level decisions to be estimated and evaluated. Policy makers must tell a compelling and clear story, so substantive information is required to enable a clear policy case. Indicators in isolation from other contextual data have limited value. Effective explanation and reporting of energy efficiency indicators is increasingly important, and requires substance and explanation, not just quality data and elegant indicators.

Analysts should also consider that policy makers often require information about future trends, before or as they occur; they want to be able to define baselines before policies are introduced and to recognise autonomous changes, as well as changes induced by policies.

Box 2.2 • Multiple benefits of energy efficiency improvements

Energy efficiency policy is moving from a naive "energy savings" perspective to one that increasingly seeks to uncover diverse consumer and societal outcomes for better understanding. These include, for instance, the ability to deliver on health, improved social services, and addressing social inequalities in the residential sector, emerging challenges in the austere environment following the global financial crisis.

Developing methodologies for measuring the multiple benefits of energy efficiency is beyond the scope of this manual. Further discussions on the multiple benefits of energy efficiency are available from the IEA publications *Spreading the Net: The Multiple Benefits of Energy Efficiency Improvements* (IEA, 2012) and the *Energy Efficiency Market Report* (IEA, 2013).

A framework for understanding policy interactions: Driving force, state, response

At the heart of all policy design and implementation is a need to understand why policies should be introduced and how well they are working. Various frameworks assist in identifying problems, assessing impacts and developing understanding of the underlying causes and effects. The driving forces-state-response (Organisation for Economic Co-operation and Development [OECD], 1996) framework is a useful framework in analysing those relationships.

Three types of information are needed to understand the context and policy options:

- Information about why the end users use energy the way they do: the driving forces of energy demand
- Information about what currently exists and how it performs: the state of energy consumption
- Information about policy options and potential impact: the response that policies should enable.

Together these form an information cycle that can regularly review and update policies based on their measured performance. Indicators are required to inform each element: driving force, state and response.

Policy responses need to address these driving forces, often in subtle ways. For example, in the residential sector, few governments are likely to manage residential energy demand by regulating occupancy density or household size. Growth in energy consumption due to increased household size has been offset by substantial energy efficiency progress (IEA, 2013).

Supplementary information from ex-post evaluation for example of appliance minimum energy performance standards (MEPS) and labelling show that most of the energy efficiency improvement has come from measurable reductions in energy demand as the appliance stock is gradually turning over to more efficient appliances.

The useful policy information is that appliance efficiency can offset population and lifestyle driving forces and appliance efficiency programmes should be enhanced or maintained to cost-effectively limit or suppress growth in energy demand.

In the indicators pyramid level 2, 3 and beyond, indicators provide the main state indicators in all sectors; energy consumption by fuel type and allocated to key end uses should be disaggregated at geographical or regional levels to reflect climate and societal drivers.

3 Decomposítíon or factorísatíon analysís

Decomposition or factorisation analysis quantifies the impact of different driving forces or factors on energy consumption. Understanding how each of the elements impact energy consumption is essential to determine which have the largest potential to reduce energy consumption and the areas that should be prioritised for the development of energy efficiency policies.

Decomposition of energy end-use trends often distinguishes among three main components affecting energy consumption: aggregate activity, sectoral structure and energy intensities. Energy intensity, in this case, is a proxy for energy efficiency improvements. This is an example of three-factor decomposition analysis. However, if more detailed data are available, it may be possible to extend the decomposition to more than three factors. A more detailed discussion on decomposition analysis and techniques is available in Annex A.

A key issue with decomposition analysis is the choice of activity definition. Ideally the selected activity metrics will utilise easily available data, and fit the stated policy objectives and programme activity objectives as closely as possible. Both physical activity metrics (e.g. tonnes) and activity value (dollars) are valuable for measuring energy efficiency, and both should be tracked on a consistent basis.

The breakdown of energy consumption by sector of different fuels allocated to key end uses should be disaggregated at geographical or regional levels to reflect climate and societal drivers. The decomposition of energy consumption can be extended to address changes in CO_2 emissions by introducing the dimension of fuel mix and carbon intensity (or CO_2 intensity).

Developing Indicators for the Residential Sector

1 What is driving energy consumption in the residential sector?

The residential sector includes those activities related to private dwellings. It covers all energy-using activities in apartments and houses, including space and water heating, cooling, lighting, cooking and the use of appliances (including large appliances and small plug loads). It does not include personal transport, which is covered in the transport sector, or energy consumption to generate electricity and heat, which is covered in the transformation sector. This is to maintain consistency with the country energy balances reported to the International Energy Agency (IEA).

Energy consumption trends in the residential sector and the different end uses are driven by a wide range of factors, including overall energy efficiency improvements, changes in population, energy mix, urbanisation rates, number of occupied dwelling, inhabitants per household, dwelling size, dwelling type, building characteristics and age profile, income level and growth, consumer preferences and behaviour, energy availability, climatic conditions, appliances and equipment penetration rate, and standards.

More generally, for the development of energy indicators, two main activity variables are considered to explain the trends in energy consumption: residential floor area (for space heating and space cooling) and number of occupied dwellings (for water heating, lighting and appliances).[1] However, understanding how each of the factors impacts energy consumption is essential to determine where the largest potential to reduce energy consumption lies, and which area should be prioritised for the development of energy efficiency policies.

Questions and Answers:

Q 1. Which indicators should be developed first in the residential sector?

In countries with a high share of fossil-fuel use in the residential sector, the priority should be to develop indicators for end uses where these energy sources are concentrated, mostly space heating (for cold countries) and water heating.

1. More details on the specificities of the activity variable in relation to each end use are provided in the following sections.

In countries where a policy goal is to reduce the electricity base or peak load (either to limit required capacity additions or to reach a 100% electrification rate), developing indicators for appliances, lighting and space cooling should be the priority, as they represent the main electricity users.

Q2. What is the required level of disaggregation for appliances?

The required level of disaggregation for large energy-using appliances, such as refrigerators, washing machines, and dishwashers, is at the individual appliance level. Data on televisions is generally available but data on other small electrical and electronic appliances, while interesting, may be difficult to obtain and in this case appliances such as computers, laptops and mobile phones can be aggregated together in the category of digital appliances.

Q3. What is climate correction?

Climate correction is an adjustment to space heating and cooling energy consumption to normalise the consumption pattern over time by removing the impact of year-to-year temperature variations. It is recommended to adjust space heating or cooling using the ratio of the number of heating degree days (HDD) or cooling degree days (CDD) in a given year to the 30-year average HDD or CDD number.*

Q4. Should total dwellings or total occupied dwellings be used?

Total occupied dwellings should be used to calculate end-use indicators in the residential sector to avoid distortion in calculations for consumption in dwellings with infrequently used or vacant dwellings. For further discussion, please refer to Energy Efficiency Indicators: Fundamentals on Statistics *(IEA, 2014)*

Q5. Should a distinction between urban and rural dwellings be used?

In countries where there is a significant distinction between the type and size of dwellings in rural or urban areas, or where the availability and fuel mix is different, an urban/rural split is a recommended if the data are available.

* Refer to IEA companion manual, *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014), for definitions of HDD and CDD.

Q6. Should biomass be excluded to compare developed and developing countries?

In certain regions highly dependent on traditional biomass, energy consumption in buildings represents as much as 80% of total final energy consumption (IEA, 2013). Therefore biomass should be included in order to cover the total energy consumption of the residential sector, but the results should not be used for ranking purposes. In countries highly dependent on biomass, high intensities are to be expected, as traditional biomass is likely to be used inefficiently. In any comparison, the local energy resources available to the countries in question should be considered.

Q7. How is electricity use for transport vehicles analysed?

Transport energy should not be included in the residential sector. However, in certain countries, some transport-related energy consumption cannot be separated from residential energy consumption. For example, electricity consumption for block heaters, used to keep the batteries of transport vehicles warm in countries with extremely harsh winters, cannot easily be separated from residential electricity consumption.

2 How is energy consumed and how has it evolved recently?

In 2011, about 23% of global final energy consumption was used in the residential sector. While the share of residential in total final energy consumption remained stable between 1990 and 2011, total residential energy consumption increased 35% as a result of a large number of factors, including increased population and number of occupied dwellings, changes in dwelling size, more appliances, and increased wealth.

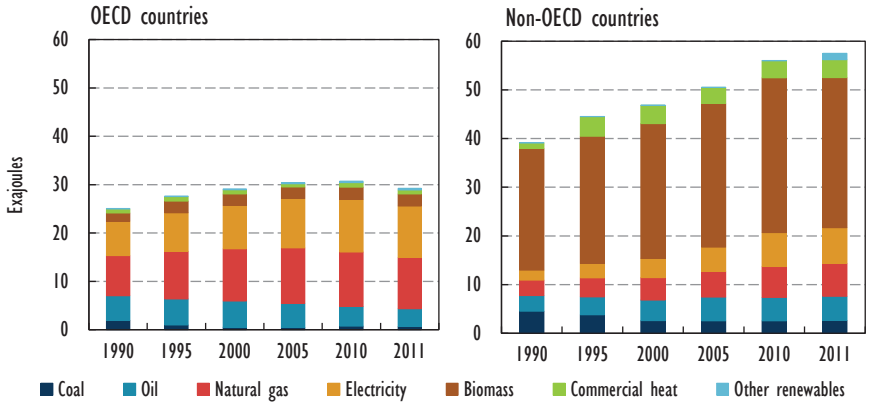
The relative importance of energy consumption in the residential sector, and the energy sources used to meet energy demand, vary dramatically among countries and regions. Electricity and natural gas are the main energy commodities used in the Organisation for Economic Co-operation and Development (OECD) member countries, providing almost three-quarters of total residential energy requirements in 2011.

Biomass remained the most important energy source for the residential sector globally. It is mostly used in tropical non-OECD countries for cooking and water heating. The share of coal and oil decreased, while natural gas and electricity became increasingly important.

Electricity use in OECD countries has been rising rapidly, largely due to the increased penetration of many small appliances and wider deployment of heat pumps for space and water heating.

In non-OECD countries, renewable energy (mostly traditional biomass) remains the dominant energy commodity, accounting for 56% of final energy consumption, but its share is decreasing. Electricity use — although accounting for only a 13% share in 2011 — is by far the fastest-growing energy commodity, its use increasing by 270% since 1990. District heating remains important in the residential sector in some countries, for example Russia, with a share of almost 50%.

Figure 3.1 • Residential energy consumption in OECD and non-OECD countries



Energy consumption per capita is the most widely used and available indicator for the residential sector. This indicator is often used to compare the relative intensity or efficiency performance of countries. While it provides interesting insights on energy consumption trends, it would be misleading to compare the performance of countries based on this indicator. It tells very little about energy consumption in homes and does not reflect specific conditions in different countries.

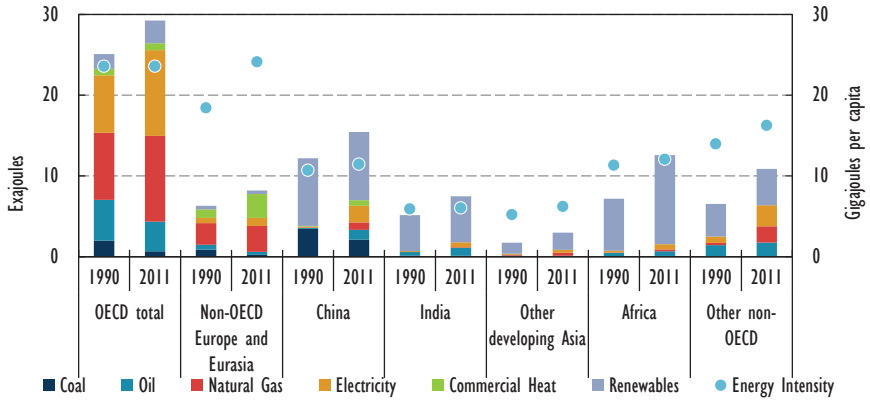
For example, the low energy per capita in India and other developing Asia is not indicative of the countries' efficiency, but reflects the fact that those countries have a very low heating requirement; a large share of population living in rural areas, some with no access to electricity; and a low penetration rate of appliances. In some countries, such factors can be offset by a large dependence on traditional biomass, notably for cooking and water heating. Traditional biomass is often used at very low efficiencies, sometimes as low as 8% to 15%. This can explain high intensities for those regions highly dependent on biomass, as is the case in Africa.

Additional information available for OECD countries indicates that the increase per capita consumption in OECD countries between 1990 and 2011 was not due to a decrease in efficiency. The increase can be explained by other factors, such as an increase in the average house size, a lower number of inhabitants per dwelling and the increase in the number of small electrical appliances owned by households. In fact, energy efficiency improved for most end uses in these countries.

As a result of increases in final energy consumption and changes to the energy mix, global residential carbon dioxide (CO_2) emissions[2] increased between 1995 and

2. CO_2 emissions include both direct and indirect emissions. As CO_2 emission factors are not available for heat in 1990, the base year used for CO_2 emissions analysis throughout the report is 1995.

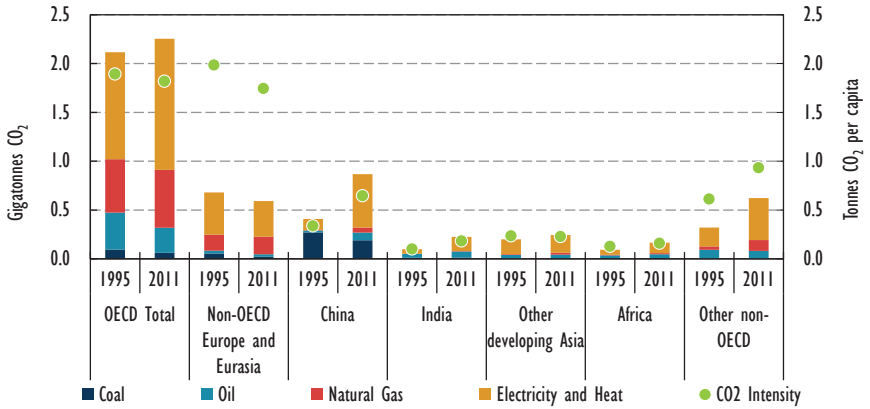
Figure 3.2 • Residential energy consumption and aggregate energy intensity



2011 by 27% to reach approximately 5 gigatonnes of CO_2 ($GtCO_2$). This is more than the increase in final energy consumption, implying an increased CO_2 intensity of the residential energy mix.

Examining residential emissions on a per capita basis reveals that in 2011, global average emissions were 0.71 tonnes of CO_2 (tCO_2) per person, 4% higher than in 1995. However, there are wide differences among countries. Per capita CO_2 emissions in OECD countries in 2011 are on average more than four times higher than in non-OECD countries. This difference can be explained by a combination of lower per capita residential energy consumption in non-OECD countries and a lower carbon intensity of the energy mix, due to a high share of renewable energy. This difference is less striking than in 1995, when OECD average CO_2 intensity was more than five times higher than in non-OECD. A decrease in the CO_2 intensity of electricity and heat in OECD countries (-14%), combined with an increase in equipment diffusion rate and higher electricity and heat CO_2 intensity in non-OECD countries (+24%), explains part of the overall trend between 1995 and 2011.

Figure 3.3 • Residential CO_2 emissions and intensity

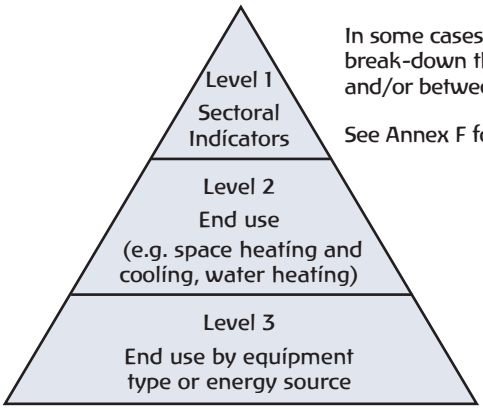


3 How to prioritise the development of indicators (Which indicators should be developed?)

There are numerous ways to define the analytical framework to develop energy efficiency indicators in the residential sector. The level of detail greatly depends on information available and the country situation. In countries where most of the building stock consists mainly of one type of building, a breakdown between different dwelling types may not be a priority, e.g. in Russia where over 70% of housing units are in multi-family dwellings (EBRD, 2011). On the other hand, this distinction may be important for other countries; for example, single-family dwellings account for about 55% of the stock in Canada and multi-family dwellings for 30%; this is particularly important as single-family dwellings in Canada use two times more energy per household than apartments.

Similarly, a distinction between rural and urban households may be essential in some countries where there are noticeable differences in availability of fuels and equipment. But in other countries where rural and urban households have access to the same source of energy and have the same relative income, this distinction is not relevant. In most OECD countries, the main difference between urban and rural household in the dwelling types – where multi-family dwellings dominate in urban areas and single-family dwellings dominate in rural areas.

Figure 3.4 • Detailed indicators pyramid of the residential sector



In some cases it may be required to further break-down this level between urban and rural, and/or between different dwelling type.

See Annex F for alternative pyramids.

4 Development of indicators by level of the pyramid

Table 3.1 summarises all the indicators described in the residential section and provides a quick overview of the usefulness of the indicator. This table matches the discussion on indicators in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 3.1 • Summary list of the most common indicators for the residential sector

Indicator	Coverage	Energy data	Activity data	Code	Recommended indicator
Space heating energy consumption per capita	Overall	Total space heating energy consumption	Total population	H2a	
Space heating energy consumption per dwelling	Overall	Total space heating energy consumption	Total number of dwellings	H2b	
Space heating energy consumption per floor area (idem per floor area heated)	Overall	Total space heating energy consumption	Total floor area	H2c	☺
	By dwelling type	Space heating energy consumption of dwellings type A	Floor area of dwellings type A	H3a	
	By heating system	Space heating energy consumption of dwellings with system α	Floor area of dwellings with heating system α	H3b	
	By energy source	Space heating energy consumption of dwellings with energy source Z	Floor area of dwellings with energy source Z	H3c	
Space cooling energy consumption per dwelling with air conditioning (A/C)	Overall	Total space cooling energy consumption	Total number of dwellings with A/C	C2a	
Space cooling energy consumption per floor area of dwellings with A/C	Overall	Total space cooling energy consumption	Total floor area cooled	C2b	☺
	By dwelling type	Space cooling energy consumption of dwellings type A	Floor area cooled of dwellings type A with A/C	C3a	
	By type of cooling system	Space cooling energy consumption of dwellings with A/C system α	Floor area cooled of dwellings with A/C system α	C3b	
	By energy source	Space cooling energy consumption of dwellings with A/C system energy source Z	Floor area cooled of dwellings with A/C energy source Z	C3c	
Water heating energy consumption per capita	Overall	Total water heating energy consumption	Total population	W2a	
Water heating energy consumption per dwelling	Overall	Total water heating energy consumption	Total number of dwellings	W2b	☺
	By type of water heating system	Water heating energy consumption for dwellings with water heating system α	Total number of dwellings with water heating system α	W3a	
	By type of energy source	Water heating energy consumption for water heating systems with energy source Z	Total number of dwellings with systems with energy source Z	W3b	
Lighting energy consumption per capita	Overall	Total lighting energy consumption	Total population	L2a	
Lighting energy consumption per dwelling	Overall	Total lighting energy consumption	Total number of dwellings	L2b	☺
	By dwelling type	Lighting energy consumption of dwellings of type A	Number of dwellings of type A	L3a	
Lighting energy consumption per floor area	Overall	Total lighting energy consumption	Total floor area	L2c	
	By dwelling type	Lighting energy consumption of dwellings of type A	Total floor area of dwellings type A	L3b	
Cooking energy consumption per capita	Overall	Total cooking energy consumption	Total population	K2a	
Cooking energy consumption per dwelling	Overall	Total cooking energy consumption	Total number of dwellings	K2b	☺
	By energy source	Cooking energy consumption with cooking energy source Z	Number of dwellings with cooking energy source Z	K3a	
Appliances energy consumption per capita	Overall	Total appliances energy consumption	Total population	A2a	
Appliances energy consumption per dwelling	Overall	Total appliances energy consumption	Total number of dwellings	A2b	
Energy consumption per appliance unit	By appliance type	Energy consumption for all appliances of type A	Number of appliances of type A	A3a	☺

Heating Cooling Water heating Lighting Cooking Appliances

Level 1 indicators

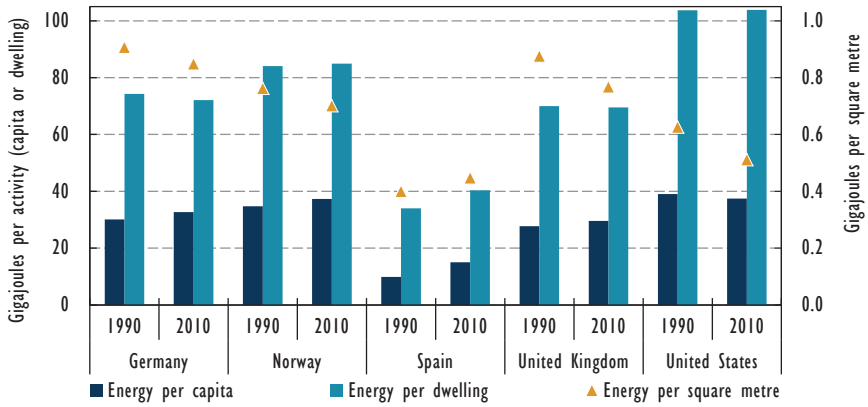
Aggregate residential energy intensity

Definition: Amount of total residential energy consumption per capita, occupied dwelling or floor area. Energy consumption per capita indicates how much energy is used by each person in a country/region.

Energy consumption per occupied dwelling and per floor area are considered better indicators than residential energy per capita as they are normalised by the key residential driver: the scale of dwellings.

- Energy consumption per occupied dwelling takes into account the changes in the number of inhabitants per house and can be used to explain why similar countries have different energy per capita consumption. For a similar population, one country may have a lower number of occupied dwellings if there are more people per dwelling. A lower number of occupied dwellings means fewer dwellings to heat and cool and fewer total appliances.
- Energy consumption per floor area takes into account the relative size of dwellings. Again, in countries with similar populations and a similar number of occupied dwellings, total energy consumption may be higher in the country where average dwellings are bigger as they require more energy to meet a similar indoor temperature. On the other hand, energy consumption for lighting, water heating and appliances is more closely related to the number of dwellings and inhabitants per dwelling than to the actual size of the dwelling.

Figure 3.5 • Example of level 1 indicators in Germany, Norway, Spain, United Kingdom and the United States



Use of level 1 indicators: Comparing these three indicators may help in understanding which end uses have the strongest impact on changes in energy consumption, as the different end uses are influenced by different activity drivers (i.e. space heating and space cooling trends are mostly driven by the total floor area, as appliances, lighting and water heating are more closely linked to the number of occupied dwellings).

Relevance for policy development: These indicators provide general insights on the evolution of the sector and how it compares internationally. But given the many factors

that influence these indicators, the information obtained is not sufficient to ascertain where efficiency improvements can be made and where more attention is required.

Cross-country comparison: Comparing countries based on these indicators may be misleading. However, it may provide indication on the future trends in energy consumption. Developing countries with very low per capita consumption will most likely increase their consumption of energy as living standards and energy access improve.

Data availability and sources:

- Energy consumption: usually available in national energy balances and in IEA energy balances
- Population: available from United Nations Department of Economic and Social Affairs and from national statistics offices
- Occupied dwellings: may be available from national statistical offices, for example through surveys on household spending.

Related indicators: Energy consumption is usually available by energy sources from energy balances. An analysis of the level and trends of different energy sources may help identify which end use is the most important and largest user of energy. Electricity is the dominant source for appliances, lighting and space cooling; biomass and coal are mostly used for cooking and water heating; and natural gas and oil are mostly used for space heating and water heating.

Table 3.2 • Description of level 1 indicators

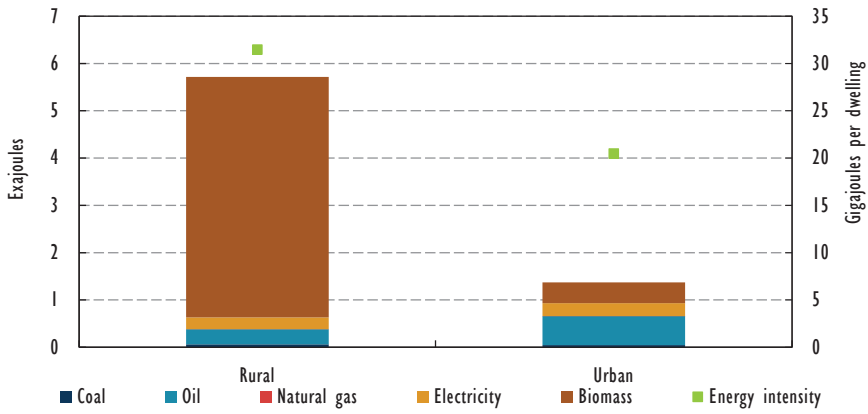
Indicator	Data required	Purpose	Limitation
Residential energy consumption per capita	• Total residential energy consumption by energy source • Population	• Can be constructed for many countries and provides a consistent basis for comparison • Provides qualitative information on which end use might have been the fastest growing	• **Does not measure energy efficiency developments** • The indicator is influenced by the penetration rate of different appliances, the number of inhabitants per house, the income level of households, the trends in house size and dwelling type, the efficiency of water and space cooling devices, the type of light bulbs used, the efficiency of the building envelope, etc.
Residential energy consumption per occupied dwelling	• Energy consumption • Number of occupied dwellings	• Provides a general overview of the trends in aggregate energy intensity • When energy consumption by end use is not known, energy consumption per occupied dwelling can be used as an energy-intensity indicator • Some important conclusions can be drawn if the weather, ownership of energy-using appliances and dwelling area are known	• **Does not measure energy efficiency developments** • Influenced by many factors not related to energy efficiency such as changes in income level or energy prices

Indicator	Data required	Purpose	Limitation
Residential energy consumption per floor area	• Energy consumption • Total floor area	• Monitor energy consumption in the residential sector • Combined with energy consumption per household, provides useful insights on what might have been the main driver of energy consumption	• Does not measure energy efficiency developments • Influenced by many factors not related to energy efficiency such as changes in income level or energy prices

Further disaggregation at level 1: Residential energy intensity in urban and rural areas

In countries where the energy consumption pattern is very different in rural and urban areas, developing indicators for each segment are required to better understand the overall trends, and define adequate policy intervention in different context. The different indicators specified in the previous level and their definitions, purpose and limitation can also be applied at this level. However, the energy consumption breakdown is not available from energy balances.

Figure 3.6 • Estimated energy consumption and intensity in rural and urban areas in India, 2010



The analysis of these indicators for India indicates that the urban areas have lower energy intensity than rural. This might be counter-intuitive, as urban populations generally have a higher income level, more energy-consuming equipment and greater access to energy sources.

This result can be largely explained by the very different fuel mix used in the residential sector in these two segments. In rural areas, more than three-quarters of energy is biomass; this share is less than 50% in urban area. This striking difference explains, in part, the higher intensity in rural areas. The efficiency of biomass, being mostly used for residential cooking in India, can be as low as 8% to 15%. As a point of comparison, natural gas used in a conventional combustion boiler has an efficiency of up to 84%.

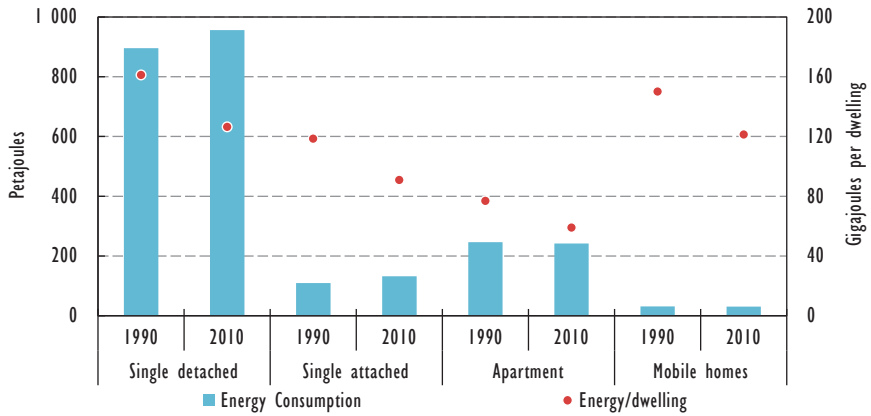
The evolution of these indicators also has an impact on the overall trend in residential energy consumption. As the urban population has lower per capita energy consumption than rural, an increase in the urbanisation rate of a country will translate into a decrease in the overall energy consumption per capita in a country. This decrease will reflect a change in the composition of the residential sector, and not an improvement in residential energy efficiency.

Further disaggregation at level 1: Residential energy intensity by dwelling type

Taking into consideration the different dwelling types may be important to understand the overall trends in residential energy consumption. The type of dwelling has a noticeable impact on heating and cooling requirement. Single-family dwellings, where all the walls and the roof are subject to exterior elements, usually require more energy to maintain the comfort level in the house than an apartment, where there may be only one wall facing the exterior. Countries with a generally higher share of single-family dwellings will therefore tend to have higher energy requirements than countries where a large share of the stock is multi-family dwellings or apartments.

At the same time, dwelling type usually has no direct impact on the energy consumption for appliances or water heating. As such, this level will be important only for countries with high heating or cooling load, and where there is a mix of very different types of dwellings. The different indicators specified in the previous level and their definitions, purpose and limitations also apply at this level. However, the energy consumption breakdown is not available from energy balances.

Figure 3.7 • Energy consumption and intensity for different dwelling type in Canada



Note: energy in Canada is reported in gross calorific value.

Source: *NRC (Natural Resources Canada)* (2013), *National Energy Use Database, Office of Energy Efficiency*, NRC, Canada.

The analysis of energy consumption per dwelling in Canada indicates that energy intensity is more than two times higher in single-family dwellings than in apartments. The comparison of energy per floor area may show different magnitude. As a result, the change in the relative importance of apartments in Canada, which decreased

between 1990 and 2010, had an upward impact on the total residential energy trends.

While the total floor area or number of occupied dwellings by dwelling type is sometimes available from national censuses or surveys, energy consumption at this level often requires the development of a specific survey on households. Given the resources required to build this indicator, its necessity should be carefully evaluated and be only developed if deemed essential to support better policy making.

Level 2 indicators

Energy intensity by end use: Space heating

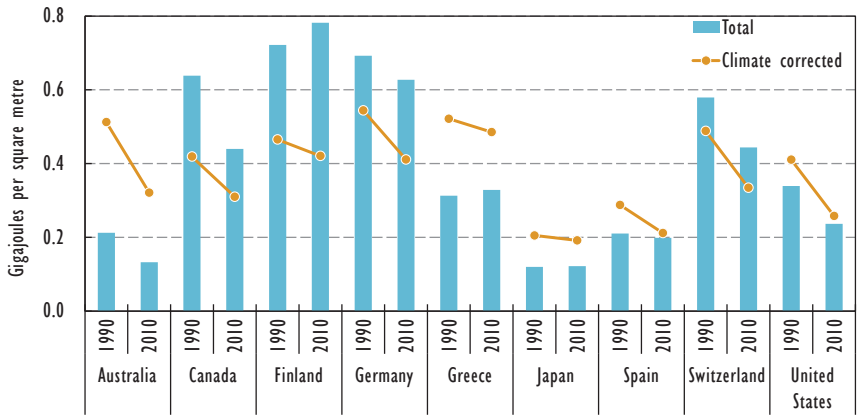
Definition: Amount of energy consumed for space heating per capita, per occupied dwelling or per floor area. In some countries, only a fraction of the total floor area is heated; in this case, this indicator should use heated floor area as the activity variable to provide more accurate results on intensity trends. The preferred indicator is energy per floor area.

Relevance for policy development: Space heating intensity is influenced not only by the climate, but also by the building volume, age of a building, the building's envelope efficiency, consumer preferences, installation practices, control features, the energy source used, operational limitations and the efficiency of the heating equipment. As a result, more detailed information on buildings and heating equipment is required to provide a strong basis for policy development.

Cross-country comparison: For this indicator to be relevant for cross-country comparison, the energy consumption for space heating should be corrected to take into account the HDD in any particular year.

While a more accurate basis for comparison is the total volume to be heated, and not the total area, house volumes are not usually available for countries. As such, indicators based on volume are not discussed in this publication.

Figure 3.8 • Energy intensity and climate-corrected intensity for space heating



Note: climate normalised at 2 700 HDD.

Data availability and sources: As for the other end uses, energy consumption is not widely available and requires specific surveys, monitoring or modelling. Details on how to collect this information are provided in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 3.3 • Description of level 2 indicators: space heating

Indicator	Data required	Purpose	Limitation
Space heating energy consumption per capita	• Energy consumption for space heating • Population	• Provides an indication of the trends in space heating consumption	• This indicator does not take into account the effect of floor area and the share of floor area heated
Space heating energy consumption per occupied dwelling	• Energy consumption for space heating • Number of occupied dwellings	• Provides an indication of the trends in space heating energy consumption.	• This indicator does not take into account the effect of floor area and the share of floor area heated
Space heating energy consumption per floor area	• Energy consumption for space heating • Total floor area	• Provides an indication of the trends in space heating energy consumption.	• Does not provide a distinction between equipment and building efficiency • Does not measure energy efficiency developments • Does not take into account the floor area not heated and the dwellings without space heating
Space heating energy consumption per floor area heated	• Energy consumption for space heating • Total heated floor area	• Where only a share of total floor area is heated, it provides a better indicator for trends in space heating energy consumption	• Does not provide a distinction between equipment and building efficiency • Does not measure energy efficiency developments

Beyond level 2 indicators

Space heating energy consumption is influenced by consumer preference (e.g. preferred in-door temperature); income of households; the type, age and efficiency of the dwelling; the energy sources; and the technology used. Detailed information including consumer behaviour is required to produce effective indicators to assess each of these driving factors.

From a technology choice perspective, there are many fundamentally different technologies that can have a large impact on energy consumption. In the future it would be advisable to collect data on whether households have heat pumps instead of electric resistance heaters, and condensing boilers instead of conventional boilers (IEA, 2013b).

Energy intensity by end use: Space cooling

Definition: Amount of energy consumed for cooling per dwelling with air conditioning or per floor area cooled. Given that only a fraction of dwellings in most countries have air conditioning, and sometimes only a fraction of the total floor area in the dwelling is cooled, indicators using total population, occupied dwellings or floor area as an activity variable would not be meaningful for this end use. While energy per dwelling with air conditioning is a relevant indicator, energy per floor area cooled is the preferred one as it also takes into consideration the area of a dwelling being cooled. The advantages and caveats associated with the space heating indicators also apply to the space cooling indicators.

Relevance for policy development: This indicator can provide insights into the potential for increase in energy consumption for cooling as well as the potential for improving energy efficiency in the end use.

Cross-country comparison: For this indicator to be relevant for cross-country comparison, the energy consumption for cooling should be corrected to take into account the CDD in any particular year.

Data availability and sources: As for the other end uses, energy consumption is not widely available and requires specific surveys, monitoring or modelling. Details on how to collect this information are provided in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 3.4 • Description of level 2 indicators: space cooling

Indicator	Data required	Purpose	Limitation
Space cooling consumption per dwelling with air conditioning	• Energy consumption for cooling • Number of dwellings with air conditioning	• Provides an indication of the trends in cooling energy consumption	• Does not consider the area of a dwelling being cooled
Space cooling energy consumption per floor area cooled	• Energy consumption for cooling • Floor area cooled	• Provides an indication of the trends in cooling energy consumption • Can be used as a proxy for cooling energy efficiency • May indicate the effectiveness of policies (either minimum energy performance, or promotion of high-efficiency air conditioners)	• Does not consider the different technologies that are used to cool dwellings, so may under- or over-estimate the actual energy efficiency

Note: Space cooling per capita is not a relevant indicator as cooling is not widely deployed in the residential sector.

Beyond level 2 indicators

There are currently only a handful of countries that can develop the proposed level 1 indicators. These indicators may serve as a proxy for energy efficiency, but better tracking of policies or potential requires further data on the different technologies

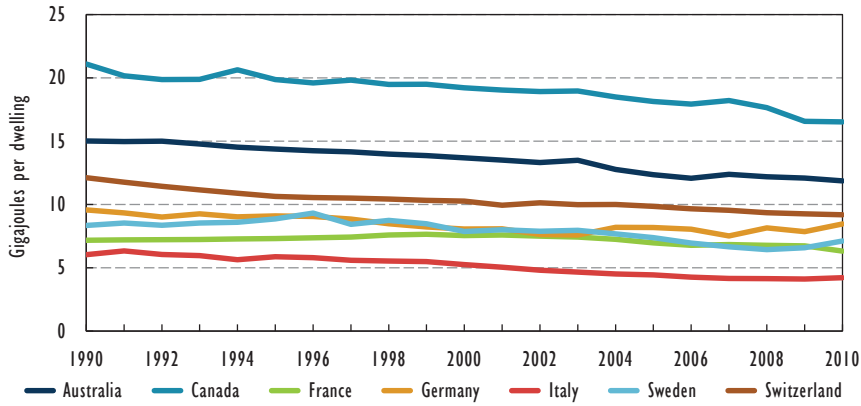
used for cooling. Clarifying the policy questions and then undertaking carefully tailored surveys are first steps. Space cooling can be provided through different technologies such as centralised, window or split systems. To better track the trends in energy efficiency for cooling, and to better understand how to influence this trend, information at the technology level (product sales trends) is required.

Energy intensity by end use: Water heating

Definition: Amount of energy consumed for water heating per capita or occupied dwelling. Energy consumption per occupied dwelling is considered a better indicator than energy per capita. Different energy sources are used for water heating, with biomass being dominant in developing countries and natural gas in OECD countries.

Energy consumption per occupied dwelling provides useful insights on the efficiency of water heating, although it is still influenced by the different average number of occupants per dwelling when used for cross-country comparisons.

Figure 3.9 • Example of water heating energy intensity by country (energy per occupied dwelling)



The comparison between developed and developing counties, where very different energy sources are used, might not be relevant in assessing the efficiency of water heaters. Where a high share of biomass is used, intensity would tend to be higher. However, looking at changes in the energy mix over time and comparing average intensity can provide insights on the effect of fuel mix on the overall intensity of water heating.

As water heating is not available or desired in all households in developing countries, it is important to consider the number of dwellings with water heating and the adequacy of service. This information is not normally collected.

Relevance for policy development: This indicator is highly dependent on the type of energy source used, the efficiency of water heaters and water outlets, and the penetration of water heating. While it provides important insights, more detail is preferable to assess the potential for reduction.

Table 3.5 • Description of level 2 indicators: water heating

Indicator	Data required	Purpose	Limitation
Water heating energy consumption per capita	• Energy consumption for water heating • Population	• Provides an indication of the trends in water heating energy consumption • If the indicator is developed at the energy source level, it may indicate the effectiveness of policies (either minimum energy performance, or promotion of solar water heating)	• This indicator does not take into account the number of people with access to or need for water heating • Does not take into account the effect of inhabitants per household • Does not consider the type of energy source used for water heating
Water heating energy consumption per occupied dwelling	• Energy consumption for water heating • Number of occupied dwellings	• Provides an indication of the trends in water heating energy consumption • If the indicator is developed at the energy source level, it may indicate the effectiveness of policies (either minimum energy performance, or promotion of solar water heating)	• Does not take into account the number of occupied dwellings with access to or need for water heating

Cross-country comparison: Comparing developed and developing countries based on this indicator may be misleading as the intensity depends on the number of occupied dwellings with water heating (or the number of water heaters) and the source of energy consumed.

Data availability and sources: As for the other end uses, energy consumption is not widely available and requires specific surveys, monitoring or modelling. Details on how to collect this information are provided in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

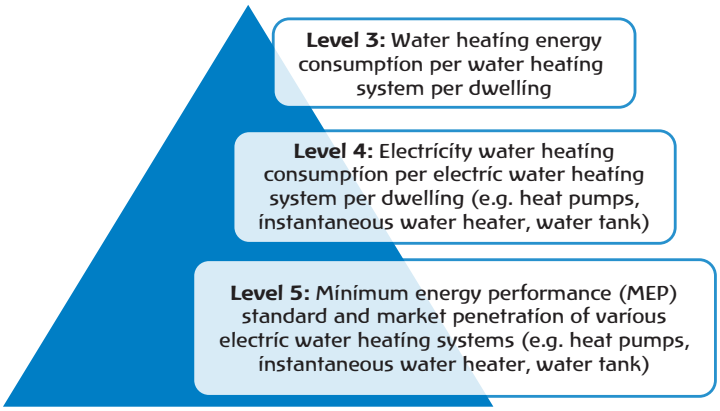
Beyond level 2 indicators

While developing level 2 indicators for water heating provides a good basis for understanding the trends in energy consumption, a better assessment of the impact and potential of efficiency improvement requires the development of indicators at a more disaggregated level.

Energy intensity should be developed by energy source and technology type (Figure 3.10) to track policy effectiveness. While an indicator based on energy source may be sufficient to understand how to influence the trends in energy consumption, the development of minimum energy performance standards (MEPS) and tracking of performance require the development of indicators by technology type. Having this level of detail would provide a good basis for understanding how a policy targeting one particular technology would affect the total energy consumption, and would also allow a comparison among countries of the efficiency of the different technologies.

For example, deriving and reporting market saturation data on heat pump water heaters and electric resistance water heaters will be important in the future. Similarly, reporting instantaneous condensing gas water heaters, condensing gas water heaters and conventional gas water heater shares will become very helpful to policy makers (IEA, 2013).

Figure 3.10 • Beyond level 2 for water heating: an example for heaters using electricity

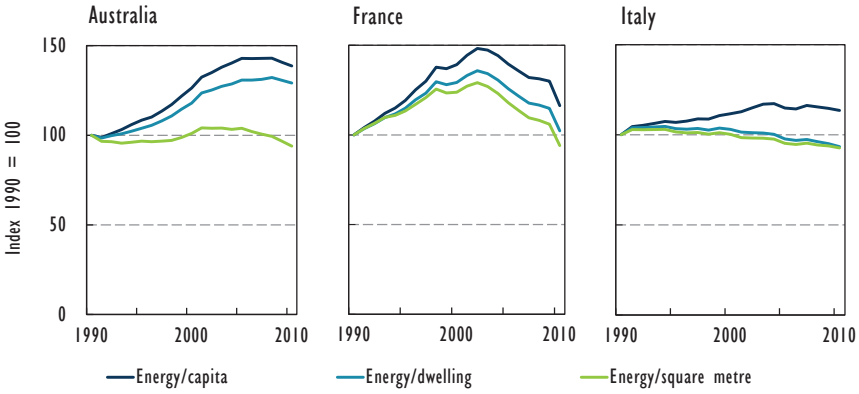


Energy intensity by end use: Lighting

Definition: Amount of energy consumed for lighting per capita, occupied dwelling or floor area. Energy consumption per capita indicates how much energy is used for lighting by each person in a country/region.

Energy consumption per occupied dwelling and per floor area are considered better indicators than energy per capita.

Figure 3.11 • Examples of lighting energy intensity in Australia, France and Italy



While there is a clear link between the lighting requirement and the population, energy consumption per dwelling takes into account the fact that several people may occupy the same room, thus requiring less energy (per capita) than if only one person is in the dwelling.

Energy consumption per floor area takes into account the area needing lighting. However, the link between lighting requirement and floor area is not as evident as energy per dwelling. One person living in a small dwelling does not, in theory, require less lighting than one living in a large multi-room dwelling – as only the room where the person is requires lighting.

Table 3.6 • Description of level 2 indicators: lighting

Indicator	Data required	Purpose	Limitation
Lighting energy consumption per capita	• Energy consumption for lighting • Population	• Provides an indication of the trends in lighting energy consumption • May indicate the effectiveness of an energy conservation campaign or the impact of efficient lighting regulation	• Includes the impact of both energy efficiency and consumer behaviour • This indicator does not take into account the effect of inhabitants per household • Does not take into account daylight flux differences per country • Does not take into account local consumer preferences for light colour
Lighting energy consumption per occupied dwelling	• Energy consumption for lighting • Number of occupied dwellings	• Can be used as a proxy for lighting energy efficiency • Provides an indication of the trends in lighting energy consumption • May indicate the effectiveness of an energy conservation campaign or the impact of efficient lighting regulation.	• Includes the impact of both energy efficiency and consumer behaviour • Does not take into account daylight flux differences per country • Does not take into account local consumer preferences for light colour
Lighting energy consumption per floor area	• Energy consumption for lighting • Total floor area	• Provides an indication of the trends in lighting energy consumption • May indicate the effectiveness of an energy conservation campaign or the impact of efficient lighting regulation.	• Includes the impact of both energy efficiency and consumer behaviour • Does not take into consideration the lighting needs of individuals • Does not measure technical energy efficiency developments • Does not take into account daylight flux differences per country • Does not take into account local consumer preferences for light colour

Generally, the three indicators follow the same trends over time, with energy consumption per square metre declining at a faster rate than energy per capita and per dwelling.

Relevance for policy development: Although it still includes the difference in daylight hours in different regions/countries, lighting energy intensity, and the differences by country, provides insights into cultural expectations of lighting quality and lighting service levels, as well as the level of lighting efficiency in a country and the potential to further reduce energy consumption.

Cross-country comparison: The different intensity among countries indicates both the different level of energy efficiency of lighting and energy conservation measures/behaviour.

Data availability and sources: As for the other end uses, energy consumption information is not widely available and requires specific surveys, monitoring or modelling. Details on how to collect this information are provided in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Related indicators: Electricity is the main energy source for lighting. However, kerosene and liquefied petroleum gas (LPG) are still in use in some countries, and solar is a new source that may increase in importance in the future. Where there are different sources of energy consumed to generate lighting, this indicator should be developed by energy source to get a better picture of the lighting energy trends.

Beyond level 2 indicators

Lighting energy consumption per occupied dwelling could provide a proxy for energy efficiency for this end use. However, it is possible to further refine this indicator and better assess policies or measures that have been put in place to reduce the energy intensity of lighting.

Lighting in a dwelling can be provided by different types of light sources (e.g. incandescent, halogen, compact fluorescent lights [CFLs], linear fluorescents, or light-emitting diodes [LEDs]). Tracking the actual impact of a measure promoting the use of efficient lighting may require detailed surveys that collect information on the number of lights in dwellings, their efficiency and usage. This requirement can be more complex, based on the collection of the number of different types of lighting sources, compared with the estimated consumption from each lighting type, which can be very different.

Energy intensity by end use: Cooking

Definition: Amount of energy consumed for cooking per capita or occupied dwelling. Energy consumption per occupied dwelling is considered as a better indicator than energy per capita. Due to the difficulty of obtaining detailed data, cooking does not include small appliances such as micro-wave ovens and rice cookers. Those small appliances are included in the "appliances" end use. While cooking is considered in the "appliances" category in many developed countries, it is presented separately here given its particularity. While the main energy source used for appliances is electricity, numerous energy sources can be used for cooking. In developing

countries, biomass is often the most widely used energy for cooking, most notably in rural areas. For three countries with disaggregated cooking data, cooking energy consumption has dropped by 20% over the past 20 years, as more efficient cooking appliances turn over in the stocks (Figure 3.12).

Figure 3.12 • Example of cooking energy intensity by country (energy/occupied dwelling)

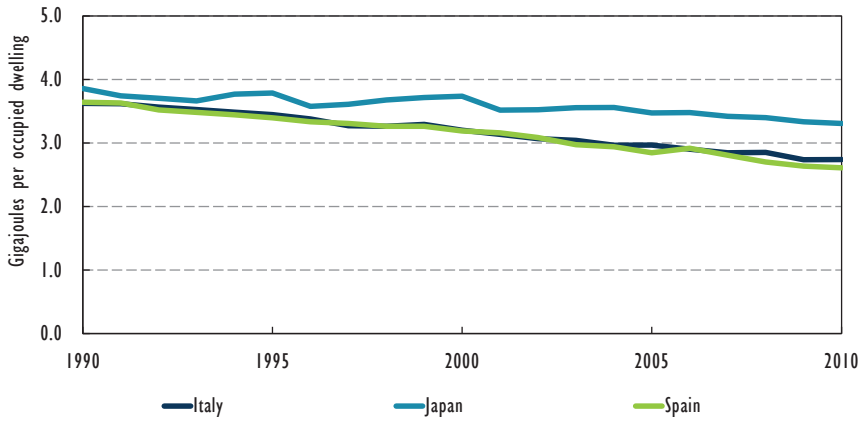


Table 3.7 • Description of level 2 indicators: cooking

Indicator	Data required	Purpose	Limitation
Cooking energy consumption per capita	• Energy consumption for cooking • Population	• Provides an indication of the trends in cooking energy consumption • If the indicator is developed at the energy source level, it may indicate the effectiveness of policies (either minimum energy performance or promotion of high-efficient biomass cook stoves)	• This indicator does not take into account the effect of inhabitants per dwelling • Does not consider the use of small appliances for cooking or cooking habits
Cooking energy consumption per occupied dwelling	• Energy consumption for cooking • Number of occupied dwellings	• Can be used as a proxy for cooking energy efficiency (if developed at the energy source level in some countries) • Provides an indication of the trends in cooking energy consumption • If the indicator is developed at the energy source level, it may indicate the effectiveness of policies (either minimum energy performance or promotion of high-efficient biomass cook stoves	• Does not consider the use of small appliances for cooking or cooking habits

As different sources of energy are used in different countries, a comparison of cooking intensity might not be relevant to assess the cooking intensity performance of a country. Comparing developing countries in Asia relying mostly on biomass with OECD countries would not provide much insight. However, this comparison is relevant in countries where the energy mix is similar, such as in developed countries. Social conditions and customs in different countries may also have an impact on this indicator.

Relevance for policy development: In countries relying mostly on conventional energy sources, this indicator provides important insights on the level of cooking efficiency. For countries where a wide range of sources is used in cooking, this indicator should be developed by energy sources.

Cross-country comparison: This indicator can be used for cross-country comparison where similar energy sources are used.

Data availability and sources: As for the other end uses, energy consumption is not widely available and require specific surveys, monitoring or modelling. Details on how to collect this information are provided in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Beyond level 2 indicators

There are numerous types of cooking devices. To better track the trends in energy efficiency for cooking, one key indicator is the unit energy consumption (UEC) of the cooking devices, usually expressed in kilowatt hours per year (kWh/year). The average UEC for a country can be obtained by dividing the total energy consumption (converted to kWh) by the total number of cooking devices. This indicator can be developed for the average stock (Table 3.8), as well as for the new cooking equipment sold in the market. Using this indicator, it is possible to shape future policies and ensure that future regulations, or MEPS, will drive best available technologies (BATs) in the market.

Table 3.8 • Average unit energy consumption of cooking in selected countries (kWh/year)

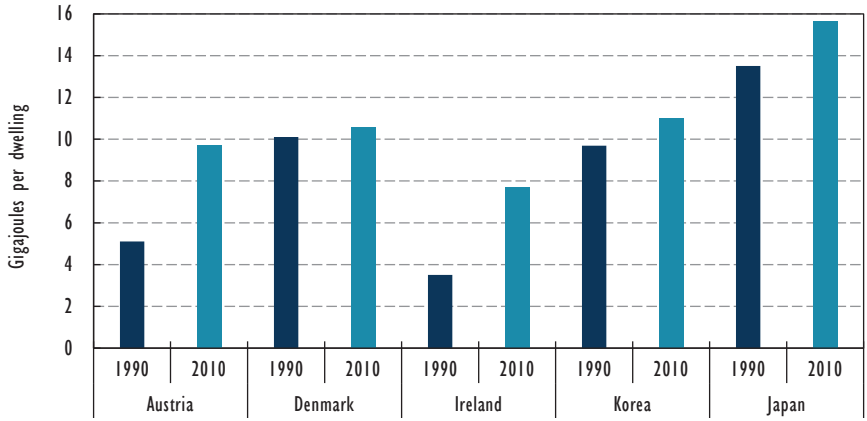
	1990	1995	2000	2005	2010
Canada	834	822	813	784	716
Finland	493	n.a.	n.a.	n.a.	308
Germany	531	477	504	508	539
New Zealand	719	686	743	650	691
United Kingdom	931	863	821	812	732

Energy intensity by end use: Appliances[3]

Definition: Amount of energy consumed for appliances per capita or occupied dwelling. Energy consumption per occupied dwelling is considered as better indicator than energy per capita.

3. Appliances include large appliances (refrigerators, freezers, clothes washers, clothes dryers, dishwashers) as well as small electrical plug-loads (e.g. computers, printers, televisions, toasters, coffee makers).

Figure 3.13 • Example of appliances energy intensity by country (energy per occupied dwelling)



Due to the many different appliances included in this end use, and the different trends and level of penetration rate for different appliances, drawing conclusions on the efficiency of a country can be misleading. However, comparing the trends in energy consumption for this end use with the other end uses can provide useful insights as to the relative impact it has on the total energy consumption in the residential sector.

Relevance for policy development: While this indicator may provide important insights on the relative importance of this end use within the sector, it is too aggregated to indicate the potential to improve energy efficiency in this end use.

Table 3.9 • Description of level 2 indicators: appliances

Indicator	Data required	Purpose	Limitation
Appliances energy consumption per capita	• Energy consumption for appliances • Population	• Provides an indication of the trends in appliances energy consumption • When compared with other end uses, provides insights of the change in its importance in the residential sector	• This indicator does not take into account the effect of inhabitants per occupied dwelling • Does not take into consideration the relative penetration rate of different appliances • Does not take into account size/capacity, usage
Appliances energy consumption per occupied dwelling	• Energy consumption for appliances • Number of occupied dwellings	• Provides an indication of the trends in appliances energy consumption • When compared with other end uses, provides insights of the change in its importance in the residential sector	• This indicator does not take into account the effect of inhabitants per occupied dwelling. • Does not take into consideration the relative penetration rate of different appliances • Does not take into account size/capacity, usage

Cross-country comparison: It would be misleading to use this indicator for cross-country comparison given its heterogeneous nature. However, the general trend observed over time and the relative importance of this end use within the residential sector can provide useful insights about a country's situation.

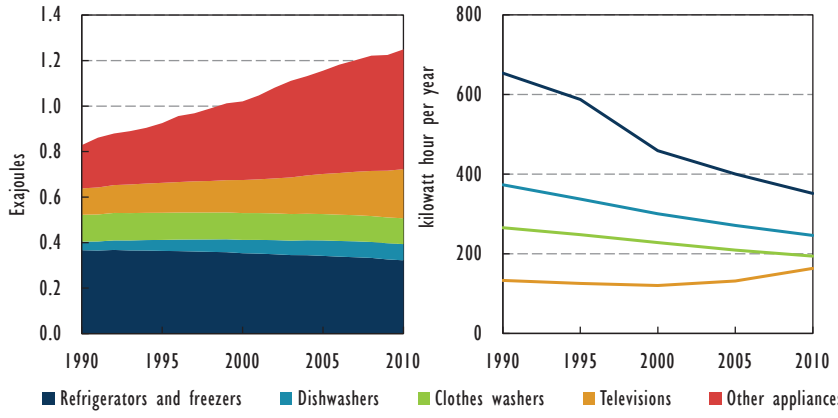
Data availability and sources: As for the other end uses, energy consumption is not widely available and requires specific surveys, monitoring or modelling. Details on how to collect this information are provided in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Beyond level 2 indicators

As there are numerous types of appliances, a further disaggregation is required to understand the trends in appliances energy consumption and to provide indicators relevant to policy making. A first step is to distinguish between large and small appliances. Analysis of the energy trends between those categories indicate that, while overall consumption for appliances increased between 1990 and 2010, this increase was solely due to small appliances (Figure 3.14). The relatively stable energy consumption for major appliances, despite the increased number in dwellings and penetration rate, shows the impact of many years of energy efficiency regulations.

To better track the trends in energy efficiency for appliances, one key indicator is the UEC (also referred to as specific consumption) of the large appliances (this indicator is rarely available for small appliances), usually expressed in kWh/year. The average UEC for a country can be obtained by dividing the total energy consumption (converted to kWh) by the total number of appliances. This indicator can be developed for the average stock, as well as for the new appliances sold in the market. Using this indicator, it is possible to shape future policies and ensure that future regulations, or minimum energy performance standards (MEPS), will drive BATs in the market.

Figure 3.14 • *Energy consumption for large and small appliances*



Note: Includes Australia, Austria, Canada, Denmark, France, Germany, Italy, Netherlands, Switzerland and United Kingdom data only.

While the UEC is an important indicator, other considerations should be taken into account to understand the differences in UEC among countries. The data available indicate that for large appliances, North American countries are much more energy intensive than European countries. One key element that explains this difference, apart from the higher penetration rate of some appliances such as dishwashers and freezers, is the size of different appliances. For example, refrigerators in the United States are, on average, 606 cubic litres, while in Europe it is closer to 279 cubic litres (4E IA, 2013). A more detailed cross-country comparison could take into consideration the size of refrigerators.

5 Additional indicators explaining the changes in residential energy consumption

As previously indicated, there are numerous factors influencing energy consumption in the residential sector. While the following indicators are not considered energy indicators, they bring vital information to better assess the macroeconomic drivers of energy consumption. It is important that these are assessed periodically so that underlying trends in population and sector structure can be tracked over time. When this is done consistently, three-factor decomposition techniques can be used to explain the changes in energy consumption into its different driving forces (see section "Decomposition of changes in residential energy demand").

Table 3.10 • Description of additional indicators: residential sector

Indicator	Data required	Purpose	Limitation
Inhabitants per occupied dwelling	• Population • Number of occupied dwellings	• Understand how occupancy rate impacts energy consumption (usually there is an inverse relationship between occupancy rates and energy demand)	• Provides little information on its own, i.e. if the decrease results from a decrease in population, the impact on energy consumption may be negligible
Average dwelling size	• Total floor area • Number of occupied dwellings	• Understand the impact that dwelling area has on energy consumption for space heating, lighting and cooling. This is usually the most significant influencing factor on energy consumption in dwellings	• Provides useful information only for end uses that are impacted by the dwelling area • One element, among many others, influencing trends in energy consumption
Electricity and useful heat price versus energy consumption	• Energy prices by energy source • Energy consumption by energy source and end use	• Assess to which extent energy prices have an influence on energy consumption, over time and among countries	• Other non-price factors also have an impact on the different levels of energy consumption, such as building codes, cultural aspects, climate and personal disposable income

Indicator	Data required	Purpose	Limitation
Socio-economic status and house tenure	• Income • Occupied dwelling tenure	• Understand how socio-economic factors influence residential energy consumption.	• Socio-economic factors do not cover all factors influencing energy consumption behaviour

6 Decomposition of changes in residential energy demand

While the detailed indicators presented provide some of the necessary explanation of the state of energy consumption in the residential sector, they don't explain what is driving the changes in observed energy consumption and cannot be used "as is" to provide guidance on policy options and the impact of energy efficiency improvements in the sector. For example, total energy consumption of appliances may increase despite energy efficiency improvements in all appliances; this increase could be driven by an increase in the number of appliances, which could be driven by an increase in consumer wealth or in the number of occupied dwellings.

The variables required for decomposition analysis of energy end use in the residential sector by end use are detailed in Table 3.11. Energy intensity is a proxy for energy efficiency improvements.

Table 3.11 • Summary of variables used for the decomposition analysis of residential energy consumption

End use	Activity (A)	Structure (S)	Intensity (I)
Space heating	Population	Floor area/population	Space heating energy*/floor area
Cooling	"	"	Space cooling energy**/floor area
Water heating	"	Occupied dwellings/ population	Water heating energy***/ occupied dwelling
Cooking	"	"	Cooking energy***/ occupied dwellings
Lighting	"	"	Lighting energy/occupied dwelling
Appliances	"	Appliances ownership/ population	Appliances energy/ appliance ownership

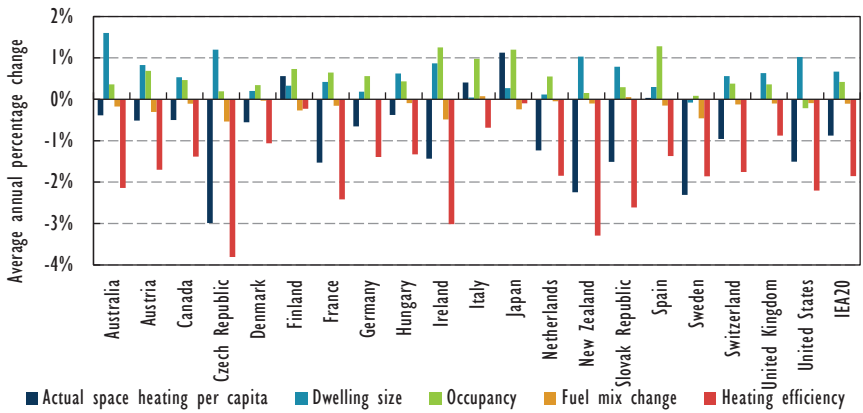
* Adjusted for climate variations using HDD.
** Adjusted for climate variations using CDD. Cooling is not included in the IEA decomposition analysis, nor in most country analysis, due to lack of data.
*** Adjusted for household occupancy.

At the total residential level, the activity component reflects the key driver of population growth. Structural changes include three key factors: dwelling area per capita (for space heating and cooling); appliance ownership per capita; and the number of occupied dwellings per person (for water heating, lighting and cooking). The intensity effect includes the impact of changes in all residential end-use intensities.

The decomposition analysis provides key insights on how different factors have influenced the energy trends over a given period. For example, the decomposition of space heating per capita reveals important information on the drivers behind the changes in energy consumption. The analysis shows that, for most of the countries analysed, fewer occupants and larger homes tend to drive up energy demand. This increase was often

offset by lower end-use conversion losses and, more importantly, a decline in the useful intensity (proxy for efficiency effect) of space heating. Spain is the noticeable exception: useful intensity of space heating is calculated based on total floor area; the increase in intensity in Spain is most likely due to a higher share of floor area heated.[4]

Figure 3.15 • Decomposition of changes in space heating per capita, 1990 to 2010



7 Policy information and evaluation in the residential sector

Human needs for shelter, food service, hygiene, mobility and entertainment drive the use of technologies that lie at the heart of the derived demand for energy in the residential sector. Modern energy-using technologies continue to transform households with increasingly effective services, liberating occupants from the manual labour of washing clothes and dishes; enabling safer food storage and cooking, improved comfort and illumination; and increasingly opening our homes to a world of visual and audible education and entertainment resources.

The importance of supplementary information

The indicators beyond level 2 are the core of energy efficiency programme information, and form an essential framework context for supplementary information. However, these nearly always need to be supplemented with technology, market and consumer behaviour information. Generally the policy-informing capability of any indicator improves as it gets closer to the underlying driving forces and state variables. It is useful to check that the indicators used accurately reflect the factors that influence the targeted policy outcome.

While energy efficiency indicators provide a strong basis for the development and tracking of policies, supplementary information to make a detailed policy assessment is required (Table 3.12).

4. The decomposition analysis results included in this manual are calculated using a three-factor decomposition analysis based on the Simple Laspeyres index decomposition methodology. See Annex A for further discussion on decomposition analysis methodologies.

Table 3.12 • Supplementary information for residential policy information

Policies and typical level 3 indices	Supplementary information needs	Supplementary indicators
Building codes kWh/m^2, kWh/capita, kWh/household, megajoule (MJ) heating service, MJ hot water service	• Ex-post stock information to enable thermal modelling and establish baselines, cost-benefit analysis of policies • Consumer well-being impacts and energy poverty demographics • Demand impacts of policies • Off-grid and solar thermal systems	• Ex-ante insulation and heating energy performance, comfort conditions; indoor temperatures, humidity, air leakage, health and well-being status • Kilowatt (kW) demand at end use
Low net energy buildings kWh/m^2, kWh/household, MJ heating service, MJ hot water service	• Future impact of increasingly cheaper off-grid electric and solar thermal systems • Cost-benefit analysis of policies	• Post-insulation heating performance, comfort conditions, health and well-being assessments • kW demand at end use from grid and renewable energy
Insulation / weatherisation retrofits kWh/m^2, kWh/household, MJ heating service	• Ex-post information to evaluate outcomes and consumer well-being impacts • Demand impacts of policies • Off-grid and solar thermal systems • Cost-benefit analysis of policies	• Pre- and post-insulation heating energy performance, comfort conditions, health and well-being impact responses • kW demand at end use
Building labelling	• Technical information for label design and review • Verification of label technical performance, consumer responsiveness	• Current stock information for label verification
Appliance MEPS and labelling (including lighting) kWh/ end-use activity (MJ/end use; lighting, kWh/ refrigeration, kWh/IT, kWh/TV…	• Appliance stock and sales data • MEPS and label impact on energy demand • Cost-benefit analysis of policies	• The number of appliances per dwelling, their usage patterns • kW demand at end-use level, sampled at <1hr time intervals for a whole year, energy consumption for information and communication technology (ICT) network • Market and consumer responses to policies • Value of avoided energy at end use
Appliance test standards and measurement	• MEPS performance verification • Market compliance • Cost-benefit analysis of policies	• Compliance testing results
Market transformation policies	• Stock and sales data • Impact on market development as well as energy demand • Cost-benefit analysis of policies	• Changes in sales volumes and prices • Market investment and growth rates

Developing Indicators for the Services Sector

1 What is driving energy consumption in the services sector?

The services sector, also referred to as the commercial and public service sectors or the tertiary sector, includes all activities related to trade, finance, real estate, public administration, health, food and lodging, education and commercial services, as classified by the International Standard Industrial Classification.[1] It covers energy consumed for space heating, cooling and ventilation; water heating; and lighting; and in a number of other miscellaneous energy-using equipment such as commercial appliances and cooking devices, x-ray machines, office equipment, and generators. Energy consumption for transportation, or for commercial transport fleets, and energy consumption for electricity and heat generation are excluded from the services sector.

The main factor affecting energy consumption in the services sector is the level of economic activity, which is usually represented by value-added output of the sector. Higher economic activity leads to increases in commercial activity and the stock of buildings, and to more people being employed in the sector. Both of these effects lead to an increased demand for energy services. The trends in total and end-use energy consumption are also influenced by climate, floor area, building type (relative to sector activity), age of building, maturity of an economy, quality of building energy management, per capita income, climatic conditions and energy efficiency improvements. The economic and demographic profile also has an impact on the structure of the sector.

Questions and Answers

Q 1. What is the best activity measure to assess efficiency in the services sector?

Although commonly used to measure energy efficiency in the services sector, value-added can be a misleading activity measure to quantify energy efficiency in the services sector. This is because value-added can be influenced by non-energy related factors, for example, different exchange rates and price effects.

Different services categories and end uses have different best activity measures. Ideally energy efficiency indicators in the services sector would be developed with these activity measures at the sub-sector or end-use level.

1. ISIC two-digit level rev. 4.0 – 33, 36-39, 45-96, 99 excluding class 8422 (UNSD, 2008).

Q2. What is the difference between value-added at PPP and at MER?

Value-added at purchasing price parity (PPP) eliminates the difference between price levels in different countries, whereas value-added at market exchange rate (MER)** does not. When possible, using value-added at PPP to assess efficiency in the services sector is preferable.*

* Purchasing power parities (PPPs) are the rates of currency conversion that equalise the purchasing power of different currencies by eliminating the differences in price levels between countries. In their simplest form, PPPs are simply price relatives which show the ratio of the prices in national currencies of the same good or service in different countries.
** Market exchange rate is used to describe exchange rates determined largely by market forces.

2 How is energy consumed and how has it evolved recently?

In 2011, global final energy consumption in the services sector was 30 exajoules (EJ), 8% of total global final energy consumption. The carbon dioxide (CO_2) emissions associated with this energy consumption, including indirect emissions from electricity, was 3 gigatonnes of carbon dioxide ($GtCO_2$) or approximately 10% of total energy-related emissions. Globally, services sector energy consumption increased by almost 56% between 1990 and 2011. Since 1990, energy consumption in the services sector grew 36% in member countries of the Organisation of Economic Co-operation and Development (OECD) (despite a small decline between 2008 and 2010 due to the economic downturn) and 123% in non-OECD countries. Developed economies have service sectors that had strong growth but have now matured, so the growth is slowing, while emerging economies are starting to grow services activities after having industrialised. Despite the slower increase in services sub-sector energy in OECD countries, and the more marked impact of the recession on those countries, OECD regions still accounted for about 68% of global energy consumption in the services sub-sector.

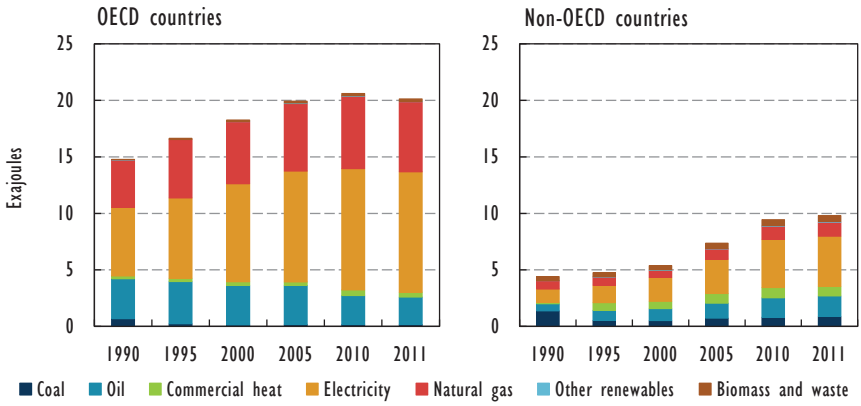
Non-OECD regions have grown more quickly than OECD regions since 1990, but this trend is explained in part by a generally low level of services sector energy consumption as a starting point (with the exception of non-OECD Europe and Eurasia). Energy consumption by China's services sub-sector increased 8.4% per year between 1990 and 2011, while other developing countries in Asia and Africa saw rates of 5% per year. China now accounts for 9% of global services sub-sector energy consumption, up from 3% in 1990. In 1990, non-OECD countries consumed about 23% of global energy in the services sub-sector; by 2011 this had grown to about 33%.

Electricity is by far the most widely used energy commodity in services, with a global share of 50% in 2011. Electricity use has more than doubled since 1990, and this has been the main factor driving the global increase in energy consumption in this sector. This reflects the growing role and importance of electricity-using devices such

as office equipment, computing and information and communication technology (ICT) equipment and the lighting and air-conditioning services that enable the high value-added from capital and human resources. Increased services activity requiring access to reliable electricity may also have played a role in some developing countries.

There are substantial differences in the services sector energy mix among countries and regions. Electricity and natural gas are the dominant final energy commodities in many OECD countries, with oil also an important fuel in the OECD Asia Oceania region, Mexico and China.[2] Biomass is still heavily used in India, accounting for 50% of total final consumption in services. Direct coal use retains a significant share in both China and South Africa. In Russia, 50% of services energy demand is met by district heating.

Figure 4.1 • Services energy consumption in OECD and non-OECD countries



Energy consumption per unit of value-added is the most widely used and available indicator for the services sector. This indicator is used to compare the relative intensity or efficiency performance of the services sector across countries. In general, this indicator decreased between 1990 and 2010, suggesting an improvement in energy efficiency for the sector in general. However, such a decrease may be induced by changes in the structure of the services sector. Additional data are required to ascertain the efficiency improvement.

In most countries, total final energy consumption in the services sector grew less rapidly than economic activity between 1990 and 2010. According to this indicator, final energy intensity (energy per unit of value-added) for 20 International Energy Agency (IEA) member countries[3] fell 18% over this period.

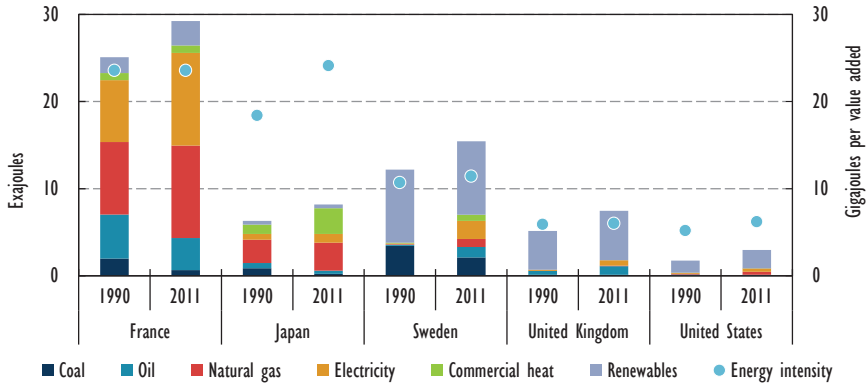
Energy consumption in services is also closely linked to floor area. For a group of nine IEA member countries for which detailed data are available, it is possible to develop both energy consumption per unit of value added and per unit of floor

2. Oil appeared to account for 39% of final energy consumption in China in 2011, this share may be inflated by a statistical convention that includes some commercial transportation energy in the services sector.

3. Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hungary, Italy, Japan, Korea, Luxembourg, Netherlands, New Zealand, Norway, Spain, Sweden, United Kingdom, United States.

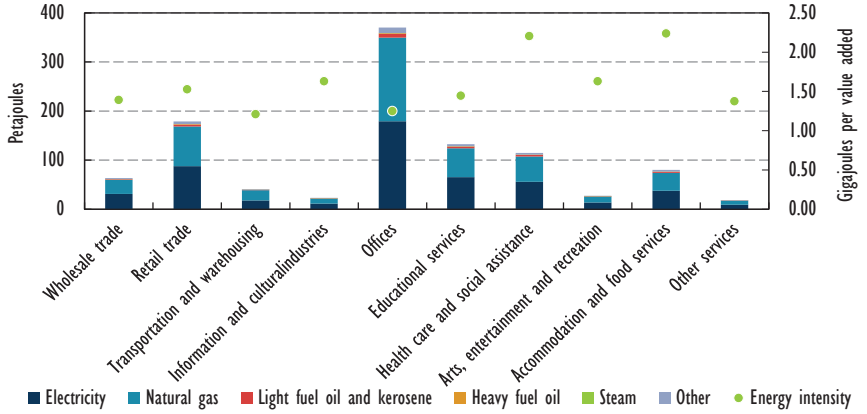
area in 2010. However, analysis from 1990 to 2010 can be done for only six of those countries. The difference between the two indicators is striking: while energy per value-added increased 3% between 1990 and 2010, energy per square metre decreased 11%.

Figure 4.2 • Services energy consumption and aggregate energy intensity



Interpreting this trend with respect to changes in energy efficiency is difficult, particularly without more detailed structural information. Different services sector activities can produce very different levels of economic output while consuming nearly the same amount of energy. For example, buildings in the finance sector can have the same final energy demand profile as buildings in the retail sector, yet produce significantly higher levels of economic activity. Energy intensity is highly dependent on the structure within a country's services sector. Different building types have different energy needs (e.g. health-care facilities require more energy than warehouses), and the relative importance of the building types within the services sub-sector will have a direct impact on the sector's energy intensity and CO_2 emissions.

Figure 4.3 • Example of different intensity levels in Canada, 2010



3 How to prioritise development of indicators (Which indicators should be developed?)

Services is the sector where the least information is available. In many countries, the services category in national energy balance is used as a "residual" or catch-all category. A necessary first step for developing meaningful indicators in this sector is to ensure that energy balance data accurately represent energy consumption within the sector. A handful of countries have information about the total floor area of the sector. Developing surveys or models to estimate this variable is another necessary step towards developing indicators for this sector. Priority should be given to designing processes that ensure the accuracy and relevance of services indicators at the aggregate level.

This sector is complex and encompasses a wide variety of building types, providing different services and requiring energy for different purposes. For example, the energy consumption pattern in hospitals will be quite different from that in restaurants or warehouses. Understanding the trends in services energy consumption thus requires detailed information by type of services and by end use.

However, given the difficulty in obtaining information even at the most aggregate level, a first step may be to develop indicators at the end-use level (Figure 4.4). Understanding which end use is relatively the most important in the sector may provide invaluable information to policy makers on where the largest potential for energy reduction may be (e.g. if 60% of energy is used for space heating, policies to improve the efficiency of building envelopes and heating equipment would be a priority).

Figure 4.4 • Detailed indicators pyramid of the services sector

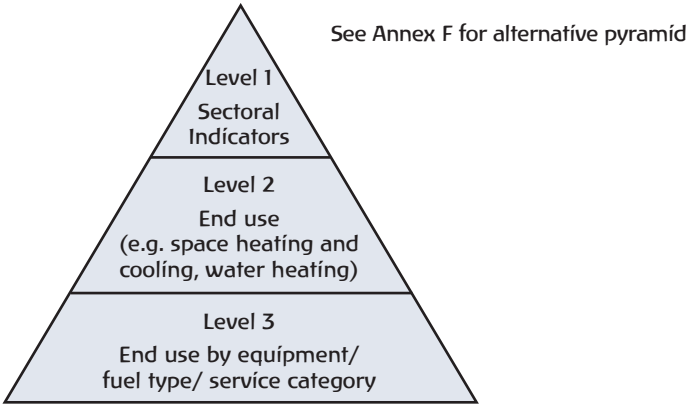


Table 4.1 summarises all the indicators described in the services section and provides a quick overview of the usefulness of the indicator. This table matches the discussion on indicators in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 4.1 • Summary list of the most common indicators for services

Indicator	Coverage	Energy data	Activity data	Code	Recommended indicator
Space heating energy consumption per value added	Overall	Total heating energy consumption	Total value added	H2a	
Space heating energy consumption per floor area	Overall	Total heating energy consumption	Total floor area	H2b	☺
	By heating system	Heating energy consumption with system α	Floor area heated with heating system α	H3a	
	By energy source	Heating energy consumption with energy source Z	Floor area heated with energy source Z	H3b	
Space heating energy consumption per unit of activity	By service category	Heating energy consumption for service category A	Unit activity of service category A	H3c	
Space cooling energy consumption per value added	Overall	Total cooling energy consumption	Total value added	C2a	
Space cooling energy consumption per floor area cooled	Overall	Total cooling energy consumption	Total floor area cooled	C2b	☺
	By space cooling system	Cooling energy consumption by cooling system α	Floor area with cooling system α	C3a	
	By service category	Cooling energy consumption for service category A	Floor area cooled of service category A	C3b	
Space cooling energy consumption per unit of activity	By service category	Cooling energy consumption for service category A	Unit activity of service category A	C3c	
Water heating energy consumption per value added	Overall	Total water heating energy consumption	Total value added	W2a	
Water heating energy consumption per unit of activity	By service category	Water heating energy consumption for service category A	Unit activity of service category A	W3a	☺
Lighting energy consumption per value added	Overall	Total lighting energy consumption	Total value added	L2a	
Lighting energy consumption per floor area	Overall	Total lighting energy consumption	Total floor area	L2b	
	By service category	Lighting energy consumption for service category A	Floor area of service category A	L3a	
Lighting energy consumption per unit activity	By service category	Lighting energy consumption for service category A	Unit activity of service category A	L3b	☺
Other equipment energy consumption per value added	Overall	Total other equipment energy consumption	Total value added	E2a	
	By service category	Other equipment energy consumption for service category A	Value added of service category A	E3a	
Other equipment energy consumption per floor area	Overall	Total other equipment energy consumption	Total floor area	E2b	
Other equipment energy consumption per unit of activity	By service category	Other equipment energy consumption for service category A	Unit activity of service category A	E3b	☺

Heating · Cooling · Water heating · Lighting · Other equipment

As energy consumption differs from one activity to another, further information by type of activity is required to understand the dynamics in the services sector. Only few countries are collecting detailed data allowing the development of detailed indicators for the services sector. Care should be taken when comparing the intensity level by end use or type of services among countries as the classification of buildings is not uniform (Table 4.2). Canada and the United States are the only countries where detailed information is available by end use for each building type. In the Online Database for Yearly Assessment of Energy Efficiency (ODYSSEE) for European Union (EU) countries and in Japan, data are available by end use and by building type – not by end use for each building type. Furthermore, not all countries have activity measures associated with each service category

Table 4.2 • Classification of services buildings in selected IEA countries

Canada	United States	ODYSSEE database (EU)	Japan
Wholesale trade	Warehouse and storage	Trade (wholesale and retail)	Wholesale and retails
Retail trade	Mercantile Retail (other than mall) Enclosed and strip malls		Department stores and supermarkets
Transportation and warehousing			
Health care and social assistance	Health care Inpatient Outpatient	Health and social action sector	Hospitals
Educational services	Education	Education, research	Schools
Offices	Offices	Offices	Offices and buildings
Accommodation and food services	Lodging	Hotels, restaurants	Hotels and inns
	Food services		Restaurants
	Food sales		
Arts, entertainment and recreation			Theatre and amusement places
Information and cultural industries			
	Public assembly	Administrations	
	Public order and safety		
	Religious worship		
	Service		
	Vacant		
Other services	Other		Other

In countries where building-level information is available, floor area is used as the activity variable for the development of indicator. While this can provide good indicators for some end uses (e.g. space heating), other end uses are more

closely related to the type of activity performed in a building. For example, energy consumption for cooking in restaurants would be more closely related to the number of meals served than the total floor area of the restaurant. The "alternative unit of activity" selected will depend on the type of services provided, as well as the end use assessed.

4 Development of indicators by level of the pyramid

Given the scarcity of the information available for the services sector, this section will focus on the different end uses of the sector without further addressing the specificities of different activity types. However, each level described below can be developed not only for the total services sector, but also for different building types.

Level 1 indicators

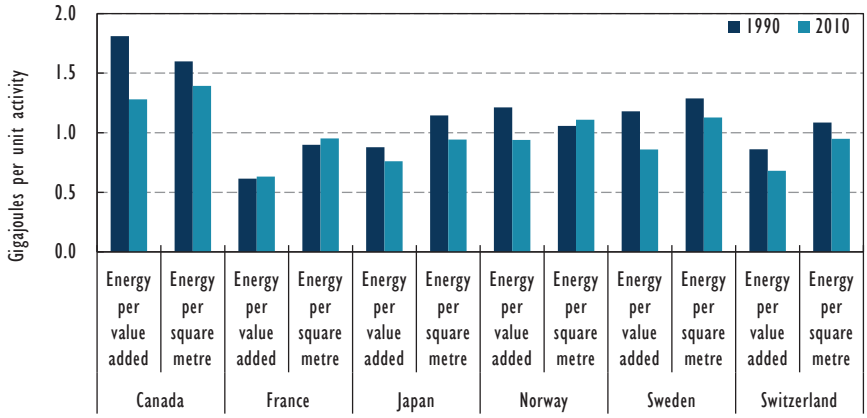
Aggregate services energy intensity

Definition: Amount of total services energy consumption per unit of value-added or floor area.

- Energy consumption per value-added indicates the general relationship of energy consumption to economic development.
- Energy consumption per floor area can provide insights on the end consumption driving the changes in energy use. Furthermore, it can provide indications on the nature of the sector driving energy consumption when combined with energy consumption per value-added.

The intensity of energy consumption per unit of floor area generally fell more than energy per value-added (Figure 4.5). This is a different trend than what was observed in years prior to the global recession. This indicates that, recently, the value generated per area in the services sector decreased in most countries.

Figure 4.5 • Example of level 1 indicators in selected countries



Use of level 1 indicators: Comparing these two different indicators, coupled with the analysis by type of energy source, may help in understanding which end uses have the strongest impact on changes in energy consumption.

Relevance for policy development: Given the many factors that influence this indicator, no conclusion can be draw as to where efficiency improvements can be made and where more attention is required.

Cross-country comparison: Comparing countries based on this indicator is highly misleading, even more if value-added is adopted as the activity indicator. The aggregate intensity of the services sector is highly dependent on the structure of the sector as well as the energy sources used.

Data availability and sources:

- Energy consumption: usually available in national energy balances and in IEA energy balances
- Services value-added: available from World Bank and may be available from national accounts
- Floor area: may be available from national statistical offices.

Related indicators: Energy consumption is usually available by energy sources from energy balances. An analysis of the level and trends of different energy sources may help identify which end use is the most important and largest user of energy. Electricity is usually the dominant source for office and high-tech equipment, lighting and space cooling; biomass and coal are mostly used for cooking and water heating; and natural gas and oil are mostly used for space heating and water heating. Furthermore, changes in fuel use per square metre can provide a proxy for space heating intensity trends in countries where electricity space heating is not significant. Electricity use per unit of floor area reflects changes in end uses such as space cooling, ventilation, lighting and office equipment.

Table 4.3 • Description of level 1 indicators

Indicator	Data required	Purpose	Limitation
Services energy consumption per services value-added	• Total services energy consumption • Total services value-added (in constant currency)	• Reflect the trends in overall energy consumption relative to value-added • Indicates the general relationship of energy consumption to economic development	• **Does not measure energy efficiency developments** • Depends on factors such as climate, geography and the structure of the services sector • Influenced by change in services structure • Different services sectors activities can produce very different levels of economic output • Value-added are influenced by a range of pricing effects that are unrelated to changes in the energy consumption

Indicator	Data required	Purpose	Limitation
Services energy consumption by floor area	• Total services energy consumption • Total services floor area	• Combined with the previous indicator, can provide indications on the nature of the sector driving energy consumption • Can provide insights on the end use driving the change in energy consumption	• **Does not measure energy efficiency developments** • Depends on factors such as climate, geography and the structure of the services sector • Influenced by change in services structure; different building types have very different energy requirements

Level 2 indicators and beyond

In general, level 2 indicators can provide enough information to be relevant for analysis of the sectors and supporting the development of energy efficiency policies. However, some end-use level 2 indicators provide only very generic information, and going to level 3 is required to develop useful indicators.

Energy intensity by end use: Space heating

Definition: Amount of energy consumed for space heating per value-added or per floor area. In some countries, only a fraction of the total floor area is heated; in this case, this indicator should use heated floor area as the activity variable to provide more accurate results on intensity trends. The preferred indicator is energy per floor area.

Relevance for policy development: Space heating intensity is influenced not only by the climate, but also by the age of a building, the building's envelope efficiency, the energy source used and the efficiency of the heating equipment. As a result, more detailed information on buildings and equipment is required to provide a strong basis for policy development.

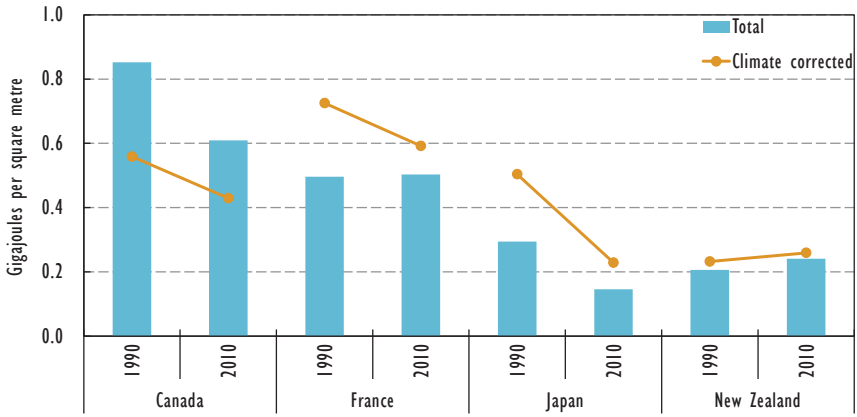
Cross-country comparison: For this indicator to be relevant for cross-country comparison, the energy consumption for space heating should be corrected to take into account the heating degree-days (HDD) in any particular year.

While a more accurate basis for comparison is the total volume to be heated, and not the total area, building volumes are not usually available for countries. As such, indicators based on volume are not discussed in this publication.

Data availability and sources: As for the other end uses, energy consumption is not widely available and requires specific surveys, monitoring or modelling. Details on how to collect this information are provided in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Related indicator: As is the case for the residential sector, the climatic condition of a country has a noticeable impact on energy consumption for space heating. Space heating energy consumption and HDD data required to perform climate adjustment are available for only four countries. This adjustment reveals interesting results. While observed space heating intensity remains stable in France, it shows an improvement when climatic conditions are taken into account. For Canada, harsh winters explain the higher energy intensity than France for space heating. Japan and New Zealand are good examples of lower need for heating energy in island nations where the oceans moderate the temperature extremes experienced in continental climates.

Figure 4.6 • Observed and climate-corrected energy intensity for selected countries



Note: intensity adjusted using 2 700 HDD.

Table 4.4 • Description of level 2 indicators: space heating

Indicator	Data required	Purpose	Limitation
Space heating energy consumption per value-added	• Energy consumption for space heating • Services value-added	• Provides an indication of the trends in space heating energy intensity	• This indicator does not take into account the effect of floor area and the share of floor area heated
Space heating energy consumption per floor area	• Energy consumption for space heating • Total floor area	• Provides an indication of the trends in space heating energy intensity	• Does not provide a distinction between equipment and building efficiency • Does not measure energy efficiency developments • Does not take into consideration the share of floor area heated • Does not consider the level of heating required by different types of buildings
Space heating energy consumption per floor area heated	• Energy consumption for space heating • Total floor area heated	• Provides a better indicator as it takes into account the share of floor area heated	• Does not provide a distinction between equipment and building efficiency • Does not measure energy efficiency developments • Does not consider the level of heating required by different types of buildings

Beyond level 2 indicators

While space heating energy consumption per floor area can provide insights on the energy efficiency of space heating for the services sector, more detailed information is required to better assess the potential for energy savings and track the performance of policies or measures. This indicator should be developed by type of building (as different buildings have different heating requirements) and by type of heating systems.

Energy intensity by end use: Space cooling

Definition: Amount of energy consumed for cooling per value-added or per cooled floor area. In countries where a large share of services floor area is cooled, total floor area can also be used as an activity measure. While energy consumption by value-added is much less relevant, it can be used in the absence of floor area data.

Relevance for policy development: This indicator can provide insights as to the potential for increase in energy consumption for cooling as well as the potential for improving energy efficiency in the end use. However, intensity is not influenced only by the climate, but also by the age of a building, the building's envelope efficiency and the efficiency of the cooling equipment. As a result, more detailed information on buildings and equipment is required to provide a strong basis for policy development.

Cross-country comparison: For this indicator to be relevant for cross-country comparison, the energy consumption for cooling should be corrected to take into account the cooling degree-days (CDD) in any particular year.[4]

Data availability and sources: As for the other end uses, energy consumption is not widely available and requires specific surveys, monitoring or modelling. Details on how to collect this information are provided in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 4.5 • Description of level 2 indicators: space cooling

Indicator	Data required	Purpose	Limitation
Space cooling energy consumption per value-added	• Energy consumption for cooling • Services value-added	• Provides a general indication of the trends in cooling use	• Does not take into account the floor area requiring cooling or the structure of the services sector • Does not consider the different technologies that are used to cool buildings, so may under- or over-estimate the actual energy efficiency
Space cooling energy consumption per cooled floor area (or total floor area)	• Energy consumption for cooling • Floor area cooled (or total floor area)	• Provides an indication of the trends in cooling energy consumption • Can be used as a proxy for cooling energy efficiency • May indicate the effectiveness of policies (either minimum energy performance or promotion of high-efficiency air conditioners)	• Does not consider the different technologies that are used to cool buildings, so may under- or over-estimate the actual energy efficiency

Beyond level 2 indicators

There are currently only a handful of countries that can develop the proposed level 2 indicators. Developing these indicators is a key first step. These indicators can serve as a proxy for energy efficiency, but better tracking of policies or potential requires

4. For more information about CDD and HDD, see the glossary of *Energy Efficiency Indicators: Fundamentals on Statistics.*

further data on the use of cooling in different building types and the different technologies used for cooling. To better track the trends in energy efficiency for cooling, and to better understand how to influence this trend, information at the technology level is required.

Energy intensity by end use: Water heating

Definition: Amount of energy consumed for water heating per value-added. As hot water demand is important for some type of activity in specific buildings, the relevance of an indicator that ignores function is minimal. Furthermore, comparison among countries where very different energy sources are used might not be relevant to assess the efficiency of water heaters. However, looking at changes in the energy mix over time and comparing average intensity can provide insights on the effect of fuel mix on the overall intensity of water heating. As water heating is not required in all types of buildings and for all activities, more detail at the buildings or activity level is required to provide useful information for policy development.

Relevance for policy development: This indicator is highly dependent on the type of energy source used and the penetration of water heating. More detail is required to assess the potential for reduction.

Cross-country comparison: Comparing countries based on this indicator may be misleading as the intensity depends on the structure of the sector, the need for water heating and the source of energy consumed.

Data availability and sources: As for the other end uses, energy consumption is not widely available and requires specific surveys, monitoring or modelling. Details on how to collect this data are provided in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 4.6 • Description of level 2 indicators: water heating

Indicator	Data required	Purpose	Limitation
Water heating energy consumption per value-added	• Energy consumption for water heating • Services value-added	• Provides an indication of the trends in water heating energy consumption • If the indicator is developed at the energy source level, it may indicate changes in the technology mix	• This indicator does not take into account the use or need of water heating • Does not consider the type of energy source used for water heating

Beyond level 2 indicators

It is necessary to develop indicators beyond level 2 to assess water heating efficiency and the potential for energy efficiency improvement.

Energy intensity should be developed, as a first step, by type of building or activity. If the share of water heating in total energy consumption of a specific building type is relatively important, then further detail at the technology level should be collected and indicators developed to support policy development and assess the potential for further reduction. Having this level of detail would provide a good basis

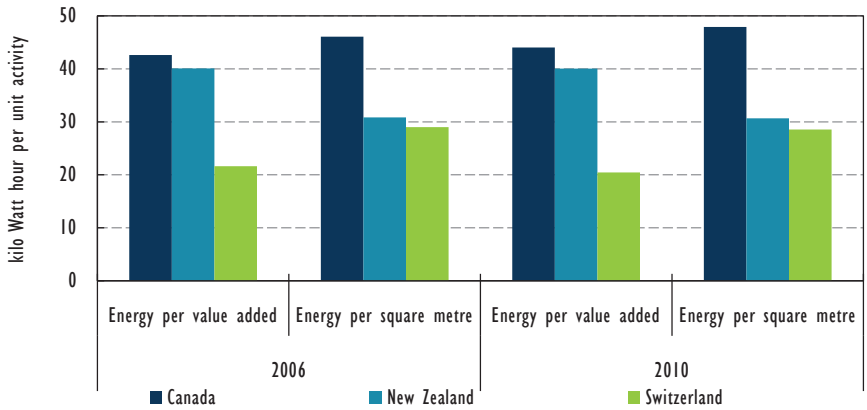
for understanding how a policy targeting one particular technology would affect the total energy consumption, and would also allow a comparison among countries of the efficiency of the different technologies.

Energy intensity by end use: Lighting

Definition: Amount of energy consumed for lighting per value-added or floor area.

- Energy consumption per floor area is considered a better indicator than energy per value-added, as it informs the policy options for improving lighting energy efficiency.
- Energy consumption per floor area takes into account the overall surface that may require lighting. While this is a better indicator than lighting energy per value-added, it does not account for the specific requirement of lighting in different parts of a building (storage versus working area), tenanted versus common areas, exterior or feature lighting, or the need for lighting intensity among different type of buildings (office space versus warehouse).

Figure 4.7 • Examples of lighting energy intensity in selected countries



Relevance for policy development: Lighting energy intensity, and the differences by country, may provide important insights into the level of lighting efficiency in a country and the potential to further reduce energy consumption.

Cross-country comparison: Differences in intensity among countries indicates the different level of both energy efficiency of lighting, and energy conservation measure/behaviour. But they do not provide indication of lighting needs/usage.

Data availability and sources: As for the other end uses, lighting energy consumption is not widely available and requires specific surveys, monitoring or modelling. Details on how to collect this information are provided in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Related indicators: Electricity is the main energy source for lighting. However, kerosene is still in use in some countries, and off-grid solar lighting is a new source that may increase in importance in the future. Where there are different sources of energy consumed to generate lighting, this indicator should be developed by energy source to get a better picture of the lighting energy trends.

Table 4.7 • Description of level 2 indicators: lighting

Indicator	Data required	Purpose	Limitation
Lighting energy consumption per value-added	• Energy consumption for lighting • Services value-added	• Provides an indication of the general trends in lighting energy intensity	• Does not take into consideration the lighting needs of specific building and activity types • Does not take into account working schedules and hours and availability of day lighting • Does not measure energy efficiency developments
Lighting energy consumption per floor area	• Energy consumption for lighting • Total floor area	• Can be used as a proxy for lighting energy efficiency • Provides an indication of the trends in lighting energy intensity • May indicate the effectiveness of an energy conservation campaign or the impact of efficient lighting regulation	• Includes the impact of both energy efficiency and lighting needs/usage for different buildings • Does not take into consideration the lighting needs of specific building types • Does not take into account working schedules and hours and availability of day lighting

Beyond level 2 indicators

Having a disaggregation of lighting intensity by service category (lighting energy consumption per unit activity of service) would provide a better metric for cross-country comparison of lighting efficiency.

Additionally, assessing the potential for energy reduction from lighting and tracking the progress of measure and policies may require detailed surveys that, for example, collect information on the type of light bulb, their number, their efficiency and their usage.

Energy intensity by end use: Other equipment[5]

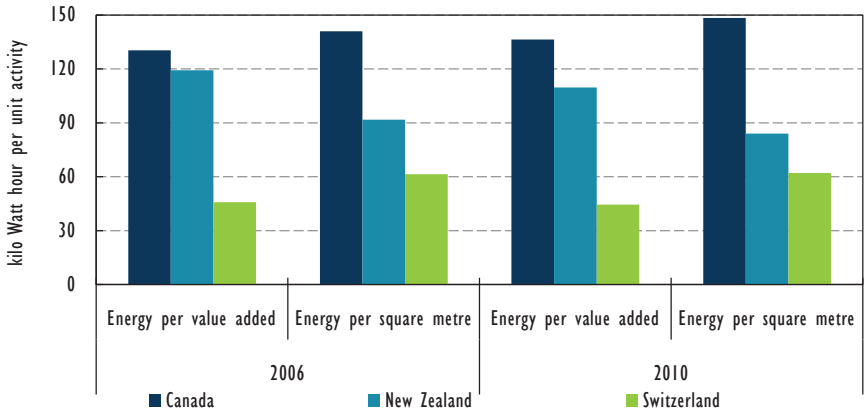
Definition: Amount of energy consumed for other equipment per value-added or floor area. At this aggregate level, not much insight is provided by the indicators. Energy consumption for office equipment is more closely related to the number of employees, energy for cooking depends on the number of meals served, etc. However, looking at the trend in the mix of fuel used may help understand the type of equipment that influenced the overall energy trend.

Relevance for policy development: This indicator is too aggregate to provide insights as to the potential to improve energy efficiency in this end use.

Cross-country comparison: It would be misleading to use this indicator for cross-country comparison given the heterogeneous nature of the other equipment category. In particular this category may have different boundaries in different countries or regions. Furthermore, as many different factors are impacting the energy consumption of other equipment, conclusions cannot be drawn on the efficiency of this end use.

5. Other equipment in the services sector includes a wide range of devices including: computers, photocopiers, refrigerators, desktop lamps, x-ray machines, cooking equipment, pumps, ventilators, compressors and conveyors.

Figure 4.8 • Example of other equipment category energy intensity for selected countries



Data availability and sources: As for the other end uses, energy consumption of the other equipment category is not widely available and requires specific surveys, monitoring or modelling. Details on how to collect this information are provided in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 4.8 • Description of level 2 indicators: other equipment

Indicator	Data required	Purpose	Limitation
Other equipment energy consumption per value-added	• Energy consumption for other equipment • Services value-added	• Provides an indication of the trends in other equipment intensity • When total energy is compared with other end uses, provides insights of the change in its importance in the services sector	• This is an aggregate intensity indicator, which does not take into account structure of the sector, type of equipment use or efficiency of different equipment
Other equipment energy consumption per floor area	• Energy consumption for other equipment • Total services floor area	• Provides an indication of the trends in other equipment intensity • When total energy is compared with other end uses, provides insights of the change in its importance in the residential sector	• This is an aggregate intensity indicator, which does not take into account structure of the sector, type of equipment use or efficiency of different equipment

Beyond level 2 indicators

As there are numerous types of services equipment, a further disaggregation is required to understand the trends in equipment energy consumption and to provide indicators relevant to policy making. Given the difficulty in developing indicators at level 2 for the services sector, and given that relevant indicators should be developed by type of building or activity, developing more detailed indicators is not, for most countries, an immediate priority.

Priority should be to develop level 2 indicators. If the analysis indicates that other equipment represent a large share of total energy consumption, then the next priority should be to develop more detailed indicators for this end use, either by collecting more information by type of activity, or by collecting information for one type of equipment.

5 Additional indicators explaining the changes in services energy consumption

Information on useful activity data for specific services sub-sectors, e.g. hotel nights or hospital nights, which can be related to energy consumption in the services sector, is discussed in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

There are several additional indicators that can help in understanding the trends in services energy consumption and provide insights on the future trends the sector may follow. Energy consumption per capita indicates how much energy is used by each person in a country or region.

Table 4.9 • Description of additional indicators: services sector

Indicator	Data required	Purpose	Limitation
Services sector floor area per capita in relation to value-added per capita (employment can also be used instead of population)	• Population • Services value-added • Services floor area	• Understand how services value-added influence floor area • Provides insights on future trends in services floor area • May help develop estimates of floor area	• This indicator is entirely activity driven • A change in the economy may change the relationship between value-added growth and floor area growth • Information on the difference in the relationship between developed and developing countries
Share of services sector output in total gross domestic product (GDP)	• Services value-added • Total GDP	• Understand the trend and importance of the services sector within the economy • May help assessing the future trends in services	• This indicator is entirely activity driven • Growth rate of services in relation to GDP may be very different depending on country level of development

6 Decomposition of changes in services energy demand

Very little information is available for the services sector. As a result, the decomposition is typically not done at end-use level, but only at the aggregate intensity level or at a few sub-sectors (Table 4.10).

For the services sector, more detailed decomposition of intensity (energy consumption per value-added) taking into account floor area productivity in the sector has been developed. Unfortunately, in the absence of comprehensive data, such analysis is currently possible for only nine IEA countries.

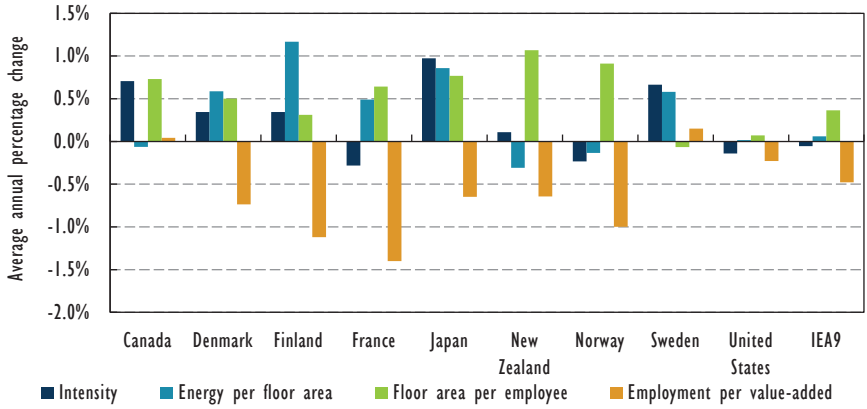
Table 4.10 • Summary of variables used for the decomposition of services energy consumption

End use	Activity (A)	Structure (S)	Intensity (I)
Services (ISIC 33-99)*	Value-added	Share of value-added	Energy/value-added

* UNSD (United Nations Statistics Division) (2008), International Standard Industrial Classification Rev. 4, United Nations, New York. Available from http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=27

Across IEA9, changes in the three factors – energy consumption per floor area, floor area per employee and number of employees per unit of value-added (the inverse of labour productivity) – have interacted and influenced the change in energy intensity (energy consumption per value-added). Improvements in labour productivity (*i.e.* reductions in the number of employees per unit of value-added) have occurred in almost all countries and have been the biggest, and often only, factor in reducing energy intensities in services. In contrast, a significant number of countries appear to have seen an increase in floor area per employee, and increased energy per floor area, which placed upward pressure on energy intensities.[6]

Figure 4.9 • Decomposition of changes in services sector energy intensity, 1990 to 2010



7 Policy information and evaluation in the services sector

In developed economies the services sector makes up a significant part of the economic structure. Challenges in policy analysis stem from the fact that the sector itself is very heterogeneous, and often multiple end-use activities can occur within a single business or building.

6. The decomposition analysis results included in this manual are calculated using a three-factor decomposition analysis based on the Simple Laspeyres index decomposition methodology. See Annex A for further discussion on decomposition analysis methodologies.

From a commercial practice perspective, principal agent barriers (such as the disparate objectives of landlords and tenants) are a particularly important issue in this sector, where most business activities occur in leased buildings.[7]

Energy efficiency policy and programme development requires information about energy consumption at these end-use outcome levels and with sufficient detail to allow programme level decisions to be estimated and evaluated. As always, policy makers seek material information that can be acted on with confidence, so that a clear and compelling policy case can be outlined. This requires substance and explanation of commercial drivers and contractual situations as well as energy and activity information at an end-use level.

The drivers of energy demand in commercial buildings

The driving forces for energy consumption in services are very much a function of development status of commercial sector activities. In developing countries, the services sector may lag behind the industrial sector and be less mature. Indeed, without a good quality of electricity supply, it is difficult for a services sector to establish due to the dependence of services energy use activities on electricity availability.

Growth of electrical equipment

At a technical level, energy consumption is dominated by the activity within services buildings rather than heat loss though the external surfaces. Internal heat loads from occupants, appliances and equipment are usually sufficiently high to require air conditioning in order to reject internal heat gains and these can be the main drivers of air-conditioning loads. In some cases equipment loads can be very high; in hospitals medical equipment is a more significant driver of hospital energy demand than patient bed numbers or climate. Furthermore, a tendency for large floor area, where high levels of artificial light are required in the core of the building and artificial ventilation and cooling are necessary, can exacerbate cooling loads.

Equipment energy load is multiplied by air-conditioning load

The importance of minimising internal loads such as office equipment, lighting and solar gain becomes clear when their relationship to air-conditioning loads is considered. With normal air-conditioning plants an additional 30% of cooling load can be added to any internal loads – i.e. it requires 30 watts (W) of additional air-conditioning cooling energy to remove the heat from a 100W lamp. Any effort to reduce internal loads is rewarded by an additional avoided demand on air-conditioning systems. It is therefore a key policy objective to reduce end-use heat loads in the services sector. The main policy options are MEPS for lighting, office equipment, and restaurant and catering equipment, and retrofits of inefficient lighting systems with high-efficiency luminaires.

7. For a full exploration of this issue and solutions refer to; Mind the Gap: Quantifying Principal-Agent Problems in Energy Efficiency (IEA, 2007).

Box 4.1 • The policy challenge: growing dependence on electricity in the services sector

Electricity consumption in the services sector constitutes a significant energy efficiency opportunity. However, the sector has received little attention in energy efficiency policies.

Worldwide, electricity consumption is expected to grow more rapidly in the services sector than in the residential sector. In OECD countries, commercial electricity consumption grew from 26% of total electricity use in 1990 to 33% in 2009, and is now on a par with that of the residential sector. Before 1990, the main energy sources in the services sector in major OECD countries were oil and gas. In 2009, electricity accounted for the largest share. The annual growth rate of electricity consumption was higher in the services sector than in the residential sector between 1990 and 2009 in OECD countries. The same trend has also occurred in some emerging economies such as Brazil, India and Russia. The US Energy Information Administration expects electricity consumption worldwide to grower faster in the services sector than in the residential sector between 2008 and 2035, much of it for lighting, space cooling and ventilation.

The potential for electricity savings by services equipment is significant globally. The largest potential in the services sector was found in lighting, air conditioning and refrigeration. Few studies have estimated the potential for electricity savings through energy efficiency policies for services equipment, while many have been made for residential appliances.

Rosenquist *et al*. (2006) analysed US national electricity savings potential of minimum energy performance standards (MEPS) for residential and services equipment. The potential for cumulative electricity savings for appliances and equipment efficiency from 2010 to 2030 was estimated at 7 167 TWh (approximately 4% of the cumulative energy consumption in the base case), of which 3 834 terawatt hours (TWh), would be generated from commercial equipment – more than the residential sector. The largest potential in the services sector was found in refrigeration, followed by lighting and air conditioning.

McNeil and Letschert, (2008) evaluated the global potential of electricity savings by energy efficiency standards and labelling policies for services equipment. In the services sector, lighting and space cooling had the largest potential for savings, followed by refrigeration.

A benchmarking study was carried out using services air conditioners in Australia. Australia started to introduce comprehensive MEPS for air conditioners in 2001. Close control air conditioners and chillers were subjected to MEPS beginning in 2009. The annual electricity savings potential from the use MEPS for air conditioners was estimated at 5 718 gigawatt hours (GWh) by 2025 (equivalent to approximately 5% of services and residential electricity consumption in 2009): 3 065 GWh for services air conditioners and 2 653 GWh for residential air conditioners.

Low-energy commercial buildings

A number of new buildings have been designed to use very low levels of imported energy. These are well insulated, minimise internal heat loads by using only the most efficient appliances and lighting, have high levels of day lighting with shading to reduce solar heat gain, and often use natural ventilation instead of air conditioning. Some older buildings also tend to lower energy requirements, as they tend to have a thinner floor form, allowing increased use of natural light and cross ventilation. Monitoring these buildings is important as the industry is still learning about how these buildings function under real operating conditions.

Key aspects of policy solutions

Policies need to respond to these driving forces, often in subtle ways. In the services sector, tenants and building owners can be enabled by providing essential building performance data combined with MEPS on commercial equipment to create a push–pull effect on the market. Most of the medium-term energy efficiency improvement in the sector has come from measurable reductions in energy demand as the equipment stock is gradually turning over to more efficient appliances. In the longer term, building retrofits and building replacement will drive a move to lower energy consumption by the buildings and their central energy systems.

The importance of supplementary information

Level 3 indicators are the core of programme information, and importantly form an essential framework context for supplementary information. However, these need to be nearly always supplemented with technology, market and consumer behaviour information. Table 4.11 shows some of the services sector policy issues that need supplementary information options.

Analysts should consider that often policy makers require information about future trends, before or as they occur. The growth in networked services points to a need to understand in some detail the power consumption by network-connected equipment in the services sector.

Table 4.11 • Supplementary information for services sector policy information

Policies and typical level 3 indices	Supplementary information needs	Supplementary indicators
Building Codes kilowatt-hour per square metre (kWh/m^2) kWh/capita kWh/USD MJ heating service, MJ hot water service	• Ex-post stock information to enable thermal modelling and establish baselines • Demand impacts of policies • Off-grid and solar thermal systems	• Ex-ante energy performance, comfort conditions and staff productivity; indoor temperatures, humidity, air leakage • Kilowatt (kW) demand at end use

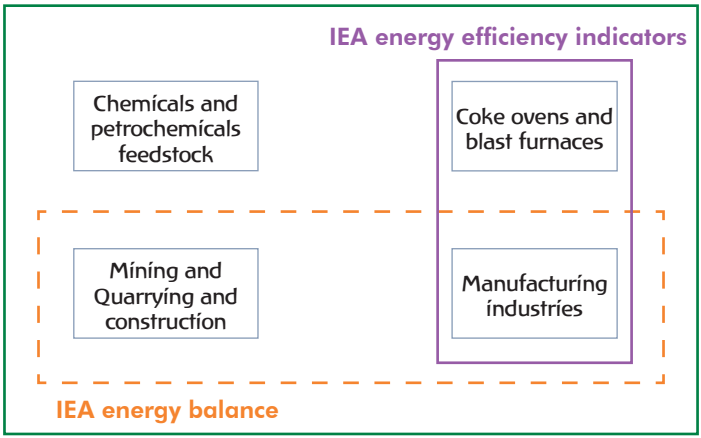
Policies and typical level 3 indices	Supplementary information needs	Supplementary indicators
Building labelling	• Technical information for certification system design and review • Verification of certification technical performance • Consumer responsiveness	• Current stock information for label verification
Insulation / weatherisation retrofits	• Ex-post information to evaluate outcomes and productivity impacts • Demand impacts of policies • Off-grid and solar thermal systems	• Pre- and post-retrofit energy performance, comfort conditions • kW demand at end use
Low net energy buildings	• Future impact of increasingly cheaper off-grid electric and solar thermal systems	• Post-insulation heating performance, comfort conditions, health and well-being impact responses • kW demand at end use from grid and renewable energy contributions
Equipment MEPS and labelling kWh/ end-use activity (MJ/lighting, kWh/refrigeration, kWh/IT, kWh/TV…)	• Equipment stock and sales data. • MEPS and label impact on services sector energy demand. • Cost-benefit analysis of policies	• The number and type of equipment per services business, their usage and derived energy demand • kW demand at end-use level including ICT network energy consumption • Market and consumer responses to policies • Value of avoided energy at end-use level

Developing Indicators for the Industry Sector

1 What is driving energy consumption in the industry sector?

The industry sector is heterogeneous and very complex. There is no unique definition of what is included or excluded from this sector (Figure 5.1). Furthermore, activity classifications (economic value-added or physical production indices) do not necessarily match directly with energy consumption allocation.

Figure 5.1 • Definitions used at the IEA for the industry sector



IEA *Energy Technology Perspectives*

Generally speaking, the industry sector covers the manufacture of finished goods and products, mining and quarrying of raw materials, and construction. Power and heat generation, refineries, and the distribution of electricity, gas and water are excluded. The International Energy Agency (IEA) energy balance follows this definition.

For the purpose of developing energy efficiency indicators, industry refers to the manufacturing sectors of industry (excluding mining and quarrying of raw material and construction) and includes blast furnaces and coke ovens (which, in the IEA energy balance, is included in the transformation sector). When assessing the potential for energy and emissions reduction, as is done in publications such as Energy Technology Perspectives, energy consumption as feedstock in the chemical and petrochemical industry is also included. In the IEA energy balance, feedstock is included in the category "non-energy use".

Energy is a key factor of production of all manufactured goods. All other parameters being equal, an increase in industry production (output) will generally lead to an increase in energy consumption, although most processes have both fixed and variable components in their normal operation, so if demand for outputs from the process drops, intensity will increase. This relationship between energy and output, and how it compares among countries, will be influenced by several factors such as the average age of plants (as newer or refurbished plants are usually more efficient than older ones); maintenance practices in place; the quality of energy (e.g. calorific value); the product quality produced, and raw materials used and the required quality of the product (level of purity for instance); the process or technology employed; and, at the aggregate level, the composition of the industry sector.

The goal of this section is to provide details on the most commonly used and available indicators for industry. However, it is recognised that an "accurate" analysis of energy efficiency in the industry sector requires a more detailed analysis for each process used in manufacturing production. In 2007, the IEA published *Tracking Industrial Energy Efficiency and CO_2 Emissions* (IEA, 2007), which provides methodologies for indicators analysis in the industry sector.

Questions and Answers

Q1. Should economic or physical unit of production be used to develop indicators?

Ideally physical unit of production data should be used to develop indicators in the industrial sector. If physical production data are not available, then value-added data could be used to provide an indication of overall trends, but cannot be used as indicators of energy efficiency.

Q2. Is it possible to account for structural differences in industry?

Yes, with sufficiently detailed disaggregation full decomposition analysis will separate out the impact of structural changes in industry.

Q3. Which sub-sectors should a country develop indicators for?

Priority should be given to the largest energy-consuming industrial sub-sectors where sufficient data are available for the analysis. If data are not available, the country should prioritise the collection of physical production and energy consumption data at the sub-sector.

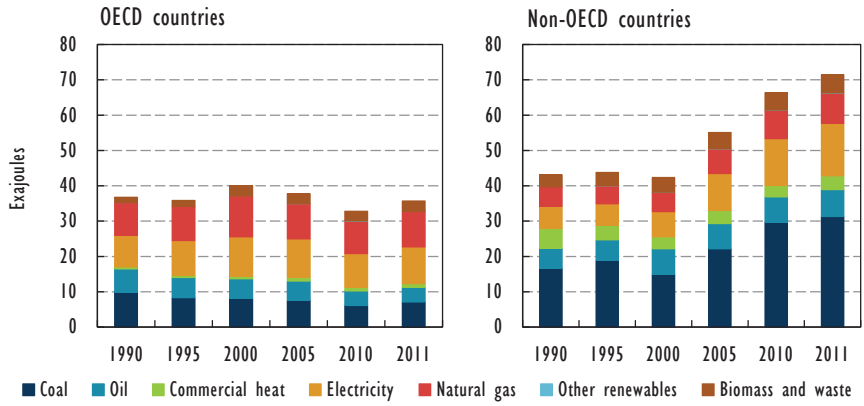
Q4. What is the difference between best available technology (BAT) and best practice technology (BPT)?

Best available technology is the most efficient technology available in the market. Best practice technology is the most efficient technology that is commercially available. In the chemical sector, the term BPT is used instead of BAT, as the latter is usually only available in one or two plants and is not widely commercialised, and reflects the unique circumstances of individual chemical plants.

2 How is energy consumed and how has it evolved recently?

Global final energy consumption in industry totalled 107 exajoules (EJ) in 2011 and accounted for 29% of global total final energy consumption. This includes energy consumed in coke ovens and blast furnaces as well as feedstocks. The associated CO_2 emissions, including indirect emissions from the use of electricity, were 10.55 gigatonnes of carbon dioxide ($GtCO_2$). Global industrial energy consumption has increased by 41% since 1990, with most of the growth being in countries that are not members of the Organisation for Economic Co-operation and Development (OECD), notably in China where increased demand and production of industrial materials since the early 2000s have driven the strong increase in energy consumption. The share of global industrial energy consumption in OECD countries declined from over 46% in 1990 to 33% in 2011, reflecting a major shift in global economic structure as more energy-intensive processes shifted to emerging economies (Figure 5.2).

Figure 5.2 • Industry energy consumption in OECD and non-OECD countries



Note: includes energy consumed in blast furnaces and coke ovens as well as feedstocks.

Box 5.1 • Methodological issues in the industry sector

Energy consumption in many industrial sub-sectors is complex. Even when necessary data are available, it is often not straightforward to calculate consistent and comparable indicators that are useful for policy analysis. Three areas in particular require careful consideration.

Aggregation levels: Energy consumption and CO_2 indicators can be developed at different levels of aggregation depending on the purpose for which they will be used and the level of information available. The aggregation level is very important as it determines the extent to which structural differences affect the results observed. Structural differences can include:

- **Availability and quality of input resources.** The energy needs for some industrial processes will depend on the quality of the natural or other resources available, e.g. ore quality. The indicators need to account for the resource quality variations in cross-country comparisons.
- **Definition of products.** Definitions require care. For example, in the case of the iron and steel industry, the choice for tonnes of iron, tonnes of crude steel or tonnes of finished steel can make a big difference.
- **Diversity of products.** Industrial products are not uniform. Indicators must be designed in a way that the product categorisation makes sense.
- **Definition of process technology.** Industrial products can be produced by different process technologies with significantly different energy requirements. The industry sub-sector level indicators should account for the different process technologies shares of total production in cross-country comparisons.

These issues can be addressed by developing indicators at different levels of aggregation.

Boundary issues: For a consistent analysis across countries, it is necessary to use common boundary definitions for each sub-sector. Such boundary limits relate to:

- **Production steps.** Industrial production processes often consist of several steps. The processes/production steps that are included in or excluded from an indicator can make a difference in cross-country comparisons and need to be fully described.
- **Embodied energy and carbon.** Both energy and carbon can be stored in materials. While energy can be recovered when materials are recycled or incinerated, any carbon stored in the product is released when it is incinerated. These factors and potentials should be assessed on a materials/product life cycle basis.
- **Process emissions.** A significant share of industrial CO_2 emissions are process emissions, not related to the use of fossil fuels. Where important, these process emissions should be included along with those from fuel combustion and segregated from energy-related emissions to allow analysis of potential for reduction of energy consumption.

Allocation issues: In addition to setting consistent boundaries, a number of important allocation issues arise in constructing energy consumption and CO_2 emissions indicators such as:

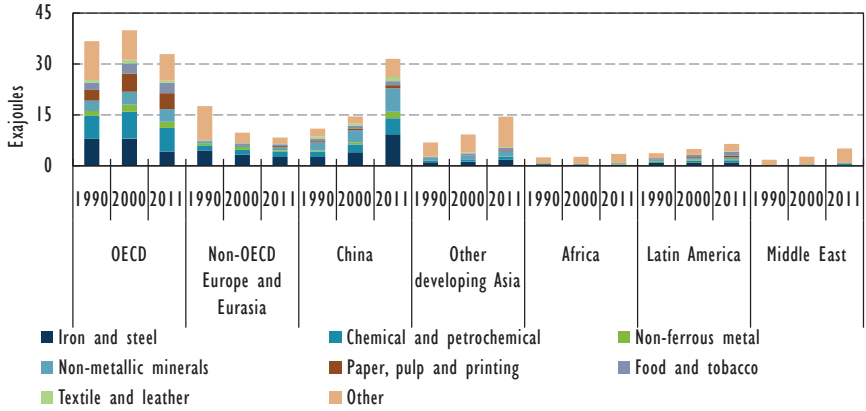
- **Industrial co-generation.*** The treatment of co-generation needs special consideration in those sub-sectors where it plays an important role to ensure that CO_2 emissions and efficiency gains from co-generation are correctly reflected. The electricity and heat generated on-site need to be associated to the site generation efficiency and the carbon footprint for that generation.
- **Treatment of waste fuels.** Industry uses large amounts of waste fuels. A first step is to improve the reporting of waste fuel used (e.g. in terms of calorific and carbon content). Indicators should use an allocation system for waste emissions that is appropriate on a system level.
- **Auto-production of electricity and heat.** Some industries produce their own electricity and heat. In terms of primary energy and CO_2 emissions allocation, it can make a big difference if the indicator uses country average efficiencies and emissions factors for electricity production or industry-specific ones.

* Co-generation refers to the combined production of heat and power.

Source: IEA, 2007.

There has also been an important structural change in the industry sector: energy consumption of the five most energy-intensive industrial sub-sectors[1] increased relative to other sub-sectors between 1990 and 2011. These five sub-sectors accounted for more than 56% of total final industrial energy consumption in 2011, compared with 45% in 1990 (Figure 5.3).

Figure 5.3 • Energy consumption by industry sub-sector



3 How to prioritise development of indicators (Which indicators should be developed?)

At the aggregate level, industry is the sector where the most information is available. In many countries, energy balances are disaggregated at International Standard Industrial Classification (ISIC) two-digit level (UNSD, 2008). A disaggregation of the gross domestic product (GDP) by broad category (e.g. for services and industry) is also widely available from different national and international organisations. This information can be used to assess the importance of the industry sector within the whole economy and indicate if priority should be given to this sector.

Given the diversity of the sector, and the very different energy profile of each industry, the use of the broad intensity indicators (energy consumption per unit of value-added) for cross-country comparison, or even for an assessment of industry performance over time, is greatly misleading. For example, in the case of China, energy per value-added decreased by 65% between 1990 and 2000, while it only decreased by 15% between 2000 and 2010. However, an analysis of the data at the industry level indicates that highly energy-intensive industries have increased their

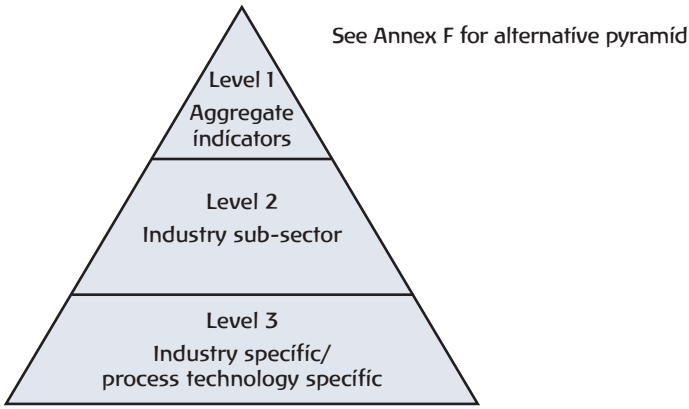
1. The five most energy-intensive sub-sectors globally: iron and steel, cement, chemicals and petrochemicals, pulp and paper, and aluminium.

share of total industry production and, as a result, had an upward impact on energy intensity despite the improvement in energy efficiency.

Additionally, different industries use a different fuel mix; the production of aluminium is electricity intensive, coal is predominant for iron production, and chemicals use mostly oil and natural gas. If the goal is to reduce the consumption of one specific fuel, and not to improve overall energy efficiency, then the prioritisation will depend on the fuel mix of the individual industry. However, as the fuel mix is highly dependent on the process technology used, it may not be possible to reduce the consumption through simple fuel switching, but would require both process changes and improvement in process energy efficiency.

Overall, the first key step is to develop aggregate indicators to understand the importance of the industry sector of the economy (Figure 5.4). Then, indicators by industrial sub-sector are required to assess where and how energy is used, and where the greater potential for reducing energy consumption may be. In-depth indicators should then be developed to ensure that policies and actions to reduce energy consumption are targeted towards areas where such potential exists. The decision about which industry should be prioritised for the development of in-depth indicators should also take into consideration the importance of the industrial sub-sector within the country's economy, the potential savings from the sector (which can be assessed through BAT analysis and/or benchmarking), and the data availability or potential to obtain the data.

Figure 5.4 • Detailed indicators pyramid of the industry sector



From the industry perspective, development of indicators is of key importance. Improvement of energy efficiency reduces the need for energy, reducing the energy cost and increasing the competitiveness and profits of the plant. Detailed indicators can help identify areas for energy reduction within their production process. Energy management systems (EMS) can help develop, track and improve energy indicators within businesses. An established EMS can help set and prioritise energy efficiency targets and define strategic energy efficiency upgrade projects.

Box 5.2 • The benefits of energy efficiency indicators for companies

Experience in IEA member countries suggests that industry itself may be very interested in relevant energy efficiency indicators. Companies can use such indicators to draw lessons on how to become more energy efficient, and can benchmark themselves against other companies or chart their own progress over time. Indicators can also help industry improve the reliability and flexibility; for example, fouling of heat exchangers may lead to a decrease of energy efficiency levels in a process, but it can also reach the stage of limiting the production capacity.

Ultimately, indicators can be used to increase competitiveness. In countries where energy is highly subsidised, more cost-reflective pricing will encourage more energy efficient behaviour – which, in turn, raises net revenues. Further stimulus for energy efficiency through national programmes could bring added incentives to industry: if shareholders view improved efficiency as supporting national goals, the company may see its share price increase.

Collecting data relating to energy consumption by small- and medium-sized enterprises (SMEs) is not yet a generalised practice globally. In many cases, the underlying legislation for mandatory reporting does not exist, such as for the large industry energy consumers involved in the EU Emissions Trading Scheme. IEA experience is that data from SMEs are an important component of the energy scene. In some IEA countries, SMEs report relevant data on a voluntary basis. In other countries, reporting is mandatory.

The IEA also finds that it may be more difficult to collect data from large enterprises: if there are one or two companies in the sub-sector, the enterprises may be averse to reporting due to confidentiality issues. However, these barriers might be overcome by developing proper mechanisms for data collection and dissemination. Several industrial associations have successfully put such mechanisms in place.

4 Development of índícators by level of the pyramíd

This section explains which indicators can be developed at each level of the pyramid and for each industrial sub-sector, and how they should be interpreted. It is rarely possible to define a single "true" indicator that satisfactorily captures all the information that needs to be conveyed about energy consumption and CO_2 emissions in a sub-sector or a process. Selecting only one indicator for cross-country comparisons can produce a misleading picture.

Even at the more detailed level, the indicators presented can provide only a general idea about the order of magnitude of the improvement potentials in industry. It is recommended that more detailed analysis on a country-by-country level be done before such indicators could be considered as a basis for target setting.

Table 5.1 summarises all the indicators described in the industry sector and provides a quick overview of the usefulness of the indicator. This table matches the discussion on indicators in the *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 5.1 • Summary of indicators used in the industrial sector

Indicator	Coverage	Energy data	Activity data	Code	Recommended indicator
Energy consumption per unit of physical output	Sub-sector	Total sub-sectoral energy consumption	Sub-sectoral physical output	IS2a	☺
	Process/ product type	Process/product type energy consumption	Process/product type output	IS3a	
Energy consumption per unit of value added	Sub-sector	Total sub-sectoral energy consumption	Sub-sectoral value added	IS2b	
	Process/ product type	Process/product type energy consumption	Process/product type value added	IS3b	

Level 1 indicators

Sectoral industry energy intensity

Definition: Measures how much energy is needed to produce one unit of economic output.

The structure of the sector – with a larger share of energy consumption and materials production coming from the most energy-intensive sub-sectors – had an upward impact on energy intensity, but has been offset mainly by energy efficiency improvements in many regions of the world, especially in developing countries, where high production growth rates have allowed the addition of new and efficient production capacity.

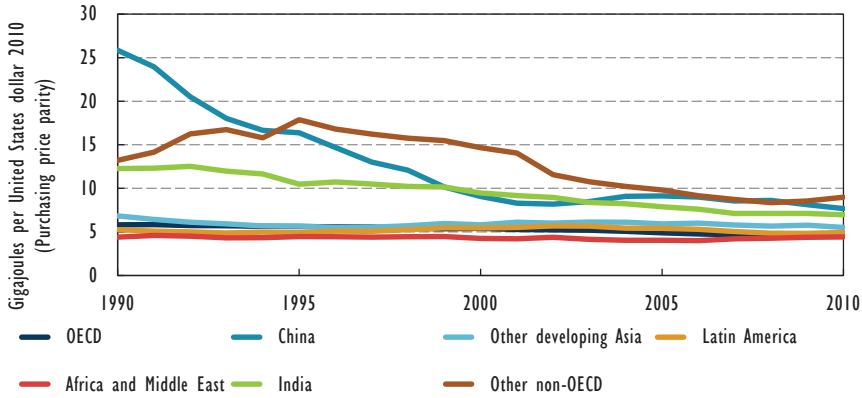
Despite industry's reducing its energy intensity since 1990, energy consumption has continued to grow due to increases in global industrial material demand, with a resulting increase in total energy consumption and CO_2 emissions (Figure 5.5). Energy intensity improvement does not necessarily imply direct improvements in energy efficiency: other factors can play a role, such as structural changes that base a higher share of the economy on more energy-intensive industry, and fluctuating material prices.

Use of level 1 indicators: Provide an overall view of the evolution of energy intensity for the industry sectors. In countries where there has been no major change in the structure of the economy or in the different process technology/feedstock used, this could indicate the general trend of energy efficiency.

Relevance for policy development: Given the many factors that influence this indicator, no conclusion can be drawn as to where efficiency improvements can be made and where more attention is required.

Cross-country comparison: It would be misleading to evaluate the performance of energy efficiency based on this indicator as it is affected by many non-energy efficiency factors such as the structure of the industry, the quality of resources and, for some industrial sub-sectors, weather conditions.

Figure 5.5 • Example of level 1 indicator: total energy consumption per unit of industry value-added



Data availability and sources:

- Energy consumption: usually available in national energy balances and in IEA energy balances
- Industry value-added: available from World Bank and may be available from national accounts.

Table 5.2 • Description of level 1 indicators

Indicator	Data required	Purpose	Limitation
Total energy consumption by unit of industry value-added	• Total industry energy consumption • Total industry value-added (in constant currency)	• Reflect the trends in overall energy consumption relative to value-added • Indicates the general relationship of energy consumption to economic development	• **Does not measure energy efficiency developments** • Influenced by factors such as structure of the economy • Changes over time are influenced by factors not necessarily related to energy efficiency

Level 2 indícators

The disaggregation of level 2 depends on the data available, both in terms of energy consumption data and activity data (value-added or physical units of production). For example, while in some countries information may be available for the overall category "pulp, paper and printing", in countries where this industry sub-sector is important more disaggregation by type of pulp and paper may be available (Figure 5.6). As a result, the pertinence of indicators developed at this level will be highly dependent on the level of information available for each sub-industry.

At this level, the best indicator to assess energy intensity is energy consumption per unit of production. However, this indicator is available only for some industries, as some industries are typically too heterogeneous to have one measure of production (e.g. chemical industry) and some products may be produced by the same process technology.

Box 5.3 • Energy and CO_2 indicators for industry: using economic or physical ratios

Energy and CO_2 indicators for industry typically comprise a measure of energy consumption or CO_2 emissions divided by a measure for activity. Activity is usually defined as the production of a given sub-sector or product, and can be measured in either economic terms (e.g. value-added) or in physical units (e.g. weight or number of products). Generally, indicators calculated in monetary units are used at a sectoral or economy-wide level. Indicators based on physical units are better suited to detailed sub-sectoral analyses.

There are several advantages in using economic ratios. First, the measure of activity (monetary value) is similar even though different products are produced. This makes it possible to compare indicators across different sub-sectors of industry. Second, on a practical level, value-added data for industry – including data disaggregated into different sub-sectors – are available from the OECD for most IEA countries. This facilitates consistent cross-country comparisons. These indicators can also provide a sense of **economic efficiency** for the different sub-sectors considering a set of energy prices – how much added value is gained for the allocated cost to the energy consumption.

However, economic-based indicators suffer from one significant drawback: they are influenced by a range of pricing effects that are unrelated to changes in the level of underlying physical production.

An alternative approach is to calculate energy consumption and CO_2 emissions indicators based on physical ratios, e.g. using a measure of activity based on tonnes of production. These types of indicators are often called the "specific" or "unit energy" consumption; their advantage is that they are not affected by changes in prices. Thus, at a disaggregated level, physical indicators can give a better measure of the technical efficiency of a particular production process, although it includes the impact of different grade of products. However, because the denominator is measured as a physical unit, it is not possible to compare indicators defined in differing units without making conversions, for example by applying the production growth rate to the value-added in a base year.

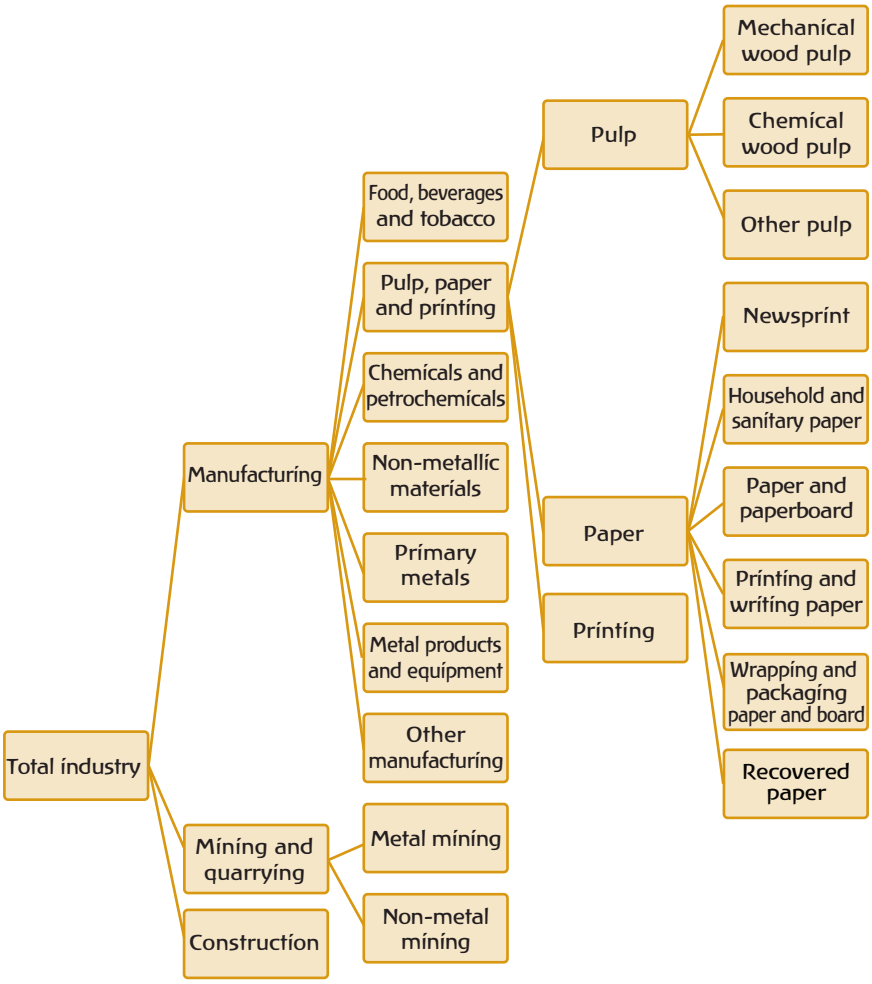
Energy intensity by industry based on value-added or physical unit of production

Definition: Measures how much energy is needed to produce one unit of economic output or one unit of physical output.

Energy consumption per unit of production is the preferred indicator, where available.

Relevance for policy development: When the indicator is developed at a rather disaggregated level, the intensity provides important insights that help understand the efficiency performance and the energy reduction potential.

Figure 5.6 • Example of industry disaggregation



Note: Categories reflect IEA Energy Technology Perspectives (ETP) modelling categories so may be different to some ISIC industry categories. See *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014) for industry ISIC categories.

Cross-country comparison: With sufficient level of disaggregation, it is possible to compare countries and assess their relative efficiency.

Data availability and sources: While energy consumption is available at the aggregate level for the industry sub-sector in energy balances, the level of disaggregation required to allow for cross-country comparison or ensure policy relevance is not. Detailed energy consumption data may be available through special industry surveys or from national industrial associations.

Related indicator: With this level of information, it is possible to calculate "structure adjusted" energy consumption. While this indicator still includes some structural change in sub-industries and differences in input quality and process used, it is a better indicator than the total energy/GDP to perform country comparison (Figure 5.7).

Figure 5.7 • Energy consumption in iron and steel and non-ferrous metals by tonne of steel produced by country in 2010

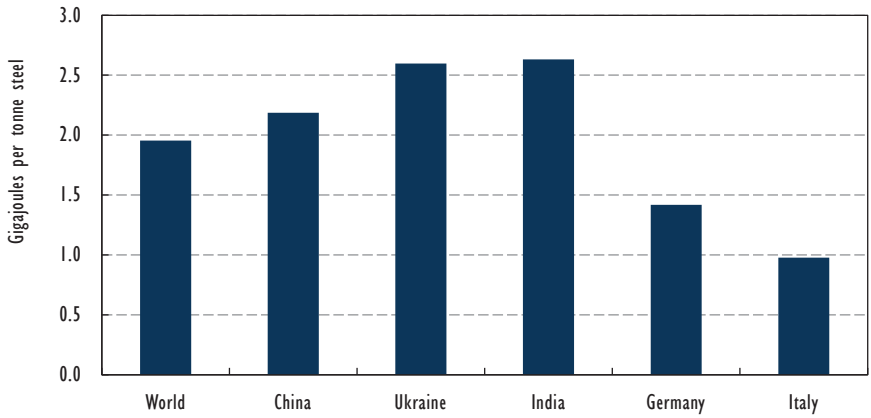


Table 5.3 • Description of level 2 indicators: industry

Indicator	Data required	Purpose	Limitation
Industry sub-sector's energy consumption by unit of value-added	• Energy consumption by industry sub-sector • Corresponding value-added (in constant currency)	• Indicate the general relationship of energy consumption to economic development	• May hide some important structural shift within an industry (but this impact will be somewhat offset by using more detailed energy and value-added data) • Value-added are influenced by a range of pricing effects that are unrelated to changes in the underlying physical production
Industry sub-sector energy consumption by unit of physical production	• Energy consumption by industry sub-sector • Corresponding physical unit of production	• Indicate the relationship of energy consumption to physical production. Often called the "specific" or "unit energy" consumption • At the disaggregated level, can give a better measure of the energy efficiency of a particular production process	• It is not possible to compare indicators defined in different units • Cannot provide an aggregate picture of energy efficiency for the whole of industry

Level 3 indicators: Industry-specific/process technology-specific indicators

Given the number of sub-sectors covered by the industry sector, it is not possible to provide an exhaustive list of process-specific indicators for each of them. As such, the discussion in this section focuses on the five most energy-intensive sub-sectors: iron and steel, cement, pulp and paper, chemicals and petrochemicals, and aluminium.

Box 5.4 • Analysis based on Best Available Technologies (BATs)

Traditionally, due to a lack of data, the IEA has used indicators for industry based on energy consumption or CO_2 emissions per unit of value-added output. While such indicators are good at capturing aggregate trends in energy consumption and efficiency, they are less suited to detailed cross-country comparison of energy efficiency developments by sub-sector or process, or for an examination of improvement potentials. This is because they do not take full account of differences in product quality and composition of the processing and feedstock mix, which can vary widely between countries. Furthermore, indicators based on economic ratios cannot be validated by technological data. The IEA therefore undertook a major study (IEA, 2007) which presents detailed indicators based on physical production, typical value for key indicators and selected benchmarking results for some industry. The advantages of this approach are that the indicators:

- Are not influenced by price fluctuations, which facilitate trends analysis
- Can be directly related to process operations and technology choice, thus allowing a closer measure of technical energy efficiency
- Enable a well-founded analysis of efficiency improvement potentials.

Disaggregate indicators have been developed for iron and steel, cement, pulp and paper, chemicals and petrochemicals, and aluminium. These indicators are used to track energy efficiency progress over time and also to calculate the technical potential for energy reductions in each sub-sector that could be achieved by moving to BAT or BPT. The latest results of the BAT analysis can be found in *Energy Technology Perspectives 2012* (IEA, 2012).

Iron and steel

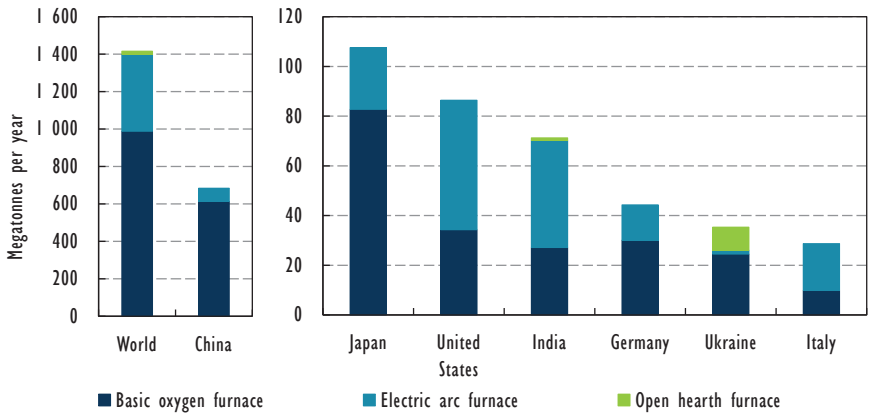
Steel is produced via a dozen or so processing steps, laid out in various configurations depending on product mixes, available raw materials, energy supply and investment capital. There are three main process routes used today:[2]

- Blast furnace (BF)/basic oxygen furnace (BOF), based on 70% to 100% iron ore and the remainder scrap for the iron input
- Scrap/electric arc furnace (EAF) method, based on scrap for the iron input
- Direct reduced iron (DRI)/EAF method, based on iron ore and often scrap for the iron input.[3]

The scrap/EAF route is much less energy intensive (4 gigajoules per tonne [GJ/t] to 6 GJ/t)[4] than the BF/BOF route (13 GJ/t to 14 GJ/t), because there is no need to reduce iron ore to iron, and it removes the need for the ore preparation, coke-making and iron-making steps.[5]

2. A fourth route, the open hearth furnace (OHF) route, has an iron input profile similar to the BOF route, but is an outdated technology and its use is less than 3% of current global production.
3. DRI can be economically substituted for scrap in places where scrap is in short supply and there are cheap sources of fossil fuels (e.g. stranded gas supplies).
4. An EAF uses about 1.6 GJ of electricity per tonne of steel for 100% scrap feedstock and somewhat more with increasing DRI inputs. In actual operation, however, EAF energy consumption is somewhat higher. To be truly comparable, the electricity should be expressed in primary energy terms. With electricity generation ranging from 35% to more than 50%, EAF primary energy consumption is in the range of 4 GJ to 6 GJ per tonne of steel.
5. For more information on different BAT values in industry, readers are referred to IEA, 2007.

Figure 5.8 • Production by process route and energy intensity for selected countries, 2010



Source: *World Steel Association* (World Steel), (2011), *Steel Statistical Yearbook 2011*, Brussels.

Note: includes energy consumption in blast furnaces. EAF steel includes both the scrap/EAF and DRI/EAF routes. India is the largest DRI producer in the world with production based on coal, which is significantly more energy intensive than DRI based on gas. Mt = million tonnes.

A broad-based comparison of total sub-sector energy consumption per tonne of crude steel is of limited use because the production processes are very different. At the very least, the BF/BOF, scrap/EAF and DRI processes need to be treated separately. Even then, there are considerable differences in the energy efficiency of primary steel production among countries and even among individual plants (Figure 5.8). These differences can be explained by factors such as economies of scale, the level of waste-energy recovery, the quality of iron ore, operation know-how and quality control. Useful indicators for this sub-sector would include:

- Total primary and final energy consumption per tonne of crude steel (including finishing)
- Total primary and final energy consumption per tonne of BF/BOF steel production
- Total final energy consumption per tonne of DRI (split between gas- and coal-based processes)
- Total primary and final energy consumption per tonne of EAF steel (excluding finishing)
- Total direct CO_2 emissions per tonne of crude steel.

These detailed indicators would need to be based on consistent boundary definitions across countries and take account of a number of common industry practices. These practices include the widespread trading of iron ore pellets, coke and scrap steel, the sale of blast furnace gas and coke oven gas for power generation, the share of coke oven gas recovered and used on-site, and the use of slag by-products as a substitute for cement clinker. However, the necessary disaggregated energy data are not currently available to construct these detailed indicators. Nor are there comparable data to develop indicators for steel rolling and finishing on an aggregate level. More work is needed to collect the necessary data.

Cement

There are two basic types of cement production processes and a number of different kiln types. Cement production is either "wet" or "dry", depending on the water

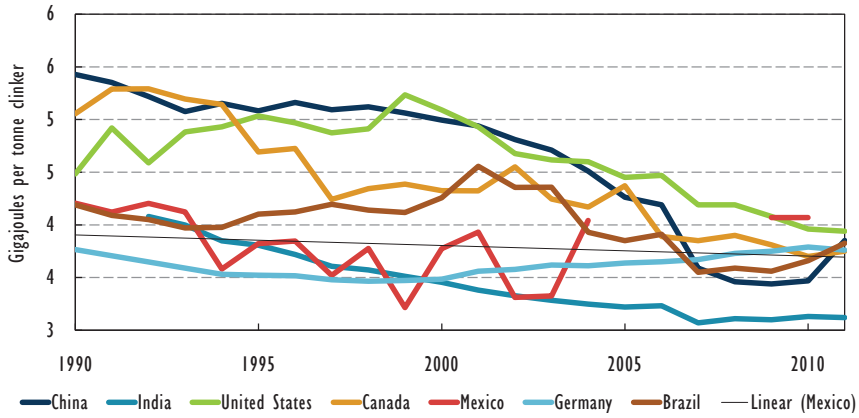
content of the raw material feedstock. The dry process avoids the need for water evaporation and consequently has much lower energy intensity (around 3.0 GJ per tonne of clinker compared with 4.2 GJ per tonne of clinker for efficient plants). The other major difference is between vertical shaft kilns and their more efficient counterparts, rotary kilns. Today's state-of-the-art dry-rotary kilns are fairly fuel efficient, using around 2.9 GJ to 3.0 GJ per tonne of clinker.

Since the production of cement is a relatively simple process, with well-defined system boundaries and a uniform product, it is well suited to indicator analysis. A number of indicators can easily be calculated for clinker (the partially fused product of a kiln, which is then ground for use in cement) and cement production to track developments over time. They include:

- Energy consumption, including alternative fuels, per tonne of clinker
- Electricity consumption per tonne of cement
- Total primary energy equivalent per tonne of cement
- Total CO_2 emissions (process and energy-related) per tonne of cement
- Alternative fuel use in clinker production
- Clinker-to-cement ratio
- Waste heat recovered per tonne of clinker
- CO_2 emissions from energy consumption (including electricity) per tonne of cement.

Perhaps the most important indicator from an energy efficiency viewpoint is the average energy consumption per tonne of clinker produced. The indicator shows that most countries experienced a downward trend in the energy intensity of clinker production between 1990 and 2011 (Figure 5.9). This has largely been due to the shift from wet- to dry-process cement kilns, coupled with the replacement of older dry kilns by the latest technology using pre-heaters and pre-calciners.

Figure 5.9 • Energy consumption per tonne of clinker by country



Sources: *CSI (Cement Sustainability Initiative)* (2013), *Getting the Numbers Right Database, World Business Council for Sustainable Development*, Geneva; IEA estimates.

Care is needed when interpreting the absolute levels of energy intensity shown. Further work is needed to refine this indicator to ensure that consistent definitions

and boundaries are being used across all countries. However, it would appear that India has the most efficient clinker production and is at, or near, the practical lower limit of heat consumption for advanced dry kilns with pre-heaters and pre-calciners. In China, the average energy consumption per tonne of clinker is currently about 3.45 GJ per tonne. The EU, Canada and the United States all use around 3.8 GJ to 4.0 GJ per tonne of clinker.

Pulp and paper

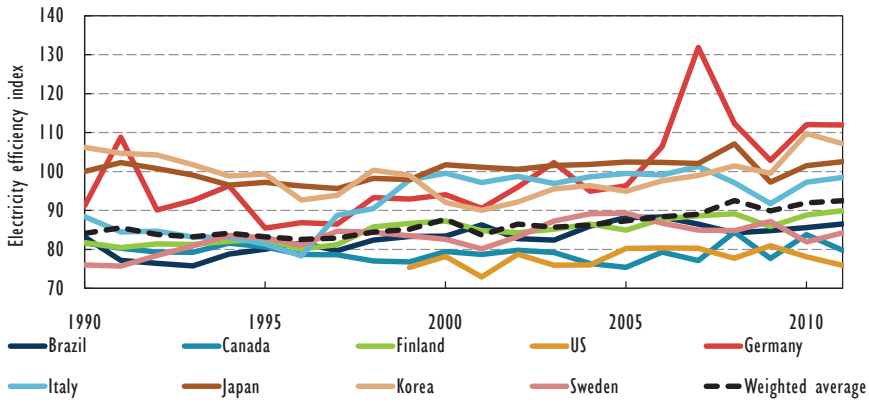
Energy consumption in the paper and pulp industry is divided among a number of different pulp production and paper production processes. The main processes are:

- Chemical pulping
- Mechanical pulping
- Paper recycling
- Paper production.

Ideally, energy and CO_2 indicators for this sub-sector should be developed for each main product category and even sub-product category (as specialty paper usually requires more energy to produce than, for example, paperboard). The energy indicators developed by the IEA for the pulp and paper sub-sector are intended for a country comparison of energy intensity in the pulp and paper industry and as a first indication of potential improvements. The lack of publicly available energy consumption data on the level of specific products makes individual process indicators infeasible, and thus aggregate product indicators are proposed:

- Energy efficiency index based on fuel use for heat
- Energy efficiency index based on electricity use (Figure 5.10)
- CO_2 emissions index.

Figure 5.10 • Electricity efficiency potentials



The methodology for calculating an energy efficiency index is as follows:

- Use IEA energy statistics for final energy consumption
- Define a BAT value for mechanical pulping, chemical pulping, waste paper pulp, de-inked waste paper pulp and seven different paper grades

- Multiply production volumes and BAT to calculate practical minimum energy consumption
- Divide practical minimum energy consumption and actual energy consumption (final energy).

This is the energy efficiency index for the aggregate pulp and paper sub-sector. The energy efficiency improvement potential is calculated as one hundred minus the energy efficiency index.

Chemícals and petrochemícals

The chemicals and petrochemicals industry is highly diverse, with thousands of companies producing tens of thousands of products in quantities varying from a few kilograms to thousands of tonnes and with several products being produced jointly through the same process technology. Because of this complexity, reliable data on energy consumption at the individual process level are not available. In addition, more than half of the total fuel inputs to this sub-sector are accounted for by feedstocks, and so is non-energy consumption.

While it would be unrealistic to develop separate indicators for all chemical and petrochemical products, it would be, in theory, possible to construct aggregate energy indicators for the sub-sector (excluding feedstock use), together with separate indicators for key products such as ammonia, ethylene, propylene and benzene, toluene, and xylene. In addition, for some products different production processes can be used, and these need to be taken into account.

However, in reality, data problems are substantial and energy associated with feedstock is not always possible to segregate from reported overall energy data, which makes it hard to analyse the impact that the feedstock quality has on energy consumption. Comparing these indicators across countries and process technologies is not obvious and can be misleading, as not all the differences can be allocated to energy savings potential. Therefore an approach similar to the paper and pulp industry has been used, with an aggregate indicator (including feedstock) developed that compares actual energy consumption with the BAT level. Separating process from energy-related CO_2 emissions also helps analysing the realistic potentials for CO_2 emissions reduction.

Production volumes for benzene, toluene and xylene are usually split between production from steam cracking (more energy intensive) and naphtha extraction. This split can be calculated based on the production volume of ethylene and the ultimate aromatics yields of steam cracking for the different feedstocks. Similarly, propylene production can be split between steam cracking and fluid catalytic cracking.

Energy indicators for chemicals and petrochemicals are different from other sub-sectors because of this locked-in feedstock energy and carbon. Ideally, indicators should be developed at the level of individual processes and products, but as with the pulp and paper sub-sector, a lack of energy data at this level of detail makes this approach infeasible. Instead, aggregate product indicators for both energy (including feedstock energy consumption) and CO_2 (including energy-related and process CO_2 emissions) are developed, based on 42 of the most important products, representing more than 95% of all energy consumed in the chemical and petrochemical industry. These indicators are:

- Total energy consumption excluding electricity use versus BPT

- Total energy consumption including electricity use versus BPT
- Total and process CO_2 emissions versus BPT.

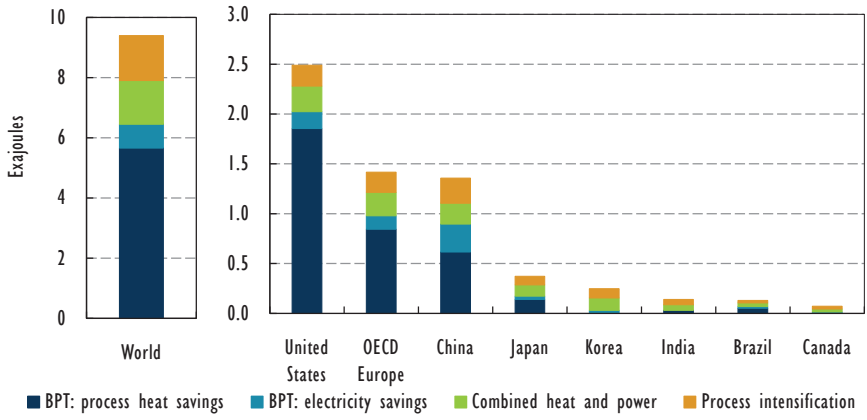
Given the heterogeneous nature of the chemical and petrochemical sub-sector, the present efficiency indicators are not appropriate for country comparisons. However, monitoring their evolution over time provides valuable information on trends in energy efficiency.

Table 5.4 • Energy improvement potential by BPT in the global chemical and petrochemical sub-sector, 2009

	Excluding electricity				Including electricity			
	Total reported (EJ)	Total BPT calculated (EJ)	Energy efficiency indicator	Improve-ment potential	Total reported (EJ)	Total BPT calculated (EJ)	Energy efficiency indicator	Improve-ment potential
United States	5.5	4.1	0.73	26.9%	6.3	4.3	0.68	31.9%
Japan	1.9	1.8	0.90	9.8%	2.1	1.8	0.84	15.8%
China	4.9	4.4	0.89	11.1%	6.1	4.4	0.73	27.3%
Germany	1.1	1.0	0.93	7.1%	1.2	1.0	0.85	14.7%
Canada	0.7	0.6	0.85	14.6%	0.7	0.5	0.82	18.1%
Netherlands	0.7	0.5	0.69	31.1%	0.8	0.5	0.66	34.0%
Brazil	0.5	0.5	0.94	6.4%	0.6	0.5	0.83	17.1%
Chinese Taipei	0.9	0.8	0.91	8.9%	1.0	0.8	0.82	18.3%
Italy	0.3	0.3	0.77	22.7%	0.4	0.3	0.69	31.1%
World	32.5	27.8	0.86	14.4%	36.1	28 .7	0.79	20.5%

The savings outlined in the aggregate intensity indicator above are only the energy savings that would be achieved by implementing BPT in core chemical processes. There are further opportunities within the sub-sector for achieving energy savings in the short-to-medium term including process intensification/integration, co-generation, recycling and energy recovery (Figure 5.11).

Figure 5.11 • Current energy savings potential for chemicals and petrochemicals, based on BPTs, 2010



Alumíníum

Aluminium production can be split into primary aluminium production and recycling. Primary production is about 20 times as energy intensive as recycling and represents the bulk of energy consumption.

Primary aluminium is produced in three distinct steps:

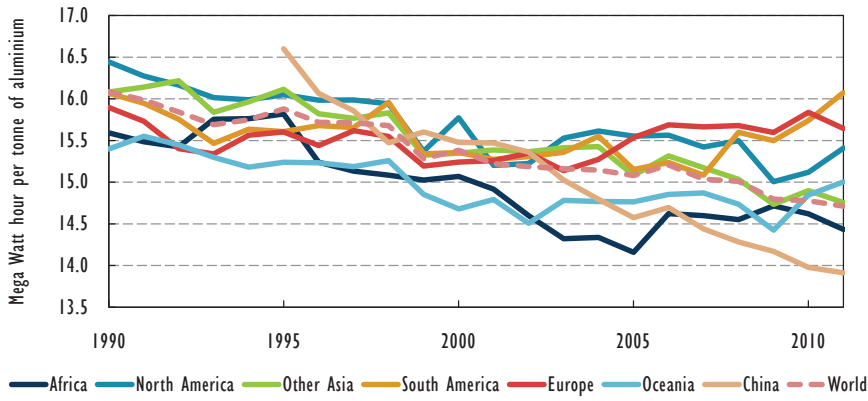
- bauxite (ore) mining
- alumina refining
- aluminium smelting.

In principle, it would be possible to construct energy efficiency and CO_2 indicators relating to each of these steps.

Most of the energy consumed in alumina refineries is in the form of steam. The calcining (drying) of the alumina requires large amounts of high temperature heat. Due to a high demand for steam, modern plants use co-generation systems.

Virtually all alumina is produced in the Bayer process, a combination of an extraction (digestion with caustic soda) and a calcination process. Fuel consumption of a Bayer plant can vary between 10 GJ/t of alumina and 15 GJ/t of alumina. This could be reduced to 9.5 GJ/t through better heat integration, further deployment of co-generation and improved co-generation systems.

Figure 5.12 • Regional specific electricity consumption in aluminium smelting



Source: IAI (International Aluminium Institute) (2013), Primary Aluminium Production, IAI, London. See *http://www.world-aluminium.org/statistics/* for definitions of geographical aggregations.

Best practice electricity use in an alumina plant is about 203 kWh/t of alumina. Energy consumption for digesting can vary between 6.3 GJ/t alumina and 12.6 GJ/t alumina, while the fuel consumption for the calcining kiln can vary from 3.4 GJ/t for stationary kilns to 4.2 GJ/t alumina for rotary kilns (Worrell and De Beer, 1991).

Electrolysis is the most energy-intensive step in the production of aluminium. Two main types of smelters are used for the electrolysis: the Hall-Héroult system with pre-baked anodes, and the older Søderberg cell with in situ baked electrodes. Electricity

consumption for pre-baked smelters is in the range of 13 000 kilowatt-hours (kWh) to 16 500 kWh per tonne while Søderberg smelters use about 15 000 kWh to 18 000 kWh per tonne of aluminium (EC, 2001). The Hall-Héroult electrolysis process is a mature technology, but improvements in its productivity and environmental performance are still possible. Due to its high electricity intensity, specific electricity consumption is the most important energy indicator for aluminium smelting.

World average electricity use for primary aluminium production in 2006 was 15 206 kWh per tonne. This average has declined about 0.4% per year over the last 25 years. On a regional basis, the 2012 averages range from 13 844 kWh per tonne of aluminium in China to 15 912 kWh per tonne in South America. China is the most efficient region due to new production facilities – and the level of capacity growth in China, now accounting for over 40% of global production, has caused an acceleration in the rate of improvement in global energy efficiency for the sector to about 0.7% per year over the period 2006 to 2012.

5 Additional indicators explaining the changes in industry energy consumption

There are several additional indicators that can help understanding the trends in industry energy consumption and provide insights on the future trends the sector may follow.

Table 5.5 • Description of additional indicators: industry sector

Indicator	Data required	Purpose	Limitation
Total industry energy consumption by energy source	• Total energy consumption by energy source	• Insights on the effect of the final energy mix on total final energy consumption • Insights on the trends in CO_2 emissions	• Observed energy trends not necessarily a result of improved (or worsening) energy efficiency • One element, among many others, influencing trends in energy consumption • Can be attributed to changes in relative fuel prices, shifts in industry structure and processes, and implementation of environmental legislation that favours the use of cleaner fuels
Energy consumption by industry sub-sectors and by energy source	• Energy consumption by industry sub-sectors and by energy source	• Explain the role energy mix plays in the trend in energy consumption in each industry sub-sector • Insights on the trends in CO_2 emissions • Not influenced by industry structure when developed at a very disaggregated level	• Observed energy trends not necessarily a result of improved (or worsening) energy efficiency • Influenced by changes in relative fuel prices, shifts in industry processes and implementation of environmental legislation • Influenced by industry structure if developed at an aggregate level

Indicator	Data required	Purpose	Limitation
Composition of industry value-added (in constant currency)	• Value-added in constant currency by industry sub-sector	• Provides information on the relative importance of each sub-sector • Insights of the impact of the structure of the industry sub-sector on energy consumption • Qualitative information helping to explain trends in energy consumption	• Value-added is influenced by a range of pricing effects unrelated to changes in the level of physical production • Composition of industry value-added may mask some important structural shift within an industry sub-sector • Does not provide the link between value-added and energy required to quantify the impact of the structural change

6 Decomposítíon of changes ín índustry energy demand

While the best indicators to support policy development and compare countries are the ones at level 3 of the pyramid, a decomposition of the sector at level 2 provides important insight on the trends in overall energy consumption and to which extent the evolution was influenced by structural change. If more detailed information on energy and value-added is available, it is possible to refine the decomposition analysis.

Table 5.6 • Summary of variables used for decomposition of industry energy consumption

Industry		Activity (A)	Structure (S)	Intensity (I)
ISIC 17	Food products, beverages, tobacco products	Value-added	Share of value-added	Energy/ value-added
ISIC 17	Paper and paper products	"	"	"
ISIC 20-21	Chemicals and chemical products	"	"	"
ISIC 23	Non-metallic mineral products	"	"	"
ISIC 24	Basic metals	"	"	"
ISIC 25-28	Fabricated metal products, machinery and equipment	"	"	"
ISIC 10 to 32, excluding ISIC 19 and those described above	Other industry	"	"	"

For a group of 20 IEA countries (IEA20) for which consistent data are available, there has been a strong decoupling of energy consumption from output (as measured by value-added). Despite a 39% increase in output, final energy consumption in the industry sector of the IEA20 increased by only 5%, between 1990 and 2010. Furthermore, the analysis shows that energy efficiency improvements (as measured

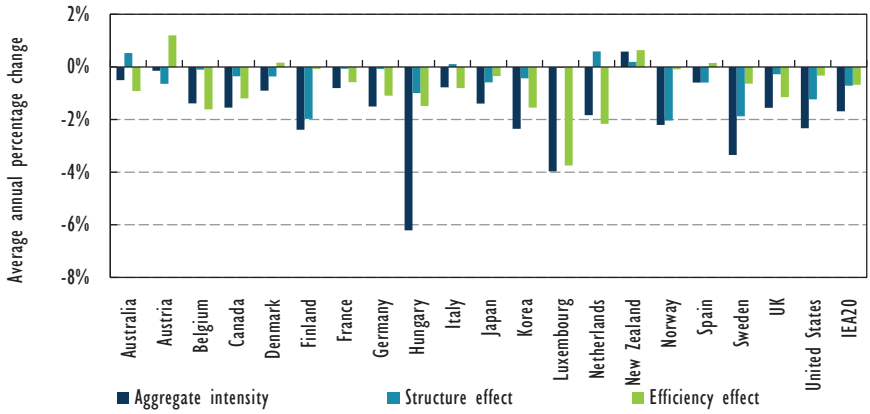
Box 5.5 • Decomposition analysis taking into account capacity utilisation and different activity basis

The recent economic crisis has had a great impact on the energy intensity of the industrial sector. In response to the decrease in demand for industrial production in most parts of the world, older and/or less efficient facilities were shut down. The result was an improvement in the overall energy efficiency of the industry. In other cases, facilities were not necessarily shut down, but the production level was lowered, thus decreasing the utilization of capacity. This decrease in capacity generally resulted in an increase in energy intensity, as some processes require the same amount of energy for different production levels, or can hardly be shut down and restarted.

Canada calculates the impact of changes in capacity utilisation for industry. During the recent economic crisis, between 2008 and 2009, energy intensity (energy consumption/GDP) increased 6.8% while capacity utilisation fell from 77.8% to 72.1%. The decomposition analysis indicates that falling capacity utilisation had a dramatic impact on energy intensity, mitigating gains to 5.5%, from 1990 to 2009. In 2011, with capacity utilisation recovering to 79%, intensity gains also returned to pre-recession levels of 12%. Such results highlight the need to consider the changes in capacity utilisation when decomposing the changes in industrial energy consumption.

by changes in the structure-adjusted intensities) were the main factor restraining energy consumption growth in most countries (Figure 5.13). Without the energy savings resulting from these improvements, energy consumption in the IEA20 would have been 21% higher in 2010. This represents an energy savings of 7.3 EJ in 2010, which is equivalent to 520 Mt of avoided CO_2 emissions in that year.[6]

Figure 5.13 • Decomposition of changes in industrial energy intensity, 1990 to 2010



6. The decomposition analysis results included in this manual are calculated using a three-factor decomposition analysis based on the Simple Laspeyres index decomposition methodology. See Annex A for further discussion on decomposition analysis methodologies.

A few countries showed different results from the overall trends. For instance, in Finland, Norway and Sweden, structural changes were the main factor restraining the growth in energy consumption. In the case of Finland and Sweden, this effect was augmented by a sharp decline in the structure-adjusted intensity. In contrast, structure-adjusted intensity increased in Norway, but because industry moved towards a less energy-intensive structure, there was a decrease in aggregate energy intensities. Denmark and Spain also showed increases in structure-adjusted intensities. In the case of Denmark this was largely due to increased energy intensities in the food and drink and non-metallic minerals sub-sectors, whereas in Spain the increased energy intensity of the chemicals sub-sector was an important factor.

7 Policy information and evaluation in the industry sector

Many options are available for improving industrial energy efficiency, including maintenance and refurbishment of equipment, retrofitting or replacing obsolete technologies, improving process integration by re-engineering and streamlining, reusing and recycling products and materials, or improving process controls to increase process productivity through minimising product reject rates and/or maximising material production yields. The high share of energy costs as a proportion of overall costs in industry often encourages the sector to implement many of these efficiency options as part of regular business practices.

However, in most cases, the implementation of efficiency options is likely to be below what is technically feasible and often even economically feasible due to a number of issues including:

- Failure to recognise the positive impact of energy efficiency on profitability
- Short investment payback thresholds and limited access to capital
- Low public acceptance for unconventional manufacturing processes
- Wide range of market failures such as split incentives, limited access to information, distorted fiscal and regulatory policies, and energy subsidies among others.

As a result governments have put in place a wide range of policy responses to attempt to address these issues. These policies include efficiency standards for process equipment, energy management requirements, energy consumption reduction targets, implementation of BATs in new capacity additions, financial incentives, fiscal incentives, energy and carbon tax, capacity building, and training.

The importance of supplementary information

The indicators beyond level 3 are the core of programme information, and form an essential framework context for supplementary information. However, these need to be nearly always supplemented with technology, resource availability and production information. Generally the policy informing capability of any indicator improves as it gets closer to the underlying driving forces behind production. It is useful to check that the indicators used accurately reflect the factors that influence the targeted policy outcome.

While energy efficiency indicators provide a strong basis for the development and tracking of policies, supplementary information to make a detailed policy assessment is required (Table 5.7).

Table 5.7 • Supplementary information for industry policy information

Policies and typical level 4 indices	Supplementary information needs	Supplementary indicators
Minimum Energy Performance Standards (MEPS) for process equipment • Energy input / energy output	• Equipment stock and sales data • Cost-benefit of policies	• The number and type of equipment, usage and derived energy demand • Age of equipment
Energy management and benchmarking • Energy savings • Energy intensity	• Evaluation of industrial context • Defined scope of programme, whether for only large companies or SMEs as well	• Pre and post energy performance • Value of investments and payback periods • Ex-ante energy performance
Recycling • Recovered paper rate • Post-consumer plastic recovery • Scrap availability (aluminium and iron and steel)	• Production consumption levels. • Recycling rates • Technical evaluation of feasible recycling rates	• Trends in demand for materials • Material quality

Analysts should also consider that industrial processes may vary depending on the availability and quality of fuels and raw materials. For example in India, the local coal is not suited for coke-making, but it can be used for DRI production and hence the country has high shares of the less efficient DRI route as a result of low-quality resources and the lack of scrap availability. In the chemical sub-sector, the choice and availability of feedstocks will also determine the level of energy consumption reduction potential. Process technologies based on gas normally require less process energy than those from other feedstocks such as oil and coal.

Developing Indicators for the Transport Sector

The transport sector includes the movement of people and goods by the transport modes of road, rail, water and air. The data for each of those modes are then broken down by fuel. Pipelines and international air and marine transport are excluded from the analysis.

Energy consumption in the transport sector is driven by a wide range of factors – those factors are different for the passenger segment and the freight segment. As a result, the passenger and freight energy and efficiency trends are calculated separately and will be presented in distinct sections.

Questions and Answers

Q1. Why is energy consumption in pipelines, international bunkers, marine and air excluded from the transport sector?

Energy consumption used in these categories often crosses many territorial boundaries. It is very challenging to attribute cross-border transport energy consumption to a single country/region, and so they are removed from the transport energy efficiency indicator analysis.

Q2. What is fuel tourism?

National energy balances count the fuel sales in individual countries. In countries where there is a significant price difference from neighbouring countries, there may be fuel tourism or cross-border trade. This results in sales in a particular country not truly reflected in the transport activity for that country. Without any adjustments, any indicators based on these numbers are not meaningful. This is a problem for both passenger and freight transport.

Q3. Why is there a need to make a distinction between passenger and freight?

Passenger and freight transport have very distinctive motivations, organisations and drivers of development and therefore should be examined separately in order to understand the main factors driving the consumption in each.

Q4. How is off-road energy consumption, where no passenger or goods are transported, accounted for?

Off-road is accounted for in other sectors (i.e. residential/services/industry). The main purpose of off-road vehicles is not to move goods or people, but to use machines for other operations (e.g. tractors, bulldozers).

Q5. Are transport-related infrastructures, such as rail stations or airports, included in this sector?

No, the energy consumption of transport-related infrastructures is included in the services sector. The energy consumption is best described as building energy consumption rather than transport energy consumption.

Trends in energy consumption by transport mode vary significantly among countries and regions. On average, the growth in non-member countries of the Organisation for Economic Co-operation and Development (OECD) (100%) was faster than in OECD countries (26%). The large increase in non-OECD countries is in part attributable to the rapid economic growth of several major countries, leading to increased personal disposable incomes, higher vehicle ownership and increased need for freight transportation. Of the countries and regions analysed, non-OECD Europe and Eurasia are the only regions showing a decline in transport energy consumption between 1990 and 2011, due to the major economic restructuring that took place in the early and mid-1990s.

Box 6.1 • Energy efficiency in the transport sector: system efficiency versus vehicle efficiency

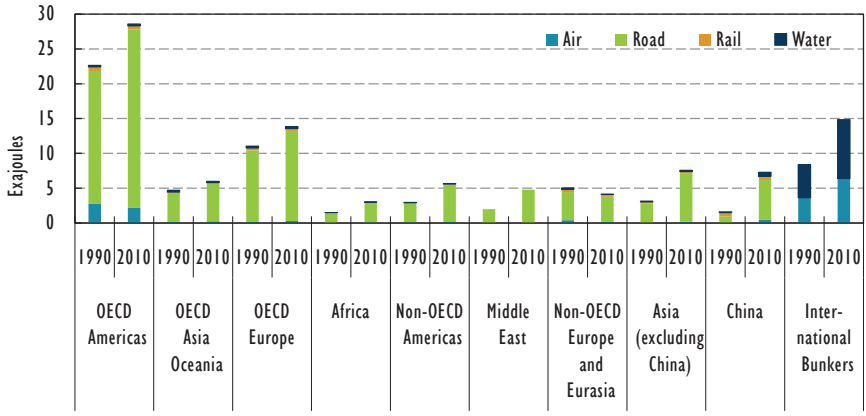
Defining energy efficiency in the transport sector is not straightforward. Many measures can lead to reductions in energy consumption and carbon dioxide (CO_2) emissions. For indicators, energy efficiency analysis aims at measuring the efficiency of specific vehicles or transport mode. As such, aggregate indicators such as consumption of energy per passenger-kilometre (energy/pkm) or tonne-kilometre (energy/tkm) are defined as "intensity indicators".

However, modal shift could also be interpreted as efficiency when assessing the overall transport system. Even if the specific energy efficiency of each vehicle is not improving, it is possible to use the transport system more efficiently by adopting a transport mode that is relatively more efficient (for example, using public transport instead of personal cars).

Choosing which indicators are the most useful depends on the policy question to be answered. For example, tracking the impact of fuel economy policies will require the development of energy efficiency indicators at vehicle type level, but tracking the impact of policies to encourage public transport will require intensity indicators.

Between 1990 and 2011, transport energy consumption increased by almost 55% to 102 exajoules (EJ) (excluding international bunkers), and was the fastest-growing end-use sector. In 2001, 27% of global total final energy consumption was transport energy consumption. The associated CO_2 emissions rose broadly in line with this increased energy consumption to reach 6.8 gigatonnes of carbon dioxide ($GtCO_2$). Road transport is by far the largest energy consumer and accounted for 90% of total transport energy consumption in 2010. It is also the main contributor to increased transport energy consumption. While non-road modes increased only 5% between 1990 and 2010, road transport energy consumption jumped 55%.

Figure 6.1 • Transportation energy consumption by mode



Note: All international navigation and aviation are included in the last bars, and are considered as a separate region. As a consequence, only domestic navigation and shipping are considered in each region or country. For the rest of the analysis, international bunkers have been excluded.

A) Developing indicators for the passenger transport segment

Passenger transport includes the movement of people by road, rail, water and air. Road transport is further subdivided into two- and three-wheelers, passenger light duty vehicles and buses. Only domestic air travel is included; international air travel is not covered.

1 What is driving energy consumption in the passenger transport sector?

The trends in passenger energy transport are driven by changes in population and density, land-use sprawl, transport infrastructure, travel patterns, income, vehicle ownership rates, vehicle occupancy rates, consumer preference, and average fuel economy.

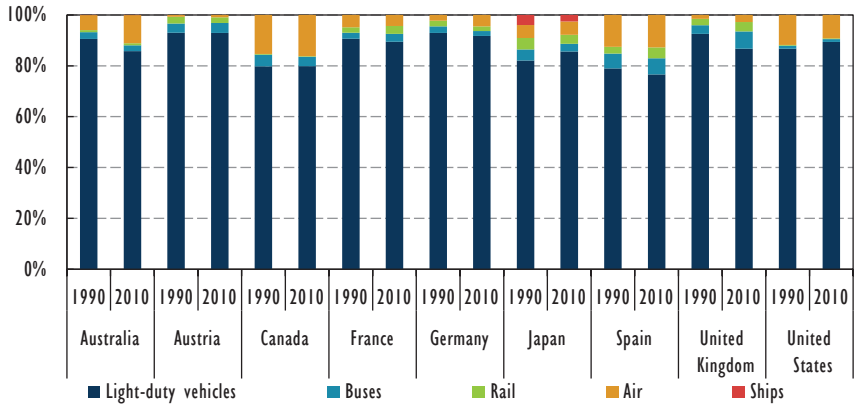
More generally, for the development of passenger transport energy efficiency indicators, the main activity variables considered to explain the trends in energy consumption are passenger-kilometres and vehicle-kilometres.

2 How is energy consumed and how has it evolved recently?

The disaggregation required to develop indicators for the passenger transport sector is available for only 15 member countries of the International Energy Agency (IEA).[1] As a result, the examples presented for this sector will cover those countries.

The share of the different modes of passenger transport in final energy consumption has remained relatively stable since 1990. Light-duty vehicles (LDVs) – four-wheeler vehicles for personal use which contain eight seats or less, (including cars, mini-vans, sport utility vehicles [SUVs] and personal-use pick-up trucks), are by far the largest energy consumers in all the countries analysed, accounting for 88% of total passenger transport energy consumption on average. Approximately 8% of passenger transport energy consumption was for domestic air travel, with the remaining shares being accounted for by buses, passenger rail and passenger ships. There is a strong link between energy consumption and emissions due to the almost total reliance on oil-based fuels for LDVs, buses and airplanes.

Figure 6.2 • Passenger transport energy consumption by mode in various countries



Passenger transport remains extremely dependent on oil products, which constitute 93% of final energy consumption. The fuel mix in passenger transport has undergone some important changes in recent years. Most significant has been the increased use of diesel in cars in Europe. As a result, the share of diesel in passenger transport

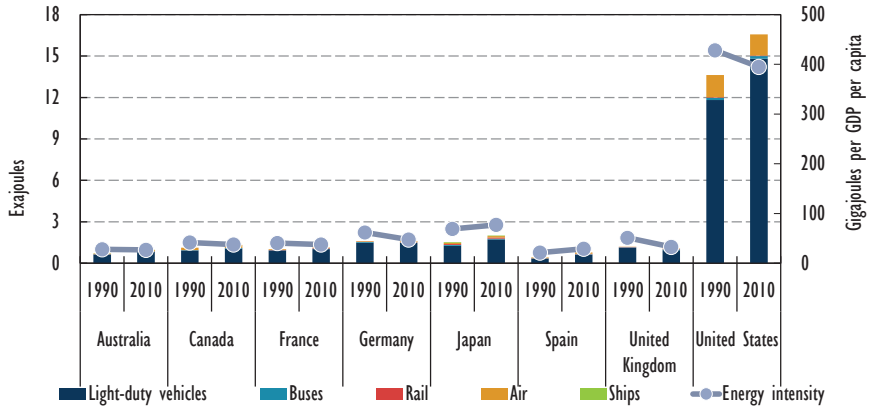
1. Passenger transport data are available for Australia, Austria, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, New Zealand, Spain, Sweden, United Kingdom and United States.

energy consumption in IEA15 has increased from 8% in 1990 to 15% in 2010. In some passenger modes there has been a notable shift from oil products.

As there is no major change in the fuel mix from year to year, the carbon dioxide (CO_2) emissions trends in the transport sector closely follow the trends in energy consumption. The purpose and limitations identified for the indicators also apply to CO_2 indicators.

Examining passenger transport energy consumption on a per-gross domestic product (GDP) per capita basis reveals interesting differences among countries in both the levels and the trends. Energy consumption per GDP per capita in several countries remained relatively stable or even decreased over the period. In contrast, Spain saw sharp increases in its energy per GDP per capita, largely due to a strong growth in car use. The energy per GDP per capita in the United States is the highest in IEA15, reflecting a combination of longer travel distances and larger and heavier vehicles. CO_2 emissions from passenger transport show a similar trend.

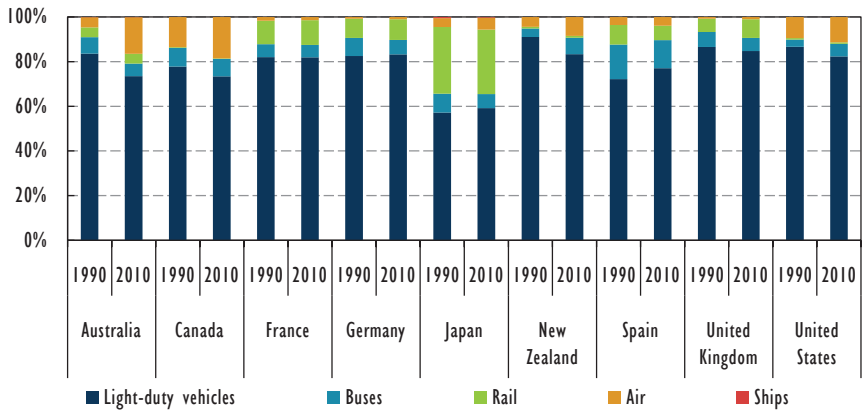
Figure 6.3 • Passenger transport energy consumption and energy per GDP per capita



In order to better understand the trends in energy and emissions, it is necessary to examine the link with the underlying drivers. Passenger travel activity, measured in passenger-kilometre (pkm), increased steadily between 1990 and 2010 in IEA15. The strongest increases in travel energy consumption were in Spain and New Zealand. LDVs clearly dominate the overall modal split in IEA15. On average, they accounted for 82% of total passenger-kilometres in 1990 and 78% in 2010. Yet the share of car travel differs from country to country, reflecting diverse demographic and geographic characteristics, as well as different levels of provision for urban and intercity transport.

As can be seen in Figure 6.4, the modal mix of passenger travel has changed very little since 1990. Air travel has increased faster than any other mode, but LDVs still dominate the overall modal split in passenger transport. In particular, travel speed is an important factor in how much and how far people choose to travel.

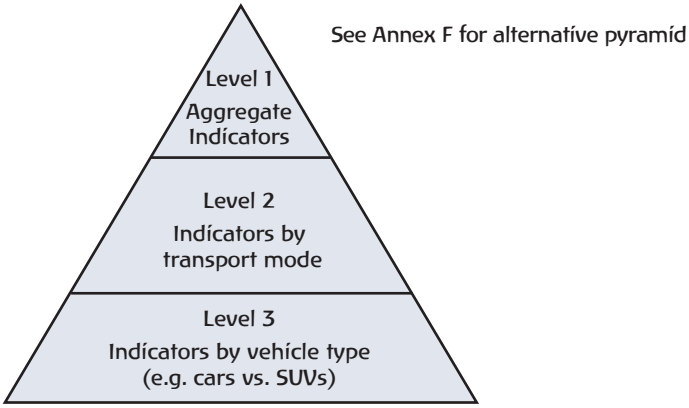
Figure 6.4 • Share of total passenger travel by mode



3 How to prioritise development of indicators for passenger transport

A difficulty for the transport sector is that energy consumption is available for the total transport section only in energy balances, and is not broken down between passenger and freight. A necessary first step is thus to develop meaningful indicators to perform a disaggregation of the total transportation energy consumption between passenger and freight transport. Attempts at cross-checking top-down (through energy consumption questionnaires) with bottom-up (from vehicle stock, mileage and fuel economy) approaches are being held at the IEA to make sure transport data are coherent. So far, the balance has been completed for 44 countries.

Figure 6.5 • Detailed indicators pyramid for passenger transport



Once this first level of disaggregation is done, the decision on which indicators to develop and the level at which they will be developed greatly depends on information available, the structure of the sector and the question to be answered.

For most countries, developing more detailed information for the road segment will most likely be a priority given the high share of this mode in total passenger transport. The level at which the road segment will be disaggregated also depends on the country situation/specificities. In most Asian countries, two- and three-wheelers are very popular modes of transport, while they represent only a marginal share of the market in most Nordic countries.

4 Development of indicators by level of the pyramid

Table 6.1 summarises all the indicators described in the passenger transport sub-sector and provides a quick overview of the usefulness of the indicators. This table matches the discussion on indicators in the *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 6.1 • Summary of indicators in the passenger transport sector

Indicator	Coverage	Energy data	Activity data	Code	Recommended indicator
Passenger transport energy consumption per GDP/capita	Overall	Total passenger transport energy consumption	GDP; Total population	P2a	
Passenger transport energy consumption per vehicle-kilometre	Overall	Total passenger transport energy consumption	Total number of passenger transport vkm	P2b	
	By mode / passenger vehicle type	Energy consumption of passenger transport by mode / vehicle type A	Number of vkm of passenger mode / vehicle type A	P3a	
Passenger transport energy consumption per passenger-kilometre	Overall	Total passenger transport energy consumption	Total number of pkm	P2c	
	By mode / passenger vehicle type	Energy consumption of passenger transport by mode / vehicle type A	Number of pkm of passenger mode / vehicle type A	P3b	☺

Level 1 indicators

Aggregate passenger transport energy intensity

Definition: Amount of total passenger transport energy consumption per passenger-kilometre or per GDP per capita. The preferred indicator is energy consumption per passenger-kilometre.

The trends in energy intensity (energy/pkm) are influenced by both the energy intensity of each mode and the share of that mode in a particular country. For most countries, energy consumption per passenger-kilometre is declining. Improvements in energy efficiency of transport modes offset the impact of an increasing share of car and air travel, which are more intensive. The exceptions are Japan, Denmark, the Netherlands, Spain and the United States, where energy consumption per passenger-kilometre has increased. For Japan this can be attributed to both a falling

share of rail (as a result of people switching to cars) and to an increase in the energy intensity of cars driven by a shift from smaller to larger vehicles (at least until recent years), which offset the improvement in energy efficiency.

Figure 6.6 • Example of level 1 indicator for selected countries: passenger transport energy consumption in passenger-kilometre

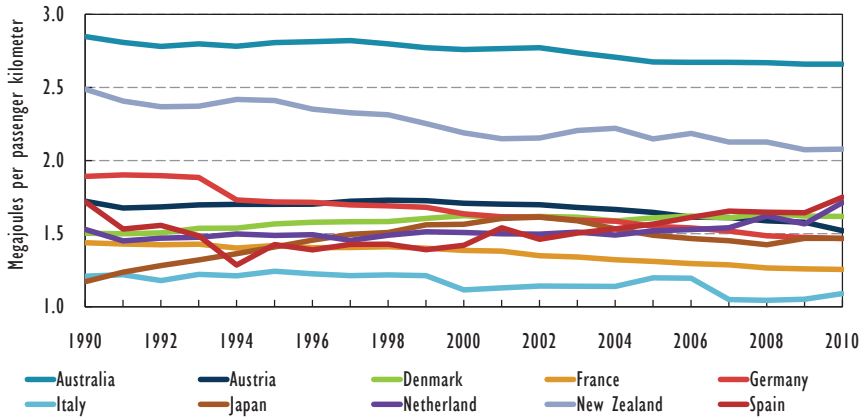


Table 6.2 • Description of level 1 indicators

Indicator	Data required	Purpose	Limitation
Passenger transport energy consumption per passenger-kilometre	• Total passenger transport energy consumption • Total passenger-kilometres	• Provides a general overview of the trends in aggregate energy intensity • Takes into account the number of passengers that are travelling – the "usage efficiency" (e.g. using one vehicle to transport three people is more efficient than using three vehicles) • Provides an overview of the impact of modal shift	• **Does not measure energy efficiency developments** • The relative importance of each transport mode is embedded into the indicator and hard to decompose • Influenced by many factors not related to energy efficiency such as public transport network, LDV ownership, population density and travel pattern
Passenger transport energy consumption per GDP per capita	• Total passenger transport energy consumption • GDP and total population	• Provides an insight into the effect of a countries change in wealth on passenger transport energy consumption	• **Does not measure energy efficiency developments** • The relative importance of each transport mode is embedded into the indicator and hard to decompose. • Influenced by many factors not related to energy efficiency such as public transport network, density and travel pattern

Use of level 1 indicator: Provides a general indication of the trend in overall intensity of passenger transport. More insights into the factors driving the change may be developed when using the share of passenger travel by mode.

Relevance for policy development: Given the many factors that influence these indicators, no conclusion can be drawn as to where efficiency improvements can be made and where more attention is required.

Cross-country comparison: Comparing countries based on this indicator may be misleading as it is driven not only by the intensity of different modes, but also by ownership level and preferred mode of transportation, among others.

Data availability and sources: Very little information is available even at this very aggregate level. Details on the different collection methods for this information are provided in the *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Level 2 indicators

Passenger transport intensity by transport mode

Definition: For each mode of transportation (road, rail, water and air), amount of energy consumed per passenger-kilometre.

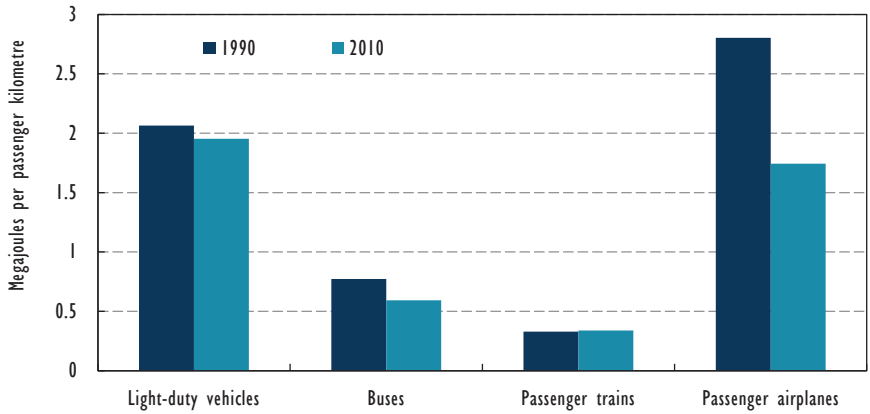
The final energy intensity of most passenger transport modes, as measured by energy consumption per passenger-kilometre, declined or changed marginally between 1990 and 2010. Air travel intensity showed the largest reduction of 38% (Figure 6.7), which can be attributed to a combination of several factors.

The energy efficiency of aircraft engines has been improving, thanks to significant advances achieved in computational fluid dynamics, advanced materials and the development of software tools for engine design. Increased use of light materials (e.g. composites) resulted in lower lift requirements. Increases in average load factors effectively lowered energy intensities: Filling an empty seat moves one more passenger a long distance with almost no change in energy consumption while more people are carried. The emergence of low-cost airlines has drastically changed the load factors of domestic flights.

Although energy intensities for other modes of passenger transport have not declined, except for a 13% decrease in rail, significant technological potential is available. Average road energy intensity increased by 3% across the IEA15. Several factors influenced this development: Improving trends in the efficiency of new passenger LDVs were offset by a greater share of larger and heavier vehicles; the wider gap between the tested fuel economy and real-life fuel economy (IEA, 2012c) that resulted from using optimized vehicles in the test cycle; and higher congestion and fuel-eager driving habits and the evolution of passenger load factors (the lower the load factor, the higher the energy intensity per passenger-kilometre, though there is very little evidence of the load factor evolution in IEA15). However, since road comprises many different type of vehicles, more detailed data are required to provide a deeper analysis of the changes in this transport segment.

Relevance for policy development: Energy intensities for rail, air and ships are relevant for the development of efficiency policies. However, care must be taken with the road indicator as this mode comprises a number of different types of vehicles that cover the vast majority of the energy consumption, and their relative shares may have an important impact on the overall intensity of road transport.

Figure 6.7 • Example of level 2 indicators for IEA15: energy consumption per passenger-kilometre by transportation mode



Cross-country comparison: Similarly, energy intensities for rail, water and air are suitable for cross-country comparison, but more detail is required to properly compare road transport. As non-road modes gain modal share, more detail might also be required to better characterise each mode's own specificities.

Data availability and sources: Energy consumption and related activity data are not widely available and require specific surveys, monitoring or modelling. Details on how to collect this information are provided in the *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 6.3 • Description of level 2 indicator: passenger transport sector

Indicator	Data required	Purpose	Limitation
Energy consumption per passenger-kilometre by transportation mode	• Passenger-kilometres by transport mode	• For rail, water and air intensities are a useful indicator to help develop transportation energy policies	• For road transport, may mask important structural changes (e.g. bus efficiency getting worse due to increased safety features or air conditioned buses)

Level 3 indicators: Road

Passenger transport intensity by road vehicle type

Definition: For each road vehicle type, an energy intensity showing the amount of energy consumed per passenger-kilometre or share of energy consumption for road vehicle by type of vehicle.

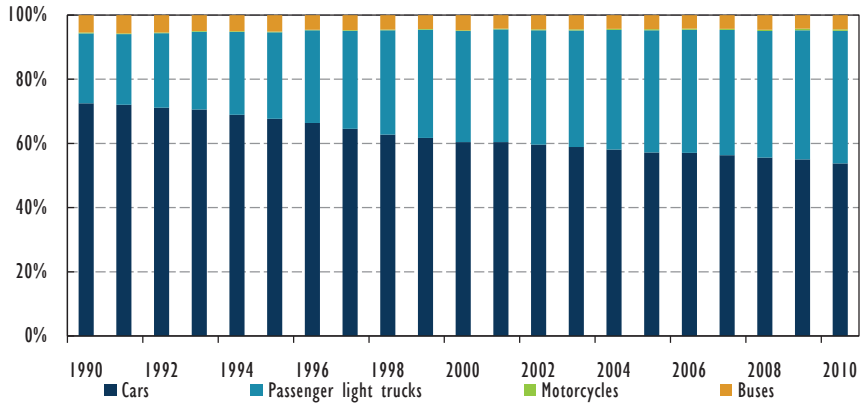
Level 2 indicators are a sound basis for policy development and tracking for the rail, water and air modes. As such, the level 3 section focuses exclusively on road transport – even if it is possible to develop level 3 indicators for the other modes (e.g. air travel intensity by type of plane, splitting rail into urban, inter-city, high speed).

The road segment of passenger transport can be disaggregated in many different ways. For example:

- Disaggregation by type of vehicle (LDVs, buses, motorcycles and 3-wheelers)
- Disaggregation by the service provided by the vehicle (e.g. personal, commercial [taxi], public services [ambulance])
- A combination of type and category.

Generally, countries developing detailed indicators for road transport are performing a disaggregation by type of vehicle. The level of disaggregation depends on the structure of the road transport in each country, the availability of data for different disaggregation, and the resources available to develop data and indicators. At a minimum, a distinction should be made between LDVs and buses. Further disaggregation may be desirable/required in some countries, e.g. two- and three-wheelers in developing countries and a distinction between cars and light trucks (such as SUVs) in North America (Figure 6.8). The evolution of the consumption patterns for different road vehicles will have an important impact on total energy consumption and intensity.

Figure 6.8 • Energy consumption of different road vehicles, example for Canada



Relevance for policy development: Depending on the level of disaggregation and the structural composition of the stock of vehicle, energy consumption per passenger-kilometre is relevant to track the efficiency of the passenger transport by road.

Cross-country comparison: The different intensities between countries both indicate the different levels of energy efficiency of road transport, and also provide an indication of change in driving conditions.

Data availability and sources: Energy consumption and associated passenger-kilometres is not widely available and requires specific surveys, monitoring or modelling. Details on how to collect this information are provided in the *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Related indicators: While energy consumption by passenger-kilometre provides a meaningful measure for efficiency of passenger transport, fuel economy (the energy consumed per distance travelled) provides the efficiency of the vehicle. The difference

between these two efficiency indicators is that energy/pkm takes into consideration the number of people travelling in one vehicle, while fuel economy relates only to the vehicle without taking into account the number of people travelling. While energy/pkm is useful to assess the success of a programme to promote carpooling, vehicle fuel economy is more relevant to assess policies to improve efficiency of vehicles.

Table 6.4 • Description of level 3 indicators: road

Indicator	Data required	Purpose	Limitation
Energy consumption per passenger-kilometre by road transport vehicle	• Passenger transport energy consumption by road transport vehicle • Passenger-kilometres by road transport vehicle	• Energy intensity by road vehicle is a meaningful summary indicator, if specified at a detailed enough level • Intensities can be used to help develop transportation energy policies	• The indicator is still affected by factors that are not related to energy efficiency such as the change in vehicle weight for LDVs within the fleet and vehicle features • May mask important structural changes if the level of disaggregation is limited
Energy consumption by vehicle-kilometre	• Stock of vehicles by type of LDV • LDV vehicle-kilometres • LDV energy consumption } • Or fleet fuel economy survey	• Provides insights on the average fuel economy of the vehicle stock. As opposed to energy/pkm, it is not influenced by vehicle occupancy	• May mask embedded structural changes if the level of disaggregation is limited

5 Additional indicators explaining the changes in passenger transport energy consumption

As previously indicated, there are numerous factors influencing energy consumption in the passenger transport sector. While the following indicators are not considered energy or efficiency indicators, they can bring vital information to better assess the macroeconomic drivers of energy consumption.

Table 6.5 • Description of additional indicators: passenger transport sector

Indicator	Data required	Purpose	Limitation
Passenger travel activity	• Total passenger-kilometres • Population • GDP	• Understand the trends in consumers' transport • Provide a benchmark to understand the potential evolution of travel	• Only activity-driven. Does not provide a measure of energy efficiency • Does not take into consideration the selected mode of transport, the purpose of travel or the different travel options available

Indicator	Data required	Purpose	Limitation
Share of passenger-kilometres by mode	• Passenger-kilometres by vehicle	• Provides assessment of the change in the share of modes • Provides useful qualitative information on activity trends in the sector • Provides qualitative information on how change in activity influences change in energy consumption	• Only activity-driven. Does not provide a measure of energy efficiency • Travel patterns are influenced by many diverse factors such as income, age profile of drivers, household size, flexible working and leisure activities, geographic characteristics, and local transport policies
Car ownership	• Stock of cars • Population • GDP per capita	• Help understand the trend in average distance travel • Provide good basis to derive the future trend in car travel • Help explain the increase in car travel	• Does not take into consideration the type of car owned
Annual kilometres per vehicle	• Average distance travelled by vehicle	• Provides assessment of the change in travel pattern • Provides useful qualitative information on activity trends in the sector	• Only activity-driven. Does not provide a measure of energy efficiency • Kilometres per vehicle are influenced by factors such as number of vehicle per household, income, flexible working and leisure activities, geographic characteristics, and local transport policies
LDV fuel economy	• Stock of vehicles by type of LDV • LDV vehicle-kilometres • LDV energy consumption	• Provides assessment of the efficiency of the vehicle stock	• May mask embedded structural changes if the level of disaggregation is limited

6 Decomposítíon of changes ín passenger transport energy demand

While the detailed indicators presented provide some of the essential tools to explain the changes in energy consumption in the passenger transport sector, they cannot be used "as is" to provide the impact of energy efficiency improvements in the sector. For example, total energy consumption of cars may increase despite improvement in fuel economy if more vehicles are sold or if consumers drive more and/or with demanding driving conditions. Similarly, a change in the mode preference (more travel by road (LDVs) and less by train) may increase energy consumption, even if each transport mode improves its energy efficiency.

At the total passenger transport level, the activity component reflects growth in total passenger-kilometres and structure reflects the relative change in the shares of passenger-kilometre by mode. The intensity effect includes the impact of intensity changes in all modes.

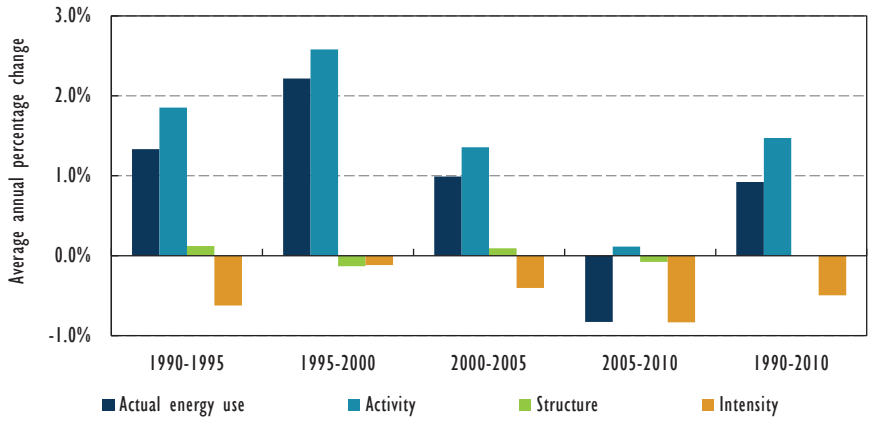
Table 6.6 • Summary of variables used for the decomposition of transport energy consumption

Passenger transport	Activity (A)	Structure (S)	Intensity (I)
Road (LDVs)	Passenger-kilometre	Share of passenger-kilometre	Energy/ passenger-kilometre
Road (Bus)	"	"	"
Rail	"	"	"
Domestic air	"	"	"

Note: Passenger transport by water is not included in the IEA decomposition analysis due to lack of data.

Energy consumption across all modes increased substantially between 1990 and 2010. Not surprisingly, increased activity (i.e. more passenger-kilometres) was the most important factor driving up energy consumption. Structural changes – particularly the increase in the shares of cars and air transport – had only a limited impact over the period. These upward pressures on energy consumption were marginally offset by reductions in energy intensity, which fell at an average rate of 0.1% per year.

Figure 6.9 • Factors affecting passenger transport energy consumption, IEA15



Growth in passenger travel was strongest between 1995 and 2000, as a result of lower fuel prices in many IEA countries and a strong global economy. Energy intensity reductions appeared to be more significant in the periods from 1990 to 1995 and 2000 to 2005 than in other periods, even though higher oil prices and the introduction of more efficient vehicles (particularly cars) accelerated reductions in energy intensity in the latter time period. While the recent economic downturn had

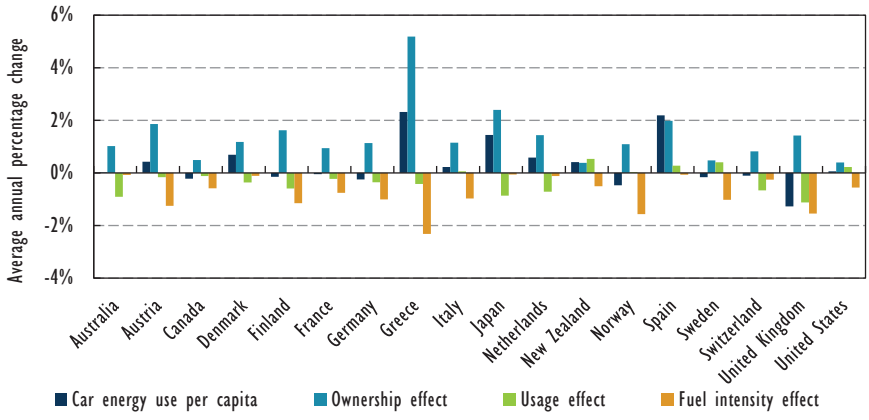
a noticeable impact on energy consumption (2005-10 in Figure 6.9), more detailed information on average load factor and the type/size of vehicle used would be required to explain the key factor behind the increase in energy intensity. It should be noted that the energy intensity effect is the result of a complicated interaction among vehicle efficiencies, operating conditions and load factors. Thus, the combined effect is often hard to predict.

More detailed decomposition can be done by type of vehicle when the required information is available. For example, the changes in LDV energy consumption per capita can be decomposed to provide an explanation of the impact of ownership effect, usage effect and fuel intensity effect (a proxy for energy efficiency).

Several factors influence car energy consumption across IEA countries. All countries showed increases in car ownership. Spain and Japan showed the strongest growth, albeit rising from comparatively low ownership levels in 1990. For most countries, the growth in car ownership tended to increase per capita car energy consumption by about 1.0% per year. The impact of car usage (i.e. the distance driven by each car) on per capita energy consumption is more varied across countries. In most countries, the distance travelled by each car decreases; this can be explained by the trend toward households owning more than one car, which means that journeys are shared between cars. As a result, travel per car tends to fall.

Together, car ownership and usage give the total distance travelled per capita. For most countries, reductions in the fuel intensity of cars were not sufficient to offset the increases in car ownership and car use. Thus, car energy consumption per capita increased in many IEA countries. The noticeable exception to this was United Kingdom. In this country, the effect of significant reductions in energy intensity was augmented by falling car usage, which more than offset increases in car ownership.[2]

Figure 6.10 • Decomposition of changes in LDV energy consumption per capita, 1990 to 2010



2. The decomposition analysis results included in this manual are calculated using a three-factor decomposition analysis based on the Simple Laspeyres index decomposition methodology. See Annex A for further discussion on decomposition analysis methodologies.

Box 6.2 • Identifying transport issues and user needs

Identifying present transport issues and expected future needs helps to organise policy responses to improve transport system efficiency. Issues to consider include:

Mobility

Are the mobility needs of individuals, households, businesses and public services monitored and understood? What are the projected mobility needs of populations?

Are there sector areas or demographic groups where mobility services are compromised?

What is the relationship among socio-economic status, access to mobility services, and employment and travel distance, time or mode?

What are city modal shares? Are low-energy modes utilised? If not, why not? Are there incentives for public transport such as bus lanes, traffic light signalling priority, private vehicle congestion and parking charges?

Are travel times becoming longer? Have the costs of congestion and excessive travel times been assessed?

What is the role of transport (including private vehicles) in cities?

Infrastructure

Is the transport network in a state of good repair, secure and reliable? Are alternative routes available if one leg of the network fails? Can it accommodate expected growth?

Are public transport transit times faster than private transport? Are existing modes effectively connected? Can visitors unfamiliar with the city easily use public transport modes to get to their destinations?

Are ticketing systems convenient, and do they enable journeys that are transferable across different modes and operators? Is public transport clean and comfortable? Are there amenities such as air conditioning and Internet access?

Is there an existing transport system development plan that encourages more energy efficient modes of transport, and an effective system maintenance and development strategy?

Land-use

Where do people work? Where do they live? Where do children go to school?

What are the size and density of the city? How is it zoned?

Are destinations far apart or randomly dispersed, or are there high-density and -activity nodes?

Is development occurring outside the city centre? What governmental mechanisms exist to change the built environment?

Economy

What is the urban economic structure now? Is there consensus among stakeholders on its future direction? How should it affect and be affected by transport and travel?

Is a lack of mobility negatively affecting the ability of a significant number or a class of citizens to access better employment?

The IEA Policy Pathway "The Tale of Renewed Cities" (IEA, 2013) outlines a process to develop these policy options.

7 Policy information and evaluation in passenger transport

Passenger transport system efficiency

Passenger transport policies and projects involve significant infrastructure planning and long-life asset investments. Analysing the social and economic implications of these projects is not easy. Many decision makers and stakeholders need to be well-informed of the costs and outcome benefits. Policy analysis should also define a clear counterfactual, i.e. a baseline case that outlines what would occur in the absence of any interventions.

Developing this case requires a clear understanding of the:

- Population trends and economic shifts that drive the demand for mobility
- Future technology options, their costs and capabilities (see IEA *Energy Technology Perspectives* [IEA, 2012a] and *Technology Roadmaps* [IEA,2012b])
- Future energy price trends from global fuel futures markets and national energy markets (e.g. IEA market reports and New York Mercantile Exchange [NYMEX])
- Costs of ongoing inadequate, or worsening, mobility and congestion
- Life-cycle costs and benefits associated with both counterfactuals and efficient policy options and modelling; their sensitivity to key variables
- Public and private costs and long-term finance options
- Substantive implications of the policy options so that all costs and benefits are clear.

The above analysis is complex. To be effective, passenger transport policy making has to transcend the main vehicle and modal indicators of passenger travel (vehicle kilometres, litres per 100 kilometres, passenger-kilometres) to understand what the future mobility needs of households and individuals are and how they can be best met. This requires information about the human and social dimensions of mobility.

In the longer term, the dependence on oil in the transport sector needs to be reduced. Declining oil reserves will result in conventional oil's becoming more expensive, so a shift is required to make the global economy more resilient to oil price shocks.

Box 6.3 • Improved operating efficiency through mobility management, eco-driving and related policies

Information and communication technology could reduce energy consumption by making traffic more fluid, intelligent control of traffic lights, avoiding congestion on streets and roads, and providing feedback instruments such as fuel consumption meters in cars, public transport vehicles, boats, etc.

A low-cost policy option is to improve the operation efficiency of vehicles though ''eco-driving''. Simple behavioural practices improve both the safety and fuel economy of vehicles.

The key policy information needs are in surveying driving practices and energy consumption rates before and after the policies are implemented.

Policies for passenger (LDV) fuel economy

The dominance of LDVs in passenger transport and their relatively poor fuel economy today mean that measures to improve light duty vehicle fuel economy is a priority. Three aspects of light duty vehicles can be considered (Table 6.7), but implementing a fuel economy standard policy is the priority for any country. The IEA Technology Roadmap *Fuel Economy for Road Vehicles* (IEA, 2012b) outlines how the potential for vehicle fuel economy can be realised, especially via government policies. The IEA's Policy Pathway publication Improving the Fuel Economy of Road Vehicles (IEA, 2012c) provides guidance on designing fuel economy policies.

Table 6.7 • Supplementary information for light-duty vehicle policy information

Policies and level 3 indices	Supplementary information needs	Supplementary indicators
Passenger light-duty vehicle fuel efficiency standards	• Vehicle usage data: distance driven; vehicle loadings, by mode (pedestrian, bicycle, car, bus, train, plane, ferry) for policy design • Standards and labelling	• Annual vehicle sales, stock and scrapping statistics (by model and number of model, by emissions band, by engine size and by vehicle weight) • Vehicle ownership rates
Polices to improve passenger vehicle fuel efficiency	• Technical vehicle information for certification system design and review. • Verification of certification technical performance	
Fuel-efficient non-engine components	• Information about the state of tyres and ancillary equipment.	

B) Developing indicators for the freight transport segment

Freight transport covers the domestic haulage of goods by freight light duty vehicles, heavy duty vehicles, rail, and ships. It excludes air freight transport because of a lack of data separating domestic and international travel. Pipelines are also excluded as they often cross many territorial boundaries, and it is very challenging to attribute this energy consumption to a single country or region.

1 What is driving energy consumption in the freight transport sector?

The trends in freight energy transport are driven by changes in total freight haulage, which is driven by economic activity associated with the movement of raw materials, intermediary products and final consumer goods. Thus, there is a strong correlation between increases in freight transport and gross domestic product (GDP) growth (although a decoupling can take place if there is a change in the industrial structure, e.g. from primary to high-value consumer goods). The choice of freight mode is, in

part, driven by the geographical situation, destination (e.g. local versus international), available infrastructure, cost and value of goods.

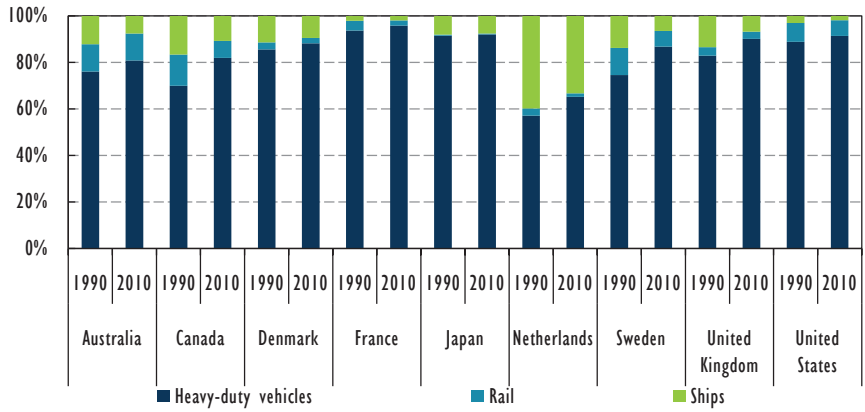
More generally, for the development of energy indicators, the main activity variables considered to explain the trends in energy consumption are vehicle-kilometres and tonne-kilometres. However, understanding how each of the factors is impacting energy consumption is essential to determine where the largest potential to reduce energy consumption lies and which area should be prioritised for the development of energy efficiency policies.

2 How is energy consumed and how has it evolved recently?

As is the case for passenger transport, the disaggregation required to develop indicators for the freight transport sector is available only for 15 member countries of the International Energy Agency (IEA). For those countries, energy consumption in freight transport increased by almost 30% between 1990 and 2010, to 14 exajoules (EJ). There was a similar growth in carbon dioxide (CO_2) emissions. The strong link between energy and emissions is due to the reliance on oil-based fuels. In 2010, total freight transport accounted for one-third of total transport sector.

The strong growth in freight energy consumption was almost entirely due to higher energy demand for heavy duty vehicles, which increased by 33%. Heavy-duty vehicles (HDVs) increased their share of total freight transport energy consumption to 90% in 2010. Total final energy consumption for rail freight increased by 6%, but its share of energy use declined from 6% in 1990 to 5% in 2010.

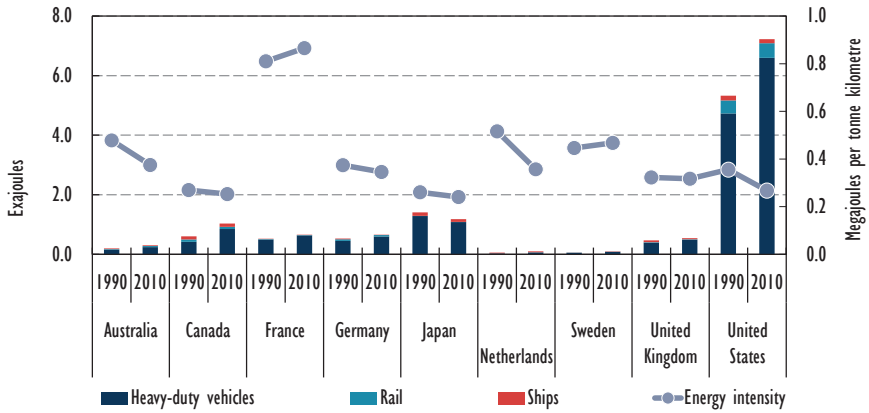
Figure 6.11 • Freight transport energy consumption by mode



The energy consumption per unit of GDP shows considerable variation among countries, which reflects a combination of three factors: The volume of freight haulage per GDP; the share of the various freight modes; and the energy intensity (energy per tonne-kilometre) of each mode. Canada has the highest energy consumption per GDP, largely as a result of long haulage distances. In contrast,

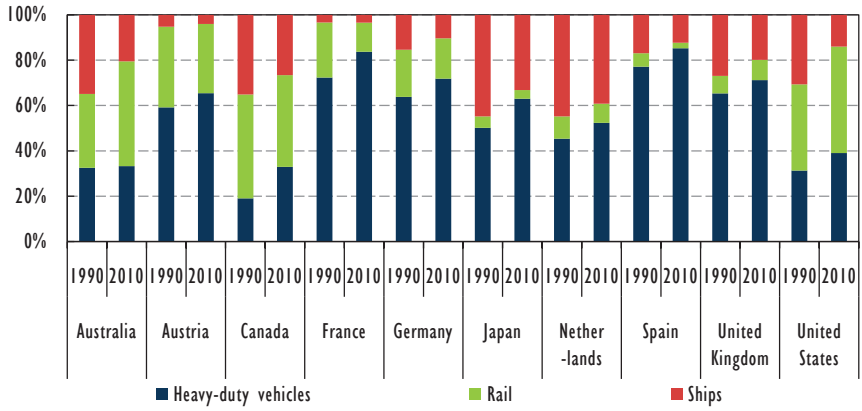
Austria and Sweden have much lower emission intensities due to a combination of significantly shorter haulage distances and lower-than-average energy intensities. In 2010, rail and shipping accounted for a significant portion of energy consumption in Canada (19%), Australia (18%) and the Netherlands (35%). All IEA15 countries, except Japan, have experienced an increase in the energy consumption from HDVs between 1990 and 2010.

Figure 6.12 • Freight transport energy consumption and intensity



In order to better understand the trends in energy and emissions, it is necessary to examine the link with the underlying drivers. Freight haulage activity, measured in tonne-kilometre, increased steadily between 1990 and 2010 in IEA15. The strongest increases in travel were in Australia, Austria and the Netherlands. Freight transport by HDVs dominates the modal split, and increased from 40% total tonne-kilometres in 1990 to 47% in 2010. Yet the share of HDVs differs significantly from country to country, reflecting diverse geographic and trade pattern characteristics.

Figure 6.13 • Share of total freight tonne-kilometres by mode



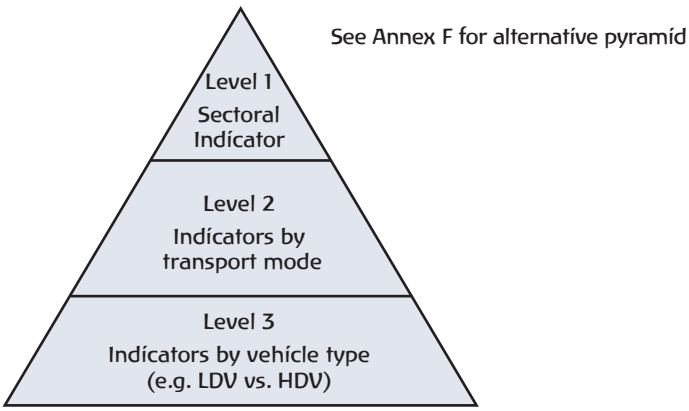
Note: International shipping and air freight are not included in this mode share.

3 How to prioritise development of indicators for freight transport

As for the passenger transport sector, energy consumption for freight is not readily available for energy balances. As a result, a necessary first step is to disaggregate the energy consumption among the different segments of freight transport.

Once this first level of disaggregation is done, the decision on which indicators to develop and the level at which they will be developed greatly depends on information available, the structure of the sector and the question to be answered. For most countries, developing more detailed information for the road segment will most likely be a priority given the high share of this mode in total freight transport. The level at which the road segment will be disaggregated also depends on the country situation/specificities. For example, Canada and the United States have a significant share of large heavy duty vehicles (18-wheelers); Australia has one of the most efficient HDV fleets hauling minerals in road trains that are travelling long distance.

Figure 6.14 • Detailed indicators pyramid for freight transport



Very little information is currently collected on the freight transport segment, and there are numerous barriers regarding the measurement of activity in the sector. Some examples of practices to collect this information are provided in the *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014). As a result, the decision on which indicator to further develop will be based on information available, the resources available, and the policy question that needs to be answered.

4 Development of indicators by level of the pyramid

Table 6.8 summarises all the indicators described in the freight transport sub-sector and provides a quick overview of the usefulness of the indicators. This table matches the discussion on indicators in the *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 6.8 • Summary of indicators in the freight transport sector

Indicator	Coverage	Energy data	Activity data	Code	Recommended indicator
Freight transport energy consumption per GDP	Overall	Total freight transport energy consumption	GDP	F2a	
Freight transport energy consumption per vehicle-kilometre	Overall	Total freight transport energy consumption	Total number of freight transport vkm	F2b	
	By freight mode / vehicle type	Energy consumption of freight transport by mode / vehicle type α	Number of vkm of freight mode / vehicle type α	F3a	
	Overall	Total freight transport energy consumption	Total number of tkm	F2c	
Freight transport energy consumption per tonne-kilometre	By freight mode / vehicle type	Energy consumption of freight transport by freight mode / vehicle type α	Number of tkm of freight mode / vehicle type α	F3b	☺

Level 1 indicators

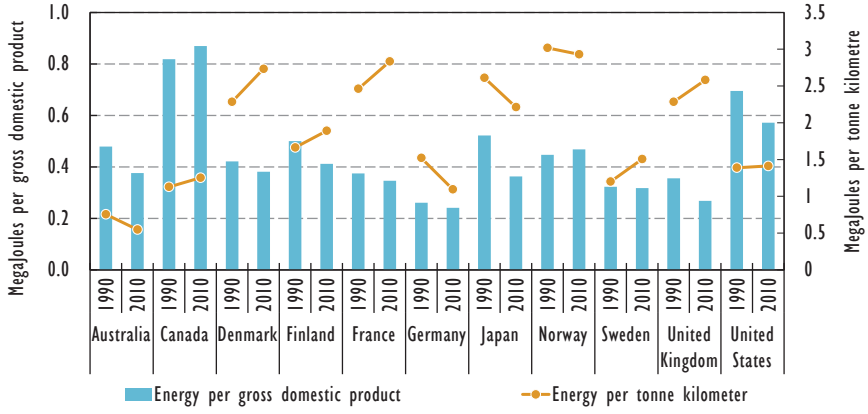
Aggregate freight transport energy intensity

Definition: Amount of total freight transport energy consumption per tonne-kilometre or per GDP.

Energy consumption per tonne-kilometre is considered a better indicator of freight energy intensity.

The freight intensity per GDP provides an indication of how energy consumption evolved in relation to the value of the goods produced. To get a better indicator of this relationship, only value-added of goods that are transported should be taken into consideration. However, this level of information is rarely available.

Figure 6.15 • Example of level 1 indicator for selected countries: freight transport energy intensities



The trend in energy consumption per tonne-kilometre is influenced by the energy intensity of each mode, by the share of that mode in a particular country and by the load factor. For most countries, energy consumption per tonne-kilometre is increasing. This increased energy intensity is explained by a higher share of freight transport by HDVs, which are more energy intensive than rail or ships. Just-in-time logistics also put additional constraints on how fast the goods have to be delivered, impacting the overall efficiency of the freight transport system.

Use of level 1 indicator: Provides a general indication of the trend in overall intensity of freight transport. More insights on the factors driving the change may be developed when using the share of tonne-kilometres by mode.

Relevance for policy development: Given the many factors that influence these indicators, no conclusion can be drawn as to where efficiency improvements can be made and where more attention is required.

Cross-country comparison: Comparing countries based on this indicator may be misleading as it is driven not only by the intensity of different modes, but also by available mode of transportation, load factors, type of vehicle used, distance travelled per trip, trade and geography of the country.

Data availability and sources: Little information is available even at this very aggregate level. Descriptions of the different methods to collect this information are provided in the *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 6.9 • Description of level 1 indicators

Indicator	Data required	Purpose	Limitation
Freight transport energy consumption per GDP	• Total freight transport energy consumption • Total GDP	• Provides a general overview of the trends in aggregate energy intensity • Provides an understanding of the relationship between economic activity and freight transport	• **Does not measure energy efficiency developments** • Does not take into account the relative importance of each transport mode • Influenced by many factors not related to energy efficiency such as availability of infrastructure, capacity utilisation, type of goods moved, and the size and geography of the country
Freight transport energy consumption per tonne-kilometre	• Total freight transport energy consumption • Total tonne-kilometres	• Provides a general overview of the trends in aggregate energy intensity • Take into account the amount of goods (in tonnage) that are transported – the "usage efficiency" (e.g. using one vehicle to transport one tonne of goods, instead of using two vehicles to transport 500 kilograms [kg] each)	• **Does not measure energy efficiency developments** • Does not take into account the relative importance of each transport mode • Influenced by many factors not related to energy efficiency such as availability of infrastructure, capacity utilisation, type of goods moved, and the size and geography of the country

Level 2 indicators

Freight transport intensity by transport mode

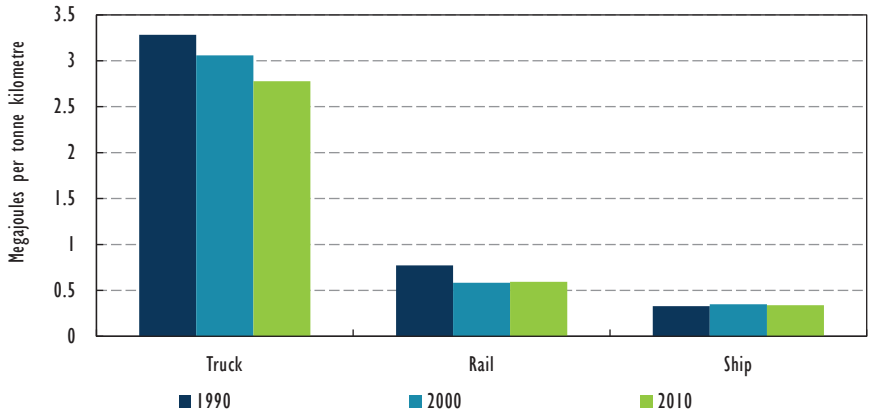
Definition: For each mode of transportation (road, rail, ships), amount of energy consumed per tonne-kilometre.

Developing the indicators for each mode allows a better understanding of the changes in the freight transport structure and the factors behind the changes in energy consumption.

The energy intensities of HDVs, ships and rail vary significantly, with HDVs being the most intensive. On average, a HDV uses between 5 and 20 times more energy than rail to move one tonne of goods a distance of one kilometre, but from a system perspective, as rail requires road connections at the beginning and end of the journey, its high efficiency is technically achieved only in some railhead-to-railhead operations. The large range for the energy intensity of HDVs can partly be explained by the type of goods moved, the size and geography of the country, and the average load factors, as well as the split between urban delivery vehicles and long-haul vehicles, which are much larger and less energy intensive.

The difference in the energy intensity among modes has some important implications for trends in freight energy consumption. First, because of its much higher energy intensity, growth in road freight haulage will have a more significant impact on energy consumption than growth in freight transport by rail or ships. Therefore, the increase in freight energy consumption in Canada and New Zealand can partly be explained by the relatively high growth of the road freight activity. Second, intensity reductions in HDVs will result in higher energy savings than intensity reductions in rail and ships or than modal switching between these two modes.

Figure 6.16 • Example of level 2: Energy consumption per tonne-kilometre by transport mode



Relevance for policy development: Energy intensities for rail and ships are relevant for the development of efficiency policies. However, care must be taken with the

road freight indicator, as this mode comprises a number of different types of vehicle and their relative shares may have an important impact on the overall intensity of road transport.

Cross-country comparison: Similarly, energy intensities for rail and ship are suitable for cross-country comparison, but more detail is required to properly compare road transport.

Data availability and sources: Energy consumption and related activity data are not widely available and requires specific surveys, monitoring or modelling. Descriptions of how to collect this information are provided in the *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Table 6.10 • Description of level 2 indicators: freight transport

Indicator	Data required	Purpose	Limitation
Energy consumption per tonne-kilometre by transportation mode	• Freight transport energy consumption by transport mode • Tonne-kilometres by transport mode	• Energy intensities by mode are meaningful summary indicators • Intensities can be used to help develop transportation energy policies	• These indicators are still affected by factors that are not related to energy efficiency, such as vehicle change in the relative weight for road freight fleet and load factors • May mask important structural changes in the road segment

Level 3 indicators: Road

Freight transport intensity by road vehicle type

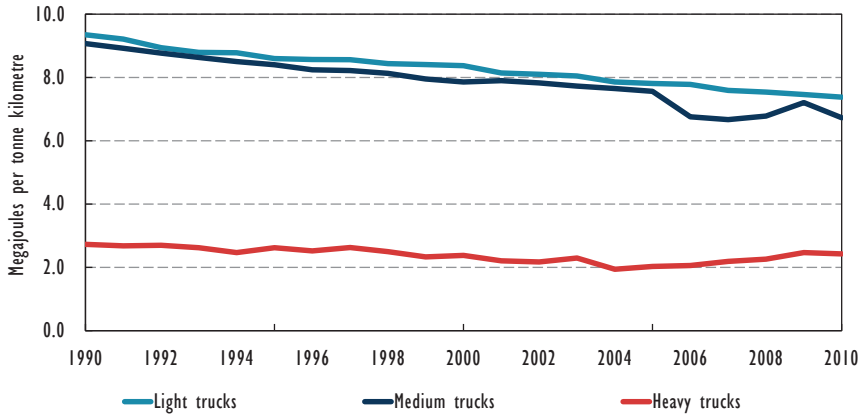
Definition: For each road vehicle type, the amount of energy consumed per tonne-kilometre.

Level 2 indicators are sufficient to provide relevant basis for policy development and tracking for the rail and shipping modes. As such, the level 3 section focuses exclusively on road transport.

The road segment of freight transport is usually disaggregated by vehicle weight or size. For example, Canada is disaggregating freight road into light truck (truck of up to 3 855 kg of gross vehicle weight), medium truck (truck with a gross vehicle weight ranging from 3 856 kg to 14 969 kg), and heavy truck (truck with a gross vehicle weight that is more than, or equal to, 14 970 kg). Not all countries use the same weight boundaries to classify vehicles, and so country comparisons should be made with care.

The level of disaggregation and the selection of the parameter used to make the disaggregation depend on the country specificities and the vehicle fleet. For example, in countries where rail or ships are usually used for long haulage and road freight vehicles are generally used for short-distance delivery, a disaggregation of road freight vehicles might not be a priority if the fleet is relatively homogeneous.

Figure 6.17 • Energy intensity trends of different road vehicles: an example from Canada



Relevance for policy development: Depending on the level of disaggregation and the structural composition of the stock of vehicle, energy consumption per tonne-kilometre is relevant to track the efficiency of the freight transport by road.

Cross-country comparison: The different intensities among countries indicate the different levels of energy efficiency of road freight transport.

Data availability and sources: Energy consumption and associated tonne-kilometre are not widely available and require specific surveys, monitoring or modelling. Details on how to collect this information are provided in the *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014).

Related indicators: While energy/tkm provides a meaningful measure for efficiency of freight transport, fuel economy (the energy consumed per distance travelled) provides the efficiency of the vehicle. The difference between these two efficiency indicators is that energy/tkm takes into consideration the number (weight) of goods transported in one vehicle, while lab-tested fuel economy relates only to the vehicle without taking into account the load of the vehicle. Those two indicators provide different information – with energy/tkm, when coupled with average load factor and load capacity being useful in assessing the potential improvement in goods movement management.

Table 6.11 • Description of level 3 indicators: road

Indicator	Data required	Purpose	Limitation
Energy consumption per tonne-kilometre by road transport mode	• Freight transport energy consumption by road transport mode • Tonne-kilometres by road transport mode	• Energy intensity by road mode is a meaningful summary indicator, if specified at a detailed enough level • Intensities can be used to help develop transportation energy policies	• The indicator is still affected by factors that are not related to energy efficiency, such as vehicle weight and vehicle features • May mask important structural changes if the level of disaggregation is limited

5 Additional indicators explaining the changes in freight transport energy consumption

As previously indicated, there are numerous factors influencing energy consumption in the freight transport sector. While the following indicators are not considered energy or efficiency indicators, they can bring vital information to better assess the macroeconomic drivers of energy consumption.

Table 6.12 • Description of additional indicators: freight transport sector

Indicator	Data required	Purpose	Limitation
Share of tonne-kilometres by mode	• Freight transport tonne-kilometres by mode	• Provides assessment of the change in the share of modes • Provides useful qualitative information on activity trends in the sector • Provides qualitative information on how change in activity influences change in energy consumption	• Only activity-driven. Does not provide a measure of energy efficiency • Tonne-kilometres are influenced by many factors such as availability of infrastructure, capacity utilisation, type of goods moved, and the size and geography of the country
Average load per road freight vehicle	• Average load per road freight vehicle	• Help explain the changes in road freight vehicle energy consumption per tonne-kilometre • Strong correlation between changes in load factors and changes in the energy intensity of freight haulage	• This indicator, taken by itself, does not provide indicators of the trend in energy efficiency for road freight vehicles • The average load can result from the change in the composition of the fleet

6 Decomposition of changes in freight transport energy demand

Changes in freight transport energy consumption are decomposed into changes in total freight haulage (activity), modal structure and energy intensities of the three freight modes included in this analysis. Overall, total energy consumption in freight transport in the IEA15 increased at an average annual rate of 1.3% between 1990 and 2010. This was in line with the increase observed in activity, as measured by total tonne-kilometres. Changes in the modal structure – particularly a shift toward more road freight – have tended to increase energy consumption, but this has been offset by reductions in energy intensity, which declined on average by 0.9% per year.

A slightly different picture emerges when these trends are further separated into specific time periods. Between 1990 and 1995, road freight haulage increased rapidly, averaging 2.4% per year. In this period, the reductions in energy intensity were not sufficient to offset the shifts to more intensive modes. Thus, energy consumption in freight transport increased more rapidly than the level of freight transport activity. Despite rapid economic growth in the second half of the 1990s, increases in freight haulage slowed.[3]

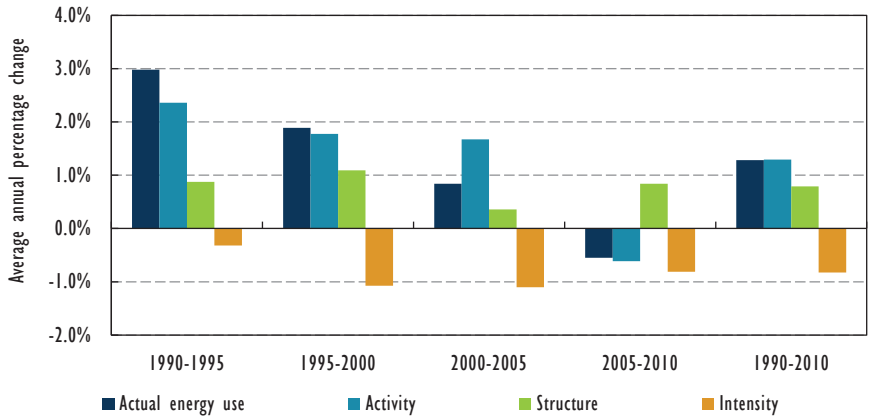
Table 6.13 • Summary of variables used for the decomposition of freight transport energy consumption

Freight transport	Activity (A)	Structure (S)	Intensity (I)
Road (Heavy-duty vehicle)	Tonne-kilometre	Share of tonne-kilometre	Energy/ tonne-kilometre
Rail	"	"	"
Domestic shipping	"	"	"

Note: : Freight transport by air is not included in the IEA decomposition analysis due to lack of data.

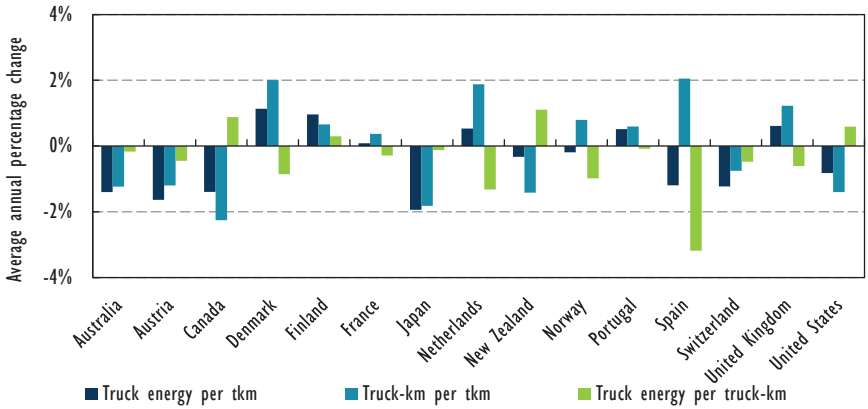
Heavy-duty vehicle energy consumption can be decomposed further to take into account the changes in load factor (HDV-km per tonne-kilometre i.e. the average amount of freight carried by each HDV) and in vehicle energy intensity (the average energy consumption by each HDV per vehicle-kilometre in moving freight). For many countries shown, vehicle energy intensity decreased over the period 1990 to 2010, illustrating that, on average, the HDVs became individually more efficient. However, the overall energy intensity of HDVs was most strongly influenced by the evolution of load factors.

Figure 6.18 • Factors affecting freight transport energy consumption, IEA15



3. The decomposition analysis results included in this manual are calculated using a three-factor decomposition analysis based on the Simple Laspeyres index decomposition methodology. See Annex A for further discussion on decomposition analysis methodologies

Figure 6.19 • Decomposition of changes in truck energy intensity in IEA15, 1990 to 2010



7 Policy information and evaluation in freight transport

Freight systems play a crucial role in getting products and services to market, an essential contribution to economic performance. Challenges in policy analysis stem from the fact that the sector serves the needs of diverse industrial, commercial and household activities in heterogeneous economies.

Key energy efficiency indicators include both based on mass (megajoule [MJ] per tonne kilometre) and based on value of freight (MJ per USD per kilometre) indicators. Both show a different perspective on the same freight activity. Energy efficiency policy and programme development requires information about energy consumption for different activities: delivery vans, couriers, line haul freighters, rail, pipeline, air freight and shipping, and end-use outcome levels, and with sufficient detail to allow programme-level decisions to be estimated and evaluated. Where systems are integrated — for example, inland railhead for seaports, road-rail-road container logistics — the performance of both components and the system as a whole need to be understood. As always, policy makers seek material information that can be acted on with confidence, so that a clear and compelling policy case can be outlined. This requires understanding also the commercial drivers and contractual situations, e.g. how freight contracts are structured, what motivates truck owners and drivers, and energy and activity information at en end-use level.

The drivers of energy demand in freight

The driving forces for energy consumption in freight are very much a function of industrial structure, resource endowment, historical development paths and how they shape the productive outputs, and imports and exports of a nation. In less developed countries and those with large primary industries, the freight sector will carry bulk primary goods (minerals, timber, food crops, etc.). In a more developed economy, freight systems will focus on delivery of final process products. Indeed without a good freight system, it is difficult for an economy to develop as it simply struggles to get goods to market. An efficient freight system is therefore a precursor to development.

Box 6.4 • Freight mobility management and logistics: key aspects of policy solutions

Increasingly the performance and energy intensity of freight systems are determined by logistics management systems that cover the following:

- Scheduling systems to optimise loads and backloads
- Computerised dispatching and consignment tracking systems
- In-vehicle global positioning systems (GPS) to provide real-time performance of individual journeys and help optimise routes under real-time traffic conditions
- Automatic feedback on fuel economy
- Automated interventions such as engine revolutions per minute (RPM) limiters and automated clutches.

The importance of supplementary information

Level 3 indicators are the core of programme information, and importantly form an essential framework context for supplementary information. However, these nearly always need to be supplemented with technology, market and consumer behaviour information. Indicators for tracking improvements in freight energy consumption and the information needs to develop these indicators were outlined earlier in this section. Additional freight policy issues and the supplementary information needed are outlined below (Table 6.14).

Table 6.14 • Supplementary information for freight transport policy information

Policies and level 4 indices	Supplementary information needs	Supplementary indicators
Heavy duty vehicle fuel efficiency standards	• Vehicle usage data: distance driven, vehicle loadings, for policy design and standards and labelling verification	• Ex-ante energy performance • Energy demand at sub-sector level
Polices to improve freight vehicle fuel efficiency	• Technical information for certification system design and review • Verification of certification technical performance	• Current stock information for policy design and evaluation, performance verification
Improved operating efficiency through eco-driving and related policies	• Driver training and use of feedback instruments such as fuel consumption meters in commercial vehicles	• Survey driving practices and energy consumption rates before and after the policies are implemented
Freight transport system efficiency	• Vehicle usage data: distance driven, vehicle loadings for policy design	

Analysts should consider that often policy makers require information about future trends, before or as they occur. The ongoing growth in industrial capacity, the types of goods and services produced, and changing export dynamics point to a need to understand in some detail the drivers of and options for developing efficient future freight transport networks.

Annex A
Decomposition/Factorisation Methodologies

This Annex briefly describes the key elements of common index decomposition or factorisation[1] analysis methodologies which decompose or factorise changes in energy consumption in the end-use sectors (residential, services, industrial and passenger and freight transportation sectors) as well as the economy as a whole for different countries or regions.

Energy efficiency indicators cannot predict variation in overall energy consumption or quantify the impact of individual components or factors on overall energy consumption. Thus, it is often necessary to undertake more detailed analysis to fully understand the combined impact of a number of different factors or driving forces on overall energy consumption. Decomposition analysis is commonly used to isolate variations in energy efficiency from other factors which impact energy consumption, such as, economic structure and physical or economic activity.

For example, a general indicator of the overall energy intensity of the economy is the ratio of energy consumption to GDP. It is widely accepted that the changes to this indicator are the result of structural changes in the economy and not only changes in technical energy efficiency. An example of structural change could be variation of the ratio of industrial GDP output, the most energy-intensive sector, to the overall GDP which would result in a change in the overall energy intensity, even if the technical energy efficiency of all sectors remained unchanged.

The purpose of decomposition is to:

- quantify relative contributions of the pre-defined factors to the change in energy consumption
- track down the origin in energy consumption variations
- measure effectiveness of energy policy and technology.

Decomposition of energy end-use trends often distinguishes among three main factors affecting energy consumption: aggregate **activity**, sectoral **structure**[2] and **energy intensities** effect[3]. Energy services can be defined as actual services for which energy is used, for example, heating a given amount of space to a standard temperature for a period of time. A quantitative measure of energy services demand in a sector is the product of the activity effect (A) and the structure effect (S). The end-use energy required to satisfy the demand for energy service is then expressed as delivered, or final, energy per unit of activity – the energy intensity (I).

Depending on data availability, breakdowns of energy use by sector or key end uses and by fuel can be incorporated into the decomposition. If possible, there

1. Referred to as decomposition in the rest of this Annex.
2. Refers to the mix of activities within a sector, e.g., modal mix (road, rail, water and air) in transport, energy end uses in residential, share of each sub-sector to total manufacturing value-added in industry.
3. Energy intensity, in this case (energy "consumed" per unit activity or output), is a proxy for technical energy efficiency improvements.

should also be disaggregation by geographical or regional level, to reflect the climate and societal drivers on overall energy consumption. If more detailed data is available, then examining the impact of a greater number of factors on overall energy consumption is preferable (such as capacity utilisation, weather etc.).

A key issue with decomposition is the choice of activity definition. Ideally the selected activity metrics will utilise easily available data, and fit stated policy objectives and programme activity objectives of the country or region or organisation undertaking the analysis as closely as possible.

Generally indices are established to examine the changes in the factors or effects decomposed over time. Four important criteria are used to determine the choice of index decomposition[4] analysis methodology:

- The index methodology must be theoretically sound, i.e. an insignificant or no residual[5] or interaction term and also must meet the index requirement of time reversibility.
- The index methodology must be applicable to all sectors and sub-sectors so that they can all be interpreted in the same way, making it possible to aggregate the sub-sectors results.
- The interpretation of the index must be straightforward (i.e. the results must be easy to understand).
- Data to calculate the different effects must be available.

Some common index decomposition methodologies are compared in Table A.1. They are largely distinguished by the weightings applied to the various sectors or sub-sectors and the presence or distribution of a residual (or interaction) term.

Table A.1 • Comparison of different decomposition analysis methods

Index	Perfect decomposition*	Sub-sectors additive	Time reversible	Easy to understand
LMDI I	Yes	Yes	Yes	Moderately
Refined Laspeyres	Yes	Yes	No	Moderately
LMDI II	Yes	No	Yes	Moderately
Fischer Ideal	Yes	No	Yes	Moderately
Simple average/ arithmetic mean/ divisia (Törnqvist)	No	No	Yes	Moderately
Adjusted PMD I and II	No	Yes	Yes	Difficult
Paasche	No	Yes	No	Very easy
Simple Laspeyres	No	Yes	No	Very easy

* No residual term

There are multiple forms of the same methodology as a result of the choice of base year and the type of mathematical form or configuration (additive or multiplicative analysis).

The choice of the base year is extremely important and can be fixed or chained base year. A chained base year is where there is not a single base year but it requires time

4. The decomposition analysis methods are derived from price/economic index number theory.
5. A small residual or interaction term relative to all the other effects analysed is tolerable as part of decomposition analysis.

series data and for every year the previous years is used as the base. The chaining method is considered to produce more accurate results and facilitate analysis of multiple time periods.

The choice of additive or multiplicative configuration largely depends on data availability and whether the impact of the individual effects or factors examined as part of the decomposition analysis are required as a relative change or an absolute value. The distinction between additive and multiplicative configurations is presented in Table A.2. For perfect decomposition the residual term for additive analysis should be 0, whereas for multiplicative decomposition should be 1.

Table A.2 • *Comparison of additive and multiplicative three-factor decomposition analysis methods*

Additive (Sum form)	Multiplicative (Product form)
$\Delta E = \Delta E_{ACT} + \Delta E_{STR} + \Delta E_{INT} + E_{RSD}$	$R = R_{ACT} \cdot R_{STR} \cdot R_{INT} \cdot R_{RSD}$
where $\Delta E = E^{YearT} - E^{Year\,0}$	$R = E^{YearT} / E^{Year0}$
$Where: ACT = Activity, STR = Structure, INT = Intensity, RSD = Residual$	

The Log Mean Divisia Index I (LMDI I) methodology (Table A.3) meets three of the four criteria examined in Table A.1, the most important of which is perfect decomposition (i.e. does not produce a residual term). However, it is considered relatively difficult to communicate to non-experts and is not suitable where there are zeros or negative numbers in the data set being analysed.

Table A.3 • *Example of three-factor Log Mean Divisia Index methodology*

	Additive	Multiplicative
Activity effect (A)	$E_t^A = \sum_i L(E_i^T, E_t^0) \cdot \ln\left(\frac{A^T}{A^0}\right)$	$R_t^A = \exp\sum_i \left(\frac{L(E_i^T, E_i^0)}{L(E^T, E^0)} \cdot \ln\left(\frac{A^T}{A^0}\right)\right)$
Structural effect (S)	$E_t^S = \sum_i L(E_i^T, E_t^0) \cdot \ln\left(\frac{S_i^T}{S_I^0}\right)$	$R_t^S = \exp\sum_i \left(\frac{L(E_i^T, E_i^0)}{L(E^T, E^0)} \cdot \ln\left(\frac{S_i^T}{S_i^0}\right)\right)$
Intensity effect (I)	$E_t^I = \sum_i L(E_i^T, E_t^0) \cdot \ln\left(\frac{I_i^T}{I_I^0}\right)$	$R_t^I = \exp\sum_i \left(\frac{L(E_i^T, E_i^0)}{L(E^T, E^0)} \cdot \ln\left(\frac{I_i^T}{I_i^0}\right)\right)$
	$E^T = energy\ consumption\ year\ T$ $E^0 = energy\ consumption\ year\ 0$ $i = sub\text{-}sector\ or\ end\ use$	$L(a,b) = \frac{a-b}{\ln a - \ln b}$ $with\ a,b > 0\ and\ a \neq b$ $\ln = natural\ log, \exp = exponential$

The simple Laspeyres methodology (Table A.4) is known as being easy to understand and communicate. However, there is a residual term with this methodology, which can be significant (in particular when examining long time periods or very fast change [as in a recession or expansion]), and raises questions about the accuracy and usefulness of results of decomposition using this methodology.

Table A.4 • *Example of three-factor Laspeyres methodology*

	Additive	Multiplicative
Activity effect (A)	$E_t^A = A_t \cdot \sum_i S_0^i \cdot I_0^i - E_0$	$R_t^A = \dfrac{A_t \cdot \sum_i S_0^i \cdot I_0^i}{E_0}$
Structural effect (S)	$E_t^S = A_0 \cdot \sum_i S_t^i \cdot I_0^i - E_0$	$R_t^S = \dfrac{A_0 \cdot \sum_i S_t^i \cdot I_0^i}{E_0}$
Intensity effect (I)	$E_t^I = A_0 \cdot \sum_i S_0^i \cdot I_t^i - E_0$	$R_t^I = \dfrac{A_0 \cdot \sum_i S_0^i \cdot I_t^i}{E_0}$
t = final year *0 = base year* *i = sub-sector or end use*		

The decomposition analysis results included in this manual are calculated using a three-factor decomposition analysis[6] based on the Simple Laspeyres index decomposition methodology. Once the relative impact on energy consumption from changes in each component examined is calculated, it is possible to isolate the impacts on energy consumption related to improved end-use energy efficiency (reductions in energy intensities) – i.e. to separate them from changes deriving from shifts in the activity and structure components for example in a three-factor decomposition analysis.

Hypothetical energy use (HEU^i) is defined as the energy consumption that would have occurred in year *t* if energy intensities in each sector remained constant at their base year values.

$$HEU_t^i = \frac{E_t}{R_t^i}$$

Energy savings from reduced energy intensities can be defined as the difference between the hypothetical energy use and actual energy consumption.

$$SAVINGS_t^i = HEU_t^i - E_t$$

6. See Annex A of the IEA publication *Energy Use in the New Millennium: Trends in IEA Countries* (IEA, 2007) and Chapter 2 of the *Oil Crises & Climate Challenges: 30 years of Energy Use in IEA Countries* (IEA, 2004) for a description of the IEA three-factor decomposition analysis methodology.

The analysis can be extended to examine changes in carbon dioxide (CO_2) emissions (G) by introducing the dimension of fuel mix and carbon intensity (or CO_2 intensity) as additional factors. A fuel mix (F) can be used to represent changes in fuel shares (including electricity) among end uses and a carbon intensity (C) referring to the CO_2 emissions per unit of energy consumed.

$$F_t^{i,f} = \frac{E_t^{i,f}}{E_t^i} \qquad C_t^{i,f} = \frac{G_t^{i,f}}{E_t^{i,f}}$$

The **CO_2 emissions** (G) in a sector can then be decomposed into the activity, structure, energy intensity, fuel mix and carbon intensity effects according to the following formula, where *f* is the type of fuel:

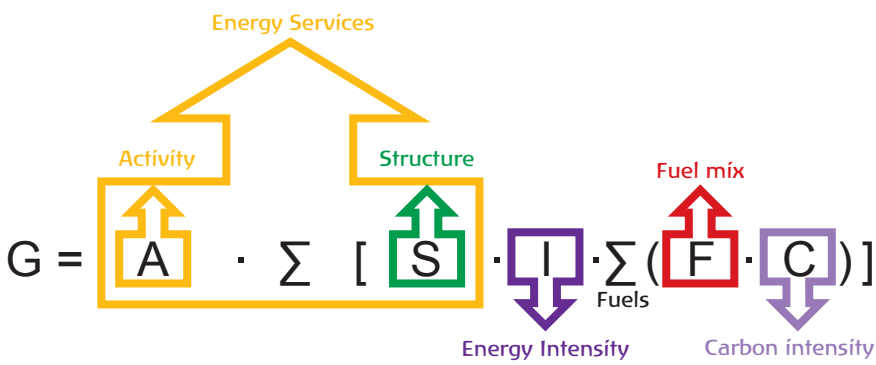
$$G_t = A_t \cdot \sum_i \left[S_t^i \cdot I_t^i \cdot \sum_f \left(F_t^{i,f} \cdot C_t^{i,f} \right) \right]$$

This makes it possible to calculate the hypothetical CO_2 emissions as well as CO_2 savings. For example, the following two formulas present the carbon intensity effect and corresponding savings.

$$G_t^C = \frac{A_0 \cdot \Sigma_i \left[S_0^i \cdot I_0^i \cdot \Sigma_f \left(F_0^{i,f} \cdot C_t^{i,f} \right) \right]}{G_0} \qquad CO_2SAVINGS_t^C = \frac{G_t}{G_t^C} - G_t$$

The separation between energy services effects and energy or CO_2 intensity effects, as shown in Figure A.1, is important from a policy perspective since restraining energy service demand is seldom a policy objective. The decomposition approach used by the IEA allows for observing the impacts of the policy elements related to energy and CO_2 intensity separately from changes in the structural and activity components of energy use. This helps both to determine where policies can be most effective and to monitor progress once they have been implemented.

Figure A.1 • Basic overview of factors in CO_2 decomposition



Annex B
Initiatives on Development of Energy Efficiency Indicators

There are a number of regional and national initiatives to support the development of energy indicators as a tool for policy making. This annex summarises the current status of work on energy indicators in selected regional organisations and member countries of the International Energy Agency (IEA).

Eurostat

Eurostat is the statistical office of the European Union, situated in Luxembourg. Its task is to provide the European Union with statistics at European level that enable comparisons among countries and regions. Eurostat's main role is to process and publish comparable statistical information at European level. Eurostat also works with member states to arrive at a common statistical "language" that embraces concepts, methods, structures and technical standards. Eurostat provides a wide range of statistical data on energy consumption.

For more information on Eurostat and to access data, visit: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home.

ODYSSEE Network

The ODYSSEE database on energy efficiency indicators has become a reference for evaluating and monitoring annual energy efficiency performances and energy-related carbon dioxide (CO_2) emissions for EU-27, Croatia and Norway. The database, which includes 200 indicators and covers the period 1980 to 2010 for EU-15 and 1996 to 2010 for EU-27, is also used to monitor and evaluate energy efficiency policies, at both national and EU levels. This database is updated regularly (at least annually) and supports the use of a common methodology to produce comparative indicators for energy efficiency. The data are collected mainly from national sources, with some additional data from Eurostat. Indicators in the ODYSSEE database cover both energy efficiency and CO_2. ADEME[1], France's Environment and Energy Management Agency, leads the project with assistance from Enerdata, the technical co-ordinator responsible for collecting submissions from national agencies.

Further information on ODYSSEE can be found at: http://www.indicators.odyssee-mure.eu/online-indicators.html.

Regional Center for Renewable Energy and Energy Efficiency

The Regional Center for Renewable Energy and Energy Efficiency (RCREEE) is an independent not-for-profit regional organisation that aims to enable and increase the adoption of renewable energy and energy efficiency practices in the Arab region. RCREEE teams with regional governments and global organisations to initiate

1. Agence de l'environnement et de la maîtrise de l'énergie (ADEME).

and lead clean energy policy dialogues, strategies, technologies and capacity development in order to increase Arab states' share of tomorrow's energy. In 2011, Plan Bleu and RCREEE initiated the Energy Efficiency Indicators in the Southern and Eastern Mediterranean Countries project. The main goals of the project are to:

- strengthen the capacities of public and private experts for the calculation and analysis of energy efficiency indicators
- disseminate a culture of indicators among policy makers in target countries
- raise the awareness among national policy makers about difficulties related to access, availability, and reliability of energy data and socio-economic data
- promote the exchange of experiences and data among countries in the region in order to gradually develop a regional database similar to ODYSSEE in Europe
- create a regional network of experts able to design, calculate and analyse energy efficiency indicators as a tool for evaluating the impact of energy efficiency policies in the region.

Further information on RCREEE can be found at: www.rcreee.org.

Asia-Pacific Economic Cooperation's Energy Working Group

The Asia-Pacific Economic Cooperation's Energy Working Group (APEC EWG) was created in 1990 with the main objective of maximising the energy sector's contribution to the region's economic and social well-being, while mitigating the environmental effects of energy supply and use. Recognising the importance of information and energy statistics, the EWG created an expert group on energy data and analysis (EGEDA). EGEDA developed the APEC energy database and established an energy data collection network among member economies.

EGEDA has been conducting capacity-building on energy statistics and energy indicators analysis in the APEC region, which includes collection of energy consumption data.

Further information on EGEDA can be found at: www.ieej.or.jp/egeda/.

Economic Commission for Latin America and the Caribbean

The United Nations Economic Commission for Latin America and the Caribbean (ECLAC) is a United Nations regional commission to encourage economic co-operation. ECLAC includes 44 member states and eight associate members. ECLAC publishes statistics, including economic, demographic, social and environmental, covering the countries of the regions. In 2001, ECLAC started the implementation of a database for energy efficiency indicators. As of early 2013, 11 countries were participating in this initiative. The database, which is based on the ODYSSEE model, includes data for 2001 onwards.

Further information on ECLAC can be found at: www.cepal.org/.

Asian Development Bank

For many years, the Asian Development Bank (ADB) has assisted its developing member countries (DMCs) in gathering and disseminating better statistical data. ADB disseminates recent key economic, financial, and social indicators compiled from DMCs and other international sources. Additionally, detailed transport indicators are developed and compiled through two major new initiatives:

- Development of the new Sustainable Transport Appraisal Rating (STAR) framework to guide the design of transport projects, so that they are made more economically, socially and environmentally sustainable. The framework includes indicators that measure the relative sustainability of a project in various aspects of sustainability.
- Development of data and a statistical collection tool, which will provide inputs to the Global Transport Intelligence (GTI) initiative for countries in the Asia and Pacific region. One of the principal outputs from this effort will be a publication, "Transport Statistics and Outlook for Asia and the Pacific".

Further information on ADB can be found at: www.adb.org.

Cement Sustainability Initiative

Under the umbrella of the Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development, a number of major cement companies have agreed on a methodology for calculating and reporting CO_2 emissions. The Cement CO_2 Protocol provides a harmonised methodology for calculating CO_2 emissions, with a view to reporting these emissions for various purposes.

The CSI also runs the global database on energy and CO_2 performance in the cement sector: "Getting the Numbers Right". The database covers more than 900 cement production facilities, owned by 46 companies, representing approximately 26% of global cement production. Global and regional reports containing data up to 2010 are available at www.wbcsdcement.org/co2data.

Further information on CSI can be found at: www.wbcsdcement.org/.

International Aluminium Institute

The International Aluminium Institute (IAI), covering about 80% of the world's primary aluminium production, provides energy and activity data on an annual basis. The electricity use of primary aluminium smelters and the energy consumption for alumina production are monitored separately. Results are available publicly at a regional level.

Further information on IAI can be found at: www.world-aluminium.org/.

Global Fuel Economy Initiative

The Global Fuel Economy Initiative (GFEI) exists to promote debate and discussion around the issue of fuel economy. On the basis of current evidence on existing technologies, it believes that huge gains could be made in fuel economy, gains that could help every country but particularly those in the developing world, to address the pressing issues of climate change, energy security and sustainable mobility. In the longer term the group wants to see real improvements in the fuel economy capacity of the global car fleet. To that end, it will continue to raise awareness, present evidence and offer support in a way that enables more and more countries to adopt effective fuel economy standards and policies that work in their circumstances and with their fleets. Within the partnership's activities, the IEA has developed a biannual data exercise to collect, compile and analyse data on the average new vehicle fuel economy to track progress of the energy efficiency of new cars. The latest update of such indicators' work was published early 2013 and can be downloaded at:

www.globalfueleconomy.org/Documents/Publications/wp8_international_comparison.pdf.

World Resources Institute EarthTrends

EarthTrends, based on the World Resources Institute (WRI) series, is a free online resource that highlights the environmental, social and economic trends that shape our world. The site offers the public a comprehensive collection of vital statistics, maps and graphics for more than 200 countries.

Much of the environmental information on the Internet is fragmented, buried or available only at a price. EarthTrends gathers data from more than 40 of the world's leading statistical agencies, along with WRI-generated maps and analyses, into a single repository for rapid searching and retrieving. EarthTrends supplements its content with detailed metadata that report on research methodologies and the information's reliability. All of these resources are made available to the public at no charge.

The site is undergoing deep maintenance and is to be relaunched soon: www.wri.org/project/earthtrends/.

Annex C
Abbreviations, Acronyms and Units of Measure

1 Abbreviations and acronyms

BATs	best available technologies
BF	blast furnace
BOF	basic oxygen furnace
BPT	best practice technology
CDD	cooling degree days
CFLs	compact fluorescent lights
CO_2	carbon dioxide
DRI	direct reduced iron
EAF	electric arc furnace
EEI	energy efficiency indicator
EMS	energy management systems
EU	European Union
GDP	gross domestic product
GPS	global positioning systems
HDD	heating degree days
ICT	information and communication technology
IEA	International Energy Agency
ISIC	International Standard Industrial Classification
LDVs	light-duty vehicles
LEDs	light-emitting diodes
LMDI	Log Mean Divisia Index
LPG	liquefied petroleum gas
MEPS	minimum energy performance standards
MER	market exchange rate
NYMEX	New York Mercantile Exchange
ODYSSEE	Online Database for Yearly Assessment of Energy Efficiency
OECD	Organisation for Economic Co-operation and Development
OHF	open-hearth furnace
PMD	Parametric Divisia Method
PPP	purchasing price parity
RPM	revolutions per minute
SMEs	Small- and Medium-sized Enterprises
SUVs	sport utility vehicles
UEC	unit energy consumption

2 Units of Measure

EJ	exajoule (10^{18} joules)
energy/pkm	energy per passenger-kilometre
energy/tkm	energy per tonne-kilometre
$GtCO_2$	gigatonnes of carbon dioxide (10^9 tonnes CO_2)
kg	kilogrames
kWh	kilowatt hours (10^3 watt hours)
MWh	megawatt hour (10^6 watt hours)
t	tonne
tCO_2	tonnes of carbon dioxide (CO_2)
TWh	terawatt hours (10^{12} watt hours)

Annex D
Glossary

Basic oxygen furnace: Process where liquid hot iron metal is converted into steel, using oxygen injection.

Best available technology: Best available technology is taken to mean the latest stage of development (state-of-the-art) of processes, facilities or of methods of operation which include considerations regarding the practical suitability of a particular measure for enhancing energy efficiency.

Best practice technology: In contrast to BAT, best practice is a term that applies to technologies and processes that are currently deployed.

Biomass: Biomass is a biological material that can be used as fuel or for industrial production. It includes solid biomass (e.g. wood, plant and animal products), gases and liquids derived from biomass, industrial waste and municipal waste.

Blast furnace: A blast furnace is a type of metallurgical furnace used for smelting. Fuel and ore are continuously supplied through the top of the furnace, while air (oxygen) is blown into the bottom of the chamber, so that the chemical reactions take place throughout the furnace as the material moves downward. The end products are usually molten metal and slag phases tapped from the bottom, and flue gases exiting from the top of the furnace. This type of furnace is typically used for smelting iron ore to produce hot metal (pig iron), an intermediate material used in the production of commercial iron and steel.

Climate correction: Climate correction is an adjustment to space heating and cooling energy consumption to normalize the consumption pattern over time by removing the impact of year-to-year temperature variations.

Coal: Coal includes both primary coal (including hard coal and brown coal) and derived fuels (including patent fuel, brown-coal briquettes, coke-oven coke, gas coke, gas-works gas, coke-oven gas, blast-furnace gas and oxygen steel furnace gas). Peat is also included.

Co-generation: Co-generation refers to the combined production of heat and power.

Combined heat and power (CHP): Combined heat and power, also called cogeneration, is a technology where electricity and steam or electricity and hot water are produced jointly. This increases the efficiency compared to separate electricity and heat generation.

Commercial heat: Refers to heat consumed by final end users. It includes heat produced for sale only.

Cooling degree days (CDD): Refers to the total seasonal cooling requirements to satisfy a desired temperature setting compared to the average daily temperature

(either actual or historical average). Desired or set temperatures vary by preference and consumer behaviour but design engineers usually follow a standard protocol by country or region. For example, if a desired temperature were 20°C and the average daily temperature were 30°C, there would be 10 CDD for that day. All days with a heating load are summed up to derive total HDDs for the season that have large variations based on climate.

Decomposition analysis: Decomposition or factorisation refers to the breakdown of energy consumption into constituent parts or factors.

Direct emissions: Direct emissions refer to emissions that are attributed directly to end-use equipment that are located on a building.

Direct reduced iron: Product made through chemical reduction of iron ore pellets in their solid state.

Dry kiln: A kiln that produces cement clinker without using a water/limestone slurry mix as the feedstock.

Electric arc furnace (EAF): Furnace for smelting of iron scrap and other metals using electricity.

Electricity production: The total amount of electricity generated by a power plant. It includes own-use electricity and transmission and distribution losses.

Energy Balance: The presentation of energy statistics expressed in natural units in the form of commodity balances between the supply and use of the energy commodities

Energy conservation: Energy conservation refers to limiting or reducing energy consumption through change in lifestyle or behaviour (e.g. turning off lights in unoccupied rooms)

Energy efficiency: Energy efficiency refers to limiting or reducing energy consumption through the adoption of more efficient devices (e.g. use of compact fluorescent light bulbs instead of incandescent light bulbs). Something is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input.

Energy intensity: Energy intensity a measure where energy is divided by a physical or economic denominator.

Factorisation: see decomposition analysis.

Gross domestic product: Gross domestic product (GDP) is the market value of all officially recognised and final goods and services produced within a country.

Heat: Heat is obtained from the combustion of fuels, nuclear reactors, geothermal reservoirs, capture of sunlight, exothermic chemical processes and heat pumps, which can extract it from ambient air and liquids. It may be used for domestic hot water, space heating or cooling, or industrial process heat. Most heat included in this category comes from the combustion of fuels in co-generation installations, although some small amounts are produced from geothermal source, electrically powered heat pumps and boilers.

Heating degree day (HDD): Refers to the total seasonal heating requirements to satisfy a desired temperature setting compared to the average daily temperature

(either actual or historical average). Desired or set temperatures vary by preference and consumer behaviour but design engineers usually follow a standard protocol by country or region. For example, if a desired temperature were 20°C and the average daily temperature were 5°C, there would be 15 HDD for that day. All days with a heating load are summed up to derive total HDDs for the season that have large variations based on climate.

Indirect emissions: Indirect emissions generally refer to emissions that are attributed to electricity generation at central power plant or at co-generation plant. They also can refer to emissions produced in power and industrial processes used for district heating and cooling networks.

Natural gas: It comprises gases, occurring in underground deposits, whether liquefied or gaseous, consisting mainly of methane. It includes both "non-associated" gas originating from fields producing hydrocarbons only in gaseous form, and "associated" gas produced in association with crude oil as well as methane recovered from coal mines (colliery gas).

Oil: Oil includes crude oil, condensates, natural gas liquids, refinery feedstocks and additives, other hydrocarbons (including emulsified oils, synthetic crude oil, mineral oils extracted from bituminous minerals such as oil share, bituminous sand and oils from coal liquefaction) and petroleum products (refinery gas, ethane, liquefied petroleum gases, aviation gasoline, motor gasoline, jet fuels, kerosene, gas/diesel oil, heavy fuel oil, naphtha, white spirit, lubricants, bitumen, paraffin waxes and petroleum coke).

Open hearth furnace (OHF): An open hearth furnace is an out-dated type of metallurgical furnace used for smelting pig iron and scrap to produce raw steel through a batch process where the charge is heated by direct flame and radiation from the roof and walls.

Power generation: Fuel use in electricity plants, heat plants and combined heat and power (CHP) plants. Both public plants and small plants that produce fuel for their own use (autoproducers) are included.

Purchasing power parity: PPP is the rate of currency conversion that equalises the purchasing power of different currencies. It makes allowance for the differences in price levels and spending patterns between different countries.

Renewables: Renewable includes biomass and waste, geothermal, hydropower, solar photovoltaic, concentrating solar power, wind and marine (tide and wave) energy for electricity and heat generation.

Residential sub-sector: The residential sub-sector includes those activities related to private dwellings. It covers all energy-using activities in apartments and houses, including space and water heating, cooling, lighting and the use of appliances. It does not include energy consumption for personal transport which is covered in the transportation sector.

Services sub-sector: The services sub-sector includes activities related to trade, finance, real estate, public administration, health, food and lodging, education and commercial services (International Standard Industrial Codes 50 to 55 and 65 to 93). This is also referred to as the commercial and public services sectors. It covers energy consumed for space heating, cooling and ventilation, water heating,

lighting and in a number of other miscellaneous energy-using equipment such as commercial appliances and cooking devices, x-ray machines, office equipment and generators. Energy consumption for transportation, or for commercial transport fleet, is excluded from the services sub-sector.

Total final consumption: Total final consumption (TFC) is the sum of consumption by the different end-use sectors. TFC is broken down into energy demand in the following sectors: industry (including manufacturing and mining), transport, residential, services and other (including agriculture and non-energy consumption).

Total primary energy supply: Total primary energy supply is equivalent to total primary energy demand. This represents inland demand only and, except for world energy demand, excludes international marine bunkers.

Value-added: Value-added is used to describe instances where an entity takes a product that may be considered a homogeneous product, with few differences (if any) from that of a competitor, and provides potential customers with a feature or add-on such as energy efficiency that gives it a greater sense of value.

Regíonal and country groupíngs

Africa: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia and Zimbabwe.

China: refers to the People's Republic of China, including Hong Kong.

Europe: Albania, Austria, Belgium, Bosnia, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Macedonia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovak Republic, Spain, Sweden, Switzerland, Turkey and United Kingdom.

European Union (27): Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden and United Kingdom.

Latin America: Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, the Dominican Republic, Ecuador, El Salvador, French Guyana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts-Nevis-Anguilla, Saint Lucia, St. Vincent-Grenadines and Suriname, Trinidad and Tobago, Uruguay, and Venezuela.

Middle East: Bahrain, Islamic Republic of Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen.

Non-OECD: Includes Non-OECD Asia, non-OECD Europe and Eurasia, Middle East, Africa and non-OECD Latin America regional groupings.

Non-OECD Asia: Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, Chinese Taipei, Cook Islands, DPR of Korea, East Timor, Fiji, French Polynesia, Hong Kong, India, Indonesia, Kiribati, Laos, Macau, Malaysia, Maldives, Mongolia, Nepal, New Caledonia, Pakistan, Papua New Guinea, People's Republic of China, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Tonga, Vanuatu and Vietnam.

Non-OECD Europe and Eurasia: Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Georgia, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Former Yugoslav Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Serbia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan. For statistical reasons, this region also includes Cyprus, Gibraltar and Malta.

Non-OECD Latin America: Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, British Virgin Islands, Cayman Islands, Brazil, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands, French Guyana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, Saint-Pierre et Miquelon, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay and Venezuela.

Oceania: Australia and New Zealand.

OECD: Includes OECD Americas, OECD Asia Oceania and OECD Europe regional groupings.

OECD Americas: Canada, Chile, Mexico and the United States.

OECD Asia Oceania: includes OECD Asia, comprising Japan, Korea and Israel, and OECD Oceania comprising Australia and New Zealand.

OECD Europe: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom

Other developing Asia: Non-OECD Asia regional grouping excluding China and sometimes excluding India (if it is analysed separately).

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Annex F
IEA Alternative Pyramids

This section contains alternative indicator pyramids for each on the end-use sectors examined in this manual. There are at least four levels to these alternative pyramids, whereas there are only three levels in the pyramids included in the main body of the manual. These four level pyramids would be applicable to countries with rather detailed end-use data. Ultimately, data availability and homogeneity within the various sectors and sub-sectors will determine what are the most appropriate indicators to be developed by countries. The indicator pyramids should be adapted to account for countries' specificities and data situation.

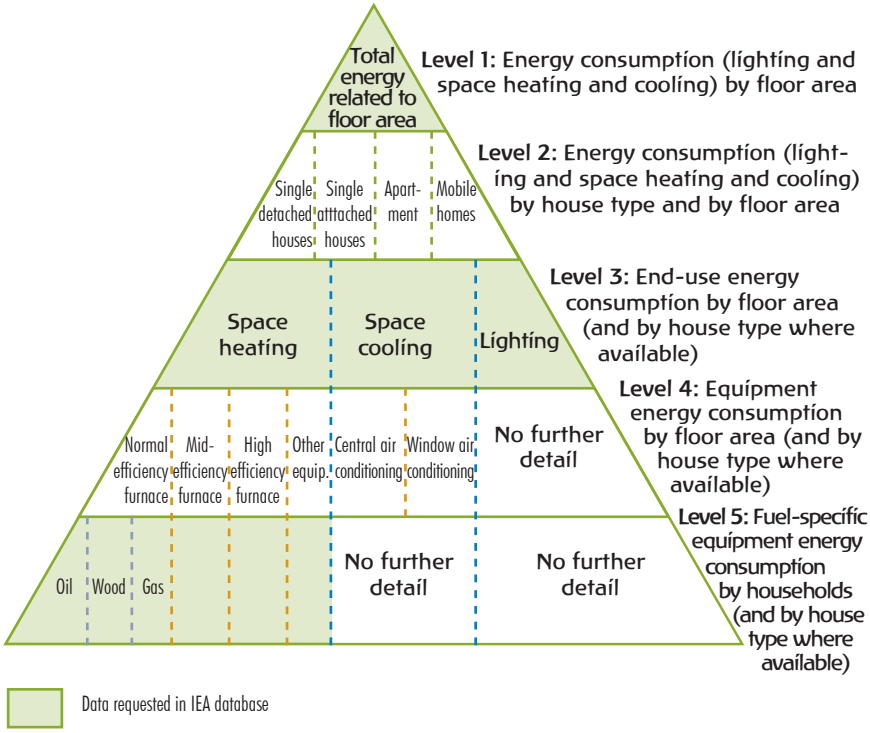
1 Example of alternative indicator pyramid: Residential sector

The residential sector includes those activities related to private dwellings. It covers all energy-using activities in apartments and houses, including space and water heating, cooling, lighting and the use of appliances. It does not include personal transport, which is covered in the transport sector.

There are numerous ways to define the analytical framework in the residential sector. The level of detail selected greatly depends on the information available. For example, Canada is using two different pyramids: one for end uses with energy consumption related to the number of households and one for end uses with energy consumption related the floor area. The indicators are then aggregated by using weighted energy consumption.

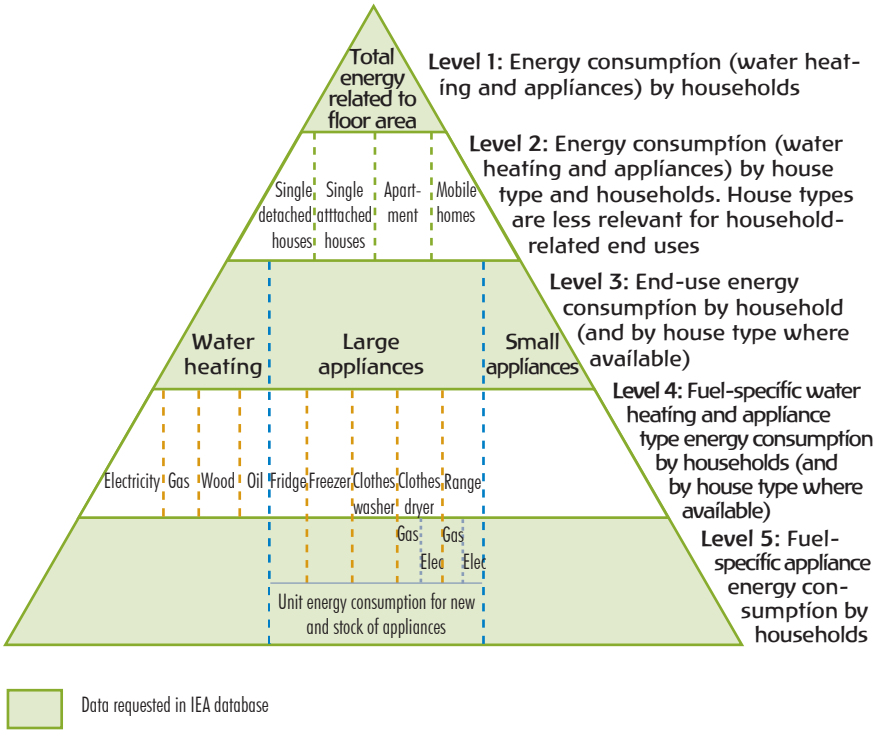
The example below shows the two indicators pyramids for the residential sector. These pyramids would be applicable to countries with rather detailed end-use data. This is not the case in each country. As previously mentioned, the pyramid should be adapted to account for countries specificities and data situation.

Figure F.1 • Residential sector pyramid based on floor area



Note: Information by house type and by housing systems is available in some countries. However, this information is not collected by the IEA. The IEA database contains information for levels 1, 3 and 5 for 18 IEA member countries. Some countries have more detailed information than what is available in the IEA database.

Figure F.2 • Residential sector pyramid based on household



Note: Information by house type and by housing systems is available in some countries. However, this information is not collected by the IEA. The IEA database contains information for levels 1, 3, 4 and 5 with the number of country reporting the data to IEA depending on the level of the pyramid. Some countries have more detailed information than what is available in the IEA database.

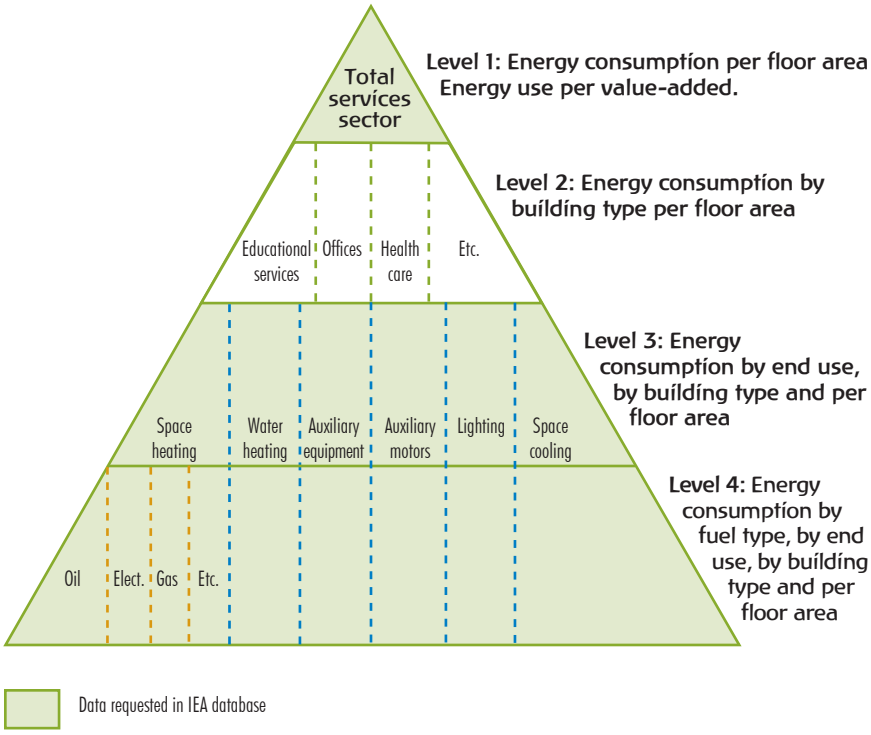
2 Example of alternative indicator pyramid: Services sector

The services sector includes activities related to trade, finance, real estate, public administration, health, education and commercial services.

Very few countries are able to analyse the energy efficiency trends in the services sector. The general aggregate indicator used is services energy consumption by unit of value-added in the services sector. However, different services sector activities can produce very different levels of economic output while consuming nearly the same amount of energy. For example, buildings in the finance sector can have the same final energy demand profile as buildings in the retail sector, yet generate significantly different levels of economic output.

Energy consumption by floor area is considered by some countries as the best indicator for this sector.

Figure F.3 • Services sector pyramid



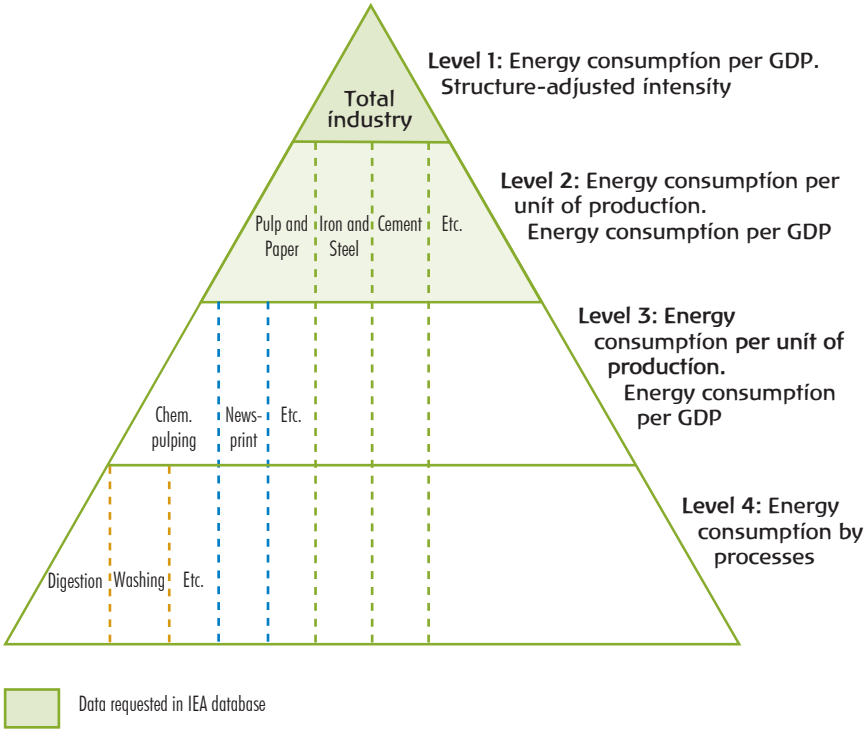
Notes: For IEA member countries, only three countries report energy consumption by end use to the IEA (Level 3). Only seven countries report total services floor area. The IEA is analysing the services sector intensity based on value-added. Some countries have more detailed information than what is available in the IEA database.

3 Example of alternative indicator pyramid: Industry sector

The industry sector covers the manufacture of finished goods and products, mining and quarrying of raw materials, and construction. Power generation, refineries and the distribution of electricity, gas and water are excluded.

The industrial pyramid shows how this sector can be disaggregated and the different indicators that can be used at each level (Figure G.4). This is only an illustration and may not be relevant for all countries.

Figure F.4 • Industry sector pyramid



Note: For IEA countries, the IEA database contains information at Level 2 for 21 member countries in the industrial sector. Some countries have more detailed information than what is available in the IEA database.

Level 1: Total industry sector

The commonly used indicator at the aggregate level is energy consumption per unit of GDP. This ratio measures how much energy is needed to produce one unit of economic output. However, it would be misleading to evaluate the performance of energy efficiency based on this indicator as it is affected by many non-energy efficiency factors such as the structure of the industry, the quality of resources and, for some industrial sectors, weather conditions.

For this reason, many countries develop structure-adjusted intensity for the total industrial sector. Constructing the structure-adjusted indicator requires the energy consumption and GDP data at Level 2 or 3 of the pyramid.

Level 2 and level 3: Industry sectors

The industries represented in Level 2 and 3 usually differ by country according to the data available and the relative importance of each industry.

At these levels, the best indicator to assess energy efficiency is energy consumption per unit of production. However, as some industries are too heterogeneous to have one measure of production, GDP (or another monetary value such as gross output) is the second-best choice.

Level 4: Process indicators

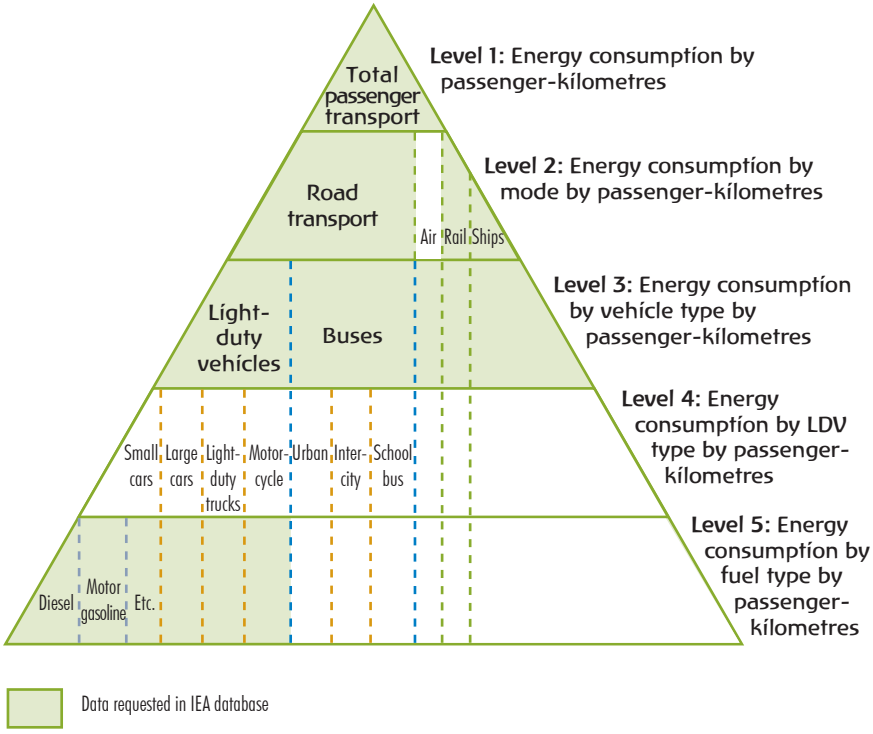
The IEA indicator database does not contain information on Level 4. Only a limited number of countries have this information for a limited number of industries. However, even partial information at this level can help explain the trends in energy consumption.

4 Example of alternative indicator pyramid: Transport sector

The transport sector includes the movement of people and goods by road, rail, water and air. Pipelines and international air and water transport are excluded from the analysis.

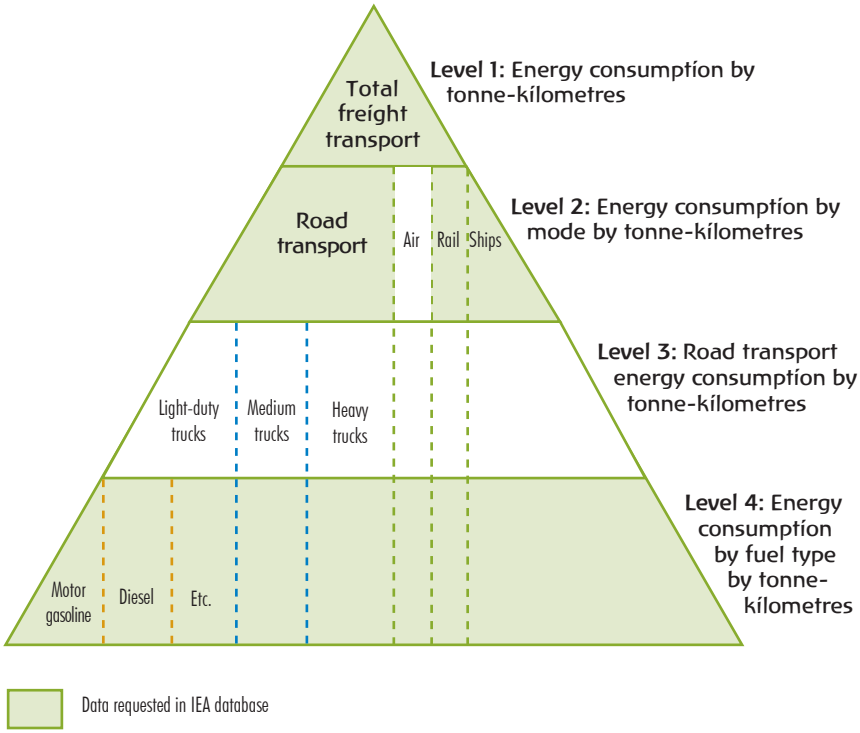
While it is possible to present energy consumption for the total transport sector, a more detailed analysis of this sector requires passenger and freight transport to be analysed separately since they are affected by different underlying factors.

Figure F.5 • Passenger transport sector pyramid



Notes: The IEA database does not contain information by type of buses. Ships are not included in the IEA analysis due to lack of information. In the IEA database, light-duty vehicles are only disaggregated between motorcycles and other LDVs. Some countries have more detailed information than what is available in the IEA database.

Figure F.6 • Freight transport sector pyramid



Notes: The IEA database does not contain information by type of road freight vehicles. Air travel is not included in the IEA analysis due to lack of information. Some countries have more detailed information than what is available in the IEA database..

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