LBNL 3702E

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Energy Efficiency Indicators Methodology Booklet

Stephane de la Rue du Can
Jayant Sathaye
Lynn Price
Michael A. McNeil

Environmental Energy Technologies Division

May 2010

This work was prepared with the support of the World Bank (ESMAP) and the International Energy Agency through the Department of Energy under contract No. DE-AC02-05CH11231.

Please direct correspondence to Stephane de la Rue du Can at sadelarueducan@lbl.gov

Acknowledgments

The authors of this report would like to thank Ashok Sarkar at the World Bank for his helpful guidance during this project. The study benefited greatly from intellectual inputs from Dr Peter Taylor, Cecilia Tam, Nathalie Trudeau, Pierpaolo Cazzola and Ghislaine Keiffer at the International Energy Agency. The study also benefited significantly from three workshops organized in China, South Africa and Mexico. We are grateful to Hu Xiulian and Jiang Kejun from Energy Research Institute (ERI), Beijing, Dr. Willem den Heijer from Energy Cybernetic, Johannesburg, and Jorge Nuño Lara from the Secretaría de Energía (SENER), Jorge Islas Samperio and Genice Kirat Grande Acosta from Centro de Investigación de Energía (CIE), and Emmanuel Gomez and Francisco Torres from Mario Molina Center, Mexico City, who organized country workshops and provided very helpful feedbacks on this report. Finally we would like to thank Barbara Adams for her kind assistance.

Abstract

This *Methodology Booklet* provides a comprehensive review and methodology guiding principles for constructing energy efficiency indicators, with illustrative examples of application to individual countries. It reviews work done by international agencies and national government in constructing meaningful energy efficiency indicators that help policy makers to assess changes in energy efficiency over time. Building on past OECD experience and best practices, and the knowledge of these countries' institutions, relevant sources of information to construct an energy indicator database are identified. A framework based on levels of hierarchy of indicators – spanning from aggregate, macro level to disaggregated end-use level metrics – is presented to help shape the understanding of assessing energy efficiency. In each sector of activity: industry, commercial, residential, agriculture and transport, indicators are presented and recommendations to distinguish the different factors affecting energy use are highlighted. The methodology booklet addresses specifically issues that are relevant to developing indicators where activity is a major factor driving energy demand.

A companion spreadsheet tool is available upon request.

Table of Contents

List of Figures

List of Tables

List of Indicators

Introduction

In a world where resources are becoming scarce and where energy consumption has a negative impact on our environment, energy efficiency appears as a critical opportunity to reduce energy consumption without compromising economic development. Recently, several governments have implemented energy efficiency targets over their energy per GDP intensity. However, little guidance is given to the stakeholder in translating these broad targets into more meaningful sectoral and sub-sectoral targets. The ability to define and measure energy efficiency is essential to the planning of a country energy strategy. Without transparent and robust measures, energy efficiency is a vague subjective concept that engenders directionless speculation rather than insightful analysis. This report attempts to guide stakeholders from developing countries in constructing energy efficiency indicators meaningful for their economy.

Construction of energy efficiency indicators is a common practice in many OECD countries. The International Energy Agency has developed a harmonized methodology that produces comparative energy efficiency indicators. The first component of the report informs on the methods and concepts that have been use to develop energy efficiency indicators and reports on past experiences in IEA[1] and OECD countries. The second component builds upon them towards a methodology directed to developing countries desiring to construct meaningful energy efficiency indicators to their economy. However, this methodology does not intend to provide a unique method to apply, but rather enumerates possible indicators to construct according to data availability, draw attention to potential issues that can be encounter, and specify some structural aspects common to developing country which are different with developed countries.

[1] Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Korea, Japan, Luxembourg, The Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, The United Kingdom, and United States.

I. Energy Efficiency Indicators Basic Methods and Concepts

A. Overview

Literature review

Since the oil crises in the 1970's, opportunities to reduce energy consumption through more efficient use of energy have been the subject of many studies. Energy-to-GDP ratios have been widely used internationally to measure the energy efficiency performance of national economies, until a body of research exposed the limits of using this indicator (Schipper et al., 1992; Patterson, 1993; Ang and Lee, 1994; Ang and Choi, 1997; Bossboeuf et al., 1997; IEA, 1997; and IEA, 2003). Energy analysts demonstrated that factors other than energy efficiency were affecting changes in energy intensity; mainly the level of aggregate activity (activity effect), and the composition of various activities (structure effect). Techniques of factorization or *decomposition analysis* were developed to isolate the energy intensity effect in order to give a better estimate of energy efficiency improvements. Ang (2004) provides a complete review of the different aspects and evolution of these techniques. Other effects have also been separated such as the effect of fuel switching (Patterson, 1993), households effect representing change in energy consumption due to energy per capita variation (Lermit and Jollands, 2001), and weather effect (NRCAN, 1996) among others. Ultimately, more are the effects affecting energy use isolated, better is the estimate of energy efficiency effect. However, the drawback is the limit of available data that allow to factorize additional component of the decomposition analyse

In 1997, *Energy Policy* devoted a complete issue on the subject (vol 25, issue7-9). For Schipper et al. (1997; 2001) energy indicators describe the link between energy consumption and human activity. Several authors refer to an energy indicators pyramid to help conceptualize the level of energy efficiency considered (Martin et al., 1997; Worrell et al., 1997; Phylipsen et al., 1998; Schipper et al., 1997; APERC, 2001). With each level of desegregation of indicators constructed, it is possible to isolate additional effects that influence our energy consumption.

Recently, a number of countries have focused on developing indices that are based on energy efficiency effects calculated at a disaggregate level, but which summarize results at more aggregate levels. The purpose of these indices is to provide a quick assessment tool to policy makers based on meaningful analysis. However, summing up energy intensities to get sector or national aggregates is often difficult. The problem stems from the fact that energy efficiency indicators are expressed in different units. Farla and Block (2000) provide a method for aggregating physical indicators. However, this method has several challenges related to data requirement. Reviews of aggregation methods are well documented (Nanduri et al., 2002; Jollands et al., 2003; Ang, 2005).

Energy Efficiency Measurement

There is no universally accepted definition of energy efficiency. Commonly, energy efficiency refers to using less energy to produce the same service or useful output (Patterson, 1996). An engineer may define energy efficiency in a restrictive sense of equipment output, whereas an environmentalist or a politician may have a more broad vision of energy efficiency. For example, an engineer may consider an efficient car to be one that requires less energy to drive the exact same distance at exactly the same speed while an environmentalist may consider it to be one with a higher load factor when people carpool.

The difficulty in defining energy efficiency is relevant to its measurement. There is no definitive quantitative measurement of energy efficiency. We know how much energy has been consumed but we don't know how much would have been consumed had we been more or less efficient. Instead, we must rely on a series of indicators to infer changes in energy efficiency (Patterson, 1996). Energy efficiency indicators are used to estimate what has been the significance of energy efficiency improvements on reducing energy consumption. They are defined as the ratio of energy use per unit of activity, such as energy per value added, liter of gasoline per km driven, etc. It's the progress over time of these indicators compares to the hypothesis of no change that allows estimating change in energy efficiency. More the indicator decomposes energy use in detail, better is the estimation of energy efficiency.

The introduction of *level* of analysis helps to identify the precision of energy efficiency assessed. Analysis at a macro level can only provide a broad assessment of energy efficiency where structural and behavioral components are not isolated. Analysis at more micro levels allows for much deeper disaggregation and uncovers far more information. The different effects that are affecting energy use needs to be clarified at each level of analysis to better understand the effects that remain alongside with the energy efficiency assessed.

The construction of meaningful energy efficiency indicators resides in understanding how energy is used and what are the main drivers. Therefore, the first step is to identify the sub-sectors or end uses that use energy intensively. The second step consists in recognizing the structural transformation, often linked to economic development, which results in significant alteration on the way energy is consumed. For example, the migration of population from rural to urban areas has significant effect on the energy consumption. Urban households have generally much higher demand for energy services. This assumption is explained by the fact that people living in urban areas are wealthier and have access to more energy services than the rural population. Hence, an increase in energy use per household in the residential sector is not due to decreases in energy efficiency but to urbanization.

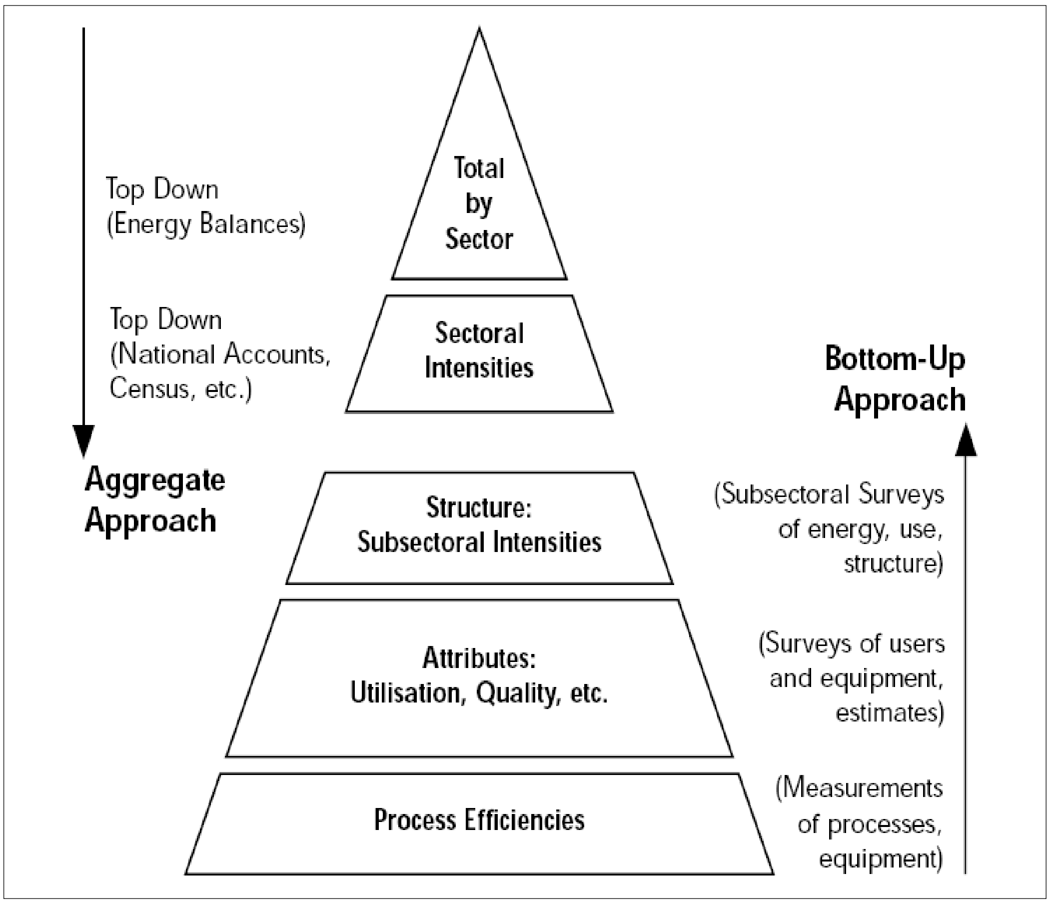
Overview of Energy Efficiency Indicators

The exercise of developing indicators meaningful to an economy's strategy to monitor energy efficiency is a complex task. This next section discusses the main points that need to be taken into account.

Level of Analysis

As mentioned earlier in the literature review, the introduction of a pyramid of energy efficiency indicators allows for identification and organization of the different indicators that can be constructed. This section reviews the different levels of analysis from a macro to a micro level. Estimates of energy efficiency improve as the level of analysis becomes more detailed.

Figure 1.Energy Efficiency Indicator Pyramid



Source: Schipper, 1997

As explained in Shipper (1997), the pyramid diagram in Figure 1 shows schematically how the most detailed data and aggregate indicators can brought together. The bottom of the pyramid represents extreme desegregation while the top displays an aggregate result. The pyramid thus portrays a hierarchy of energy indicators. It also shows the bottom-up approach and the top-down approach. The top down approach looks at energy consumption at the economy wide and sectoral level while the bottom up approach is based on detailed data. Conceptually, the two methods converge; however, the bottom approach is the result of much deeper desegregation and uncovers far more information. The bottom up approach is composed of several rungs in the pyramid and each descent requires more data, but also brings the analyst closer to what s really energy efficiency. Top-down and bottom-up are finally brought together by matching bottom-up totals to higher level data.

At a macro level, construction of indicators implies the use of economic ratios, defined as ratios between energy consumption, measured in energy units (Terajoules (TJ)), and indicators of economic activity, measured in monetary units at constant prices (gross domestic product (GDP), value added, etc.). The economic ratios, referred to as *energy intensities (*Energy Consumption per $ GDP or $ PPP), are used to measure energy efficiency at a high level of aggregation, that is, at the level of a whole economy or of a sector. However this indicator can be misleading as other forces than energy efficiency affect the energy intensity of GDP, such as structural and activity effect. The development of an index based on disaggregated intensity at the subsector level helps to avoid these shortcomings and allows for better measurement of energy efficiency trends.

At a subsectoral level, techno-economic ratios are calculated at a disaggregated level by relating energy consumption to an indicator of activity measured in physical terms (tonnes of steel or number of passenger-kilometers) or to a consumption unit (e.g. per vehicle or dwelling). Physical ratios, or *unit consumption*, are calculated at a disaggregated level (by sub-sector) by relating energy consumption to an indicator of activity measured in physical terms. Depending upon the way data are collected and maintained in different economies, these indicators are developed on an annual basis and for different sectors, fuel types, and sub-regions (within countries).

At a micro level, technical ratios are calculated by process or for end-use devices by relating energy consumption to an indicator of activity measured in physical terms, e.g., tonnes of steel or number of passenger-kilometers that are specific to the provided energy service. For example, in the sector of passenger transport, a disaggregate analysis will be able to show how size and weight of vehicles have caused an increase in energy consumption. As a general rule, the closer the analysis is to a micro level, the more effects can be revealed.

Intensity versus Efficiency

Energy efficiency indicators are related, but not equivalent, to the inverse of energy intensities, since an increase in energy efficiency helps reduce energy intensity. The boundary between energy efficiency indicators and energy intensities depends on the level of analysis. Energy efficiency, in the sense of energy efficiency isolated from all other effects, can generally only be measured by energy intensity at the equipment level (e.g., the energy efficiency of a refrigerator or a car). In more aggregate level, decrease in energy intensity is used as a proxy for efficiency improvements. At the level of the aggregate economy or aggregate sector, energy intensity is a less meaningful concept to estimate energy efficiency because significant factors other than energy efficiency improvement contribute in shaping total energy consumption. These changes may be structural, behavioral, or they may be due to exogenous factors such as the weather. For example, when the share of the service sector of an economy increases as opposed to the industry sector, energy intensity per unit of total GDP for the all economy tends to decrease. However, his trend is not due to energy efficiency improvements but rather to structural effects resulting from the fact that the service sector requires much less energy per $ of value added than the industry sector. Hence, in this case, the reduction of total energy consumption is not due to energy efficiency improvements but to structural effects.

Physical versus Economic

When output is measured in physical units, an estimate of physical energy intensity can be defined (e.g., TJ / tonne). Economic energy intensity, on the other hand, is calculated using dollar value output measures (e.g., TJ/Gross Domestic Product in $). Physical-activity indicators are often preferred because they do not include the monatary fluctuaction and have a closer relationship with technical (process) energy efficiency (Nanduri et al., 2002; Phylipsen et al 1998; Worrell et al., 1997). Another reason is the fact that physical indicators improve comparability across counties. A tonne of steel produced is closer to a tonne of steel produced in another country than the market value ($) of tonne of steel.

However, in some cases defining physical energy intensity proves to be difficult, and even inadequate. For example in the textile sector, where the output is heterogeneous and quality is an important energy driver, the measure in tonne or yard of textile does not reflect the driver of energy consumption. In that case, only physical indicators at a more disaggregate level are sufficient to parameterize energy intensity.

Primary Energy

Energy is generally measured in final terms and stands for the energy used under the form it is delivered. It can include primary or secondary forms of fuel. Primary forms includes energy as embodied in natural resources (e.g., coal, crude oil, sunlight, uranium) while secondary forms cover energy contained in products or carriers resulting from the transformation or conversion of primary energy. Secondary energy products mainly consist of electricity, petroleum products and different coal products. The main purpose of secondary energy production is to convert primary form of energy into more useful energy products. However this conversion results in considerable energy loses. About a third of the energy supplied in the world is lost during the process of converting primary energy into secondary energy, most of which due to the production of electricity(IEA, 2007b; de la Rue du Can and Price, 2006).

Hence, consuming one terajoule of electricity is not equivalent to the consumption of one terajoule of natural gas or coal. The energy consumed represents additional energy consumption due to the amount of energy expended upstream in the production of the electricity. Depending on countries and accounting methodologies, primary energy input per unit of electricity is between one to three times the final energy value (de la Rue du Can and Price, 2006).When comparing energy use between different entities, it is recommended to calculate energy consumption in primary terms by adjusting final energy consumption and adding energy lost in the generation, transmission, or distribution of the energy. Energy efficiency indicators expressed in primary term are more adequate for comparing overall energy requirements; In general, it is good practice to provide results in terms of both final and primary energy and to clearly indicate the accounting methods chosen to calculate primary energy for electricity produced from non fossil fuel.

OECD Country Experiences

Since the 1980s, governments around the world have been increasingly aware of the needs of energy efficiency indicators to measure the performance of energy-related policies. Energy intensity indicators are used for monitoring purposes and, increasingly, as a basis for policy-making. This section describes several national and international examples that show how energy efficiency indicators have been constructed to respond to this need.

IEA

In 2007, the International Energy Agency (IEA, 2007c) published its latest report on the development of energy efficiency indicators in IEA countries, which extends the analysis presented in "Oil Crises and Climate Change: 30 years of Energy Use Analysis" (IEA, 2004). This publication provides to policy makers many important insights about current energy use patterns that will help shape priorities for future action. It draws on detailed end use information from manufacturing, household, service and transport sectors of 20 IEA countries over the period 1990-2004[2]. Over the last 10 to 15 years, fruitful discussions, publications, and official statistics covering dozens of countries have emerged from the work on energy efficiency indicator conducted at the IEA (1997a, 1997b, 1998, 1999, 2000a, 2000b, 2004; 2007a, and 2007c).

When analyzing energy end-use developments, the IEA indicator approach distinguishes between three main groups of indicators: sectoral activity levels, structure (the mix of activities within a sector) and energy intensities (energy use per unit of sub-sectoral activity). Depending on the sector, *activity* is measured either as value-added, passenger-kilometers, tonne-kilometers, population, or built area. "*Structure*" divides activity further into industry branches, transportation modes, or measures of residential end-use activity. Table 1 gives an overview of the various measures used for activity, structure and energy intensities in each sector analyzed in the IEA Indicator Project.

[2] For a complete review of previous work, see Schipper at al, 2001.

Table 1. Summary of variables used in the IEA energy decomposition methodology

Sector (i)	Sub-sector (j)	Activity (A)	Structure (S_j)	Intensity ($I_j = E_j/A_j$)
Residential				
	Space Heating	Population	Floor area/capita	Heat*/floor area
	Water Heating	"	Person/household	Energy/capita†
	Cooking	"	Person/household	Energy/capita†
	Lighting	"	Floor area/capita	Energy/floor area
	Appliances	"	Ownership‡/capita	Energy/appliance‡
Passenger Transport				
	Cars	Passenger-km	Share of total p-km	Energy/pass-km
	Bus	"	"	"
	Rail	"	"	"
	Domestic Air	"	"	"
Freight Transport				
	Trucks	Tonne-km	Share of total t-km	Energy/t-km
	Rail	"	"	"
	Domestic Shipping	"	"	"
Services				
	Total Services	Value added	(not defined)	Energy/GDP
Manufacturing				
	Paper & Pulp	Value added	% Value Added	Energy/Value added
	Chemicals	"	"	"
	Non-metallic Minerals	"	"	"
	Iron & Steel	"	"	"
	Non-Ferrous Metals	"	"	"
	Food & Beverages	"	"	"
	Other	"	"	"

* Adjusted for climate variations and for changes in the share of homes with central heating systems.
† Adjusted for home occupancy (number of persons per household).
‡ Includes ownership and electricity use for six major appliances.

Source: Schipper, 2001

To separate the effect of various components over time, the IEA uses a factorial decomposition where changes in energy use E can be described by the relation that has come to be known as "***ASI***,":

$$E_i = A_i * \sum S_j * I_j \qquad (1)$$

In this decomposition:

E_i represents total energy use in a sector

A_i represents overall sectoral activity (e.g. value-added in manufacturing),

S_j represents sectoral structure or mix of activities within a sub-sector *j* (e.g. shares of output by manufacturing sub-sector *j*),

I_j represents the energy intensity of each sub-sector or end-use *j* (e.g. energy use/real US$ value-added).

IEA, 2003

The effect of each component is calculated by comparing actual energy consumption to the case in which that component is held constant. For example, the impact of energy efficiency improvements on the total energy consumption is estimated by holding constant the energy intensity from the base period and letting the other components fluctuate. This type of analysis is called the ***Laspeyres Index*** method. The strength of the Laspeyres index method is the ease of understanding of the underlying concept. Over the years, problems with this method have been pointed out, specifically due to a significant residual component in some cases (Ang and Liu, 2007). Recently, a shift toward the use of more refined mathematical methods can be observed among different organization and national government. The main methods includes: Modified Fisher ideal index method, Arithmetic mean Divisia index method (AMDI), Logarithmic mean Divisia method I (LMDI I), and the Logarithmic mean Divisia method II (LMDI II). Ang (2004) provides a thorough review of the different approaches that can be used and exposes the pros and cons of each.

Results of decomposition are summarized in a graph where actual and hypothetical energy use are shown side by side, the difference being the energy reduction resulting from energy efficiency improvements after factoring out the activity and structural effects. Hypothetical energy use represents the energy that would have been necessary if no energy efficiency improvements had been made. This representation has the merit of being very explicit.

European Union

Starting in 1992, the French Agency for Environment and Energy Management (ADEME) lead the European SAVE project on energy efficiency indicators in collaboration first with 12 national agencies augmented to 26 agencies today (Bosseboeuf et al, 1997, Ang, 2006). The objective was to develop a permanent structure for monitoring national achievement in energy efficiency. A common database called Odyssee (2005) was constructed and is now regularly updated. The coverage is vast, with approximately 600 indicators of energy efficiency for 27 countries dating back to 1973. However, the level of representation varies across countries, with indicators only available at an aggregate level for some countries.

The database contains standard energy efficiency indicators based on economic and physical variables, but also some more innovative indicators that are directed to summarize results from bottom-up indicators. An energy efficiency index is calculated based on bottom up outcomes on energy efficiency improvements from each subsector or end-use. At the level of the economy, an aggregate index is developed to summarize the result in a single indicator. Table 2 provides an overview of the subsectors covered for each sectors as well as indicator unit used. ODEX, the index representing energy efficiency improvement at the level of the economy, is calculated by weighting each sectoral index with the share of each sector in the final energy consumption (26 sectors used: 7 in transport, 9 for households and 9 in industry, 1 in services).

Table 2. ODYSEE Sectoral Index

Sectors	Subsectors	Unit consumption
Industry	Steel, cement and pulp & paper, chemicals, food, textile & leather and equipment good, and 2 residual branches: other primary metals (i.e., primary metals minus steel), other metallic minerals (i.e., non-metallic mineral minus cement)	Expressed in terms of energy used • per ton produced for energy intensive products (steel, cement, and paper) • per unit of production index for the other branches
Residential	8 end-uses/appliances : heating, water heating, cooking, 5 large appliances (refrigerators, freezers, washing machine, dishwashers and TV)	• Heating: unit consumption per m2 at normal climate (toe/m2) • Water heating: unit consumption per dwelling with water heating • Cooking: unit consumption per dwelling • Large elec. appliances: specific consumption per appliance (kWh/year)
Transport	7 modes: cars, trucks & light vehicles, air (domestic), rail, water, motorcycles and buses	• cars: specific consumption in liters/km • trucks & light vehicles : unit consumption per ton-km • air : unit consumption per passenger-km • rail ,water : unit consumption/pkm or tkm • motorcycles, buses: toe/vehicle
Services	No breakdown by building type	• Per floor space • Per value Added

Innovative indicators also include ***Adjusted index indicators*** that have been developed to take into account of differences between countries, such as climate for example. Availability of data for some countries also influences the development of alternative sectoral index indicators that are slightly less disaggregated but cover more countries. The increasing need to monitor energy efficiency policy has led ADEME to develop indicators that track the penetration rate of new standard and labeling programs. ***Diffusions indicators*** monitor the diffusion of energy efficient equipment and practices and allow an estimate of the energy savings resulting in the implementation of EE policies. ADEME has also developed ***target indicators*** to be set up, for each country target or benchmark in comparison to countries with better performance. Finally, ***CO_2 indicators*** are calculated to complement the energy efficiency indicators.

United States

The US Department of Energy (DOE) began to analyze energy efficiency in detail in 1993 and published its first comprehensive report on the development of robust energy efficiency indicators for each of the sector of the US economy in 1995 (EIA, 1995). This report was not intended as a definitive statement, but rather, as a means of describing the issue surrounding energy efficiency and its evaluation for the US economy. In parallel, DOE published a report describing energy efficiency trends in the US economy as a whole and for each end use and sector. This analysis was conducted by the Pacific Northwest National Laboratory (PNNL) and Oak Ridge National

Laboratory (ORNL) by developing measures of energy saved in each sector and discussing structural changes. In 1997, the EIA organized an influential workshop on the subject of Energy Efficiency Indicators that gathered experts and stakeholders from a broad spectrum to debate approaches to follow in measuring energy efficiency in the US for each sector (EIA, 1996).

More recently, as part of a national priority for improving energy efficiency, the DOE's Office of Energy Efficiency and Renewable Energy (EERE, 2003) has established a new national system of indicators to track changes in the energy intensity over time. The system employs a hierarchal structure in which indices are calculated at lower levels and then used to generate aggregate indexes for higher levels. The Logarithmic mean Divisia method II (LMDI II) approach is used to decompose changes in energy use into components of total activity, economic structure and energy intensity at each component level. Table 3 shows the hierarchical structure, with the most aggregate representing the economy as a whole and the most disaggregated extended to level 5 in the transport sector. When energy is measured in final energy (i.e. excluding electricity generation and transmission loses), a separate electricity generation sector is also considered by EREE (EREE, 2003).

Table 3. Structure of US Energy Intensity Indicators

Sectors	Sub-sectors Level 1	Sub-sectors Level 2	Sub-sectors Level 3	Sub-sectors Level 4	Activity
Industry	Manufacturing Non-Manufac.	21 NAICS[5] Sectors			GDP
Residential	Northeast Midwest South West	Single-family Mobiles Home Multi-family (2-4 Units) Multi-family (> 4 Units)			m^2
Services					m^2
Transport	Passenger	Highway	Personal vehicles	Automobiles Light duty trucks	Passenger -miles
			Buses		
		Air	Scheduled carriers General aviation		
		Rail	Urban rail		
			Intercity rail	Commuter rail Heavy rail Light rail	
	Freight	Trucking	Single unit Combination		Ton-miles
		Pipelines	Natural Gas Petroleum		
		Air			

Source: EREE, 2003

For each subsector or component level, two indicators are calculated; an aggregate energy intensity indicator and a component-based energy intensity index. The aggregate energy intensity indicator is simply the total energy used divided by activity for that level. The component-based energy intensity index is computed based upon aggregation of the individual component energy intensity weighted with each component share of energy consumption. EREE used the analogy to the Consumer Price Index to illustrate how the index is calculated. As for the CPI, the component-based energy intensity index is calculated relative to a year of reference and represents the best estimate of the energy efficiency improvement over the period considered for the subsector studied. In the system of energy intensity indicators developed by EREE, the difference between the aggregate energy intensity indicator and the component-based energy intensity index is regarded as a measure of structural change (EREE, 2003).

Canada

Canada's National Action Program on Climate Change requires the development of energy efficiency indicators to monitor progress. In 1996, Natural Resources Canada (NRCAN, 1996) published its first publication on the subject and analyses the factors that have caused changes in energy demand in Canada. The analysis isolates the effect of activity, structure, weather, and energy intensity. In 2009, the twelfth annual review was published. Over the years, better data coverage and methodology modifications have occured. In 2006, the technique used to separate factors influencing energy demand was revised to use the Logarithmic mean Divisia method I (LMDI I) methodology (NRCAN, 2006). Recently, the method was further revised by incorporating a rolling base year and by redefining various structural levels (NRCAN, 2009).

The publication also includes the OEE (Office for Energy Efficiency) energy efficiency index which provides a single index of sectoral energy efficiency, adjusted for structural changes in the economy and weather, for five sectors. Table 4 shows the detail of analysis available for each sector. The report deals mainly with final energy use (called secondary in the report), but also calculates primary energy use and relates to it in its analysis.

Table 4. Definitions of Activity and Structure Used in NRCAN Report, by Sector

Sector	Sub-sectors		Activity
Residential	Household Services appliances (8) : refrigerator, freezer, clothes washer, electric and gas dryers, electric and gas ranges, dishwasher water heating		Number of households
	Floor Space Services space heating (8): normal, mid- and high-efficiency furnaces, electric baseboard heaters, heat pumps, coal, dual wood and propane furnace system space cooling (2): room air conditioners and central air conditioners lighting		m²
Commercial	Schools Retail Health		m²

	Accommodation and Restaurant Religious Recreation Other Institutions Wholesale (warehouse)	Space Heating, Equipment, Cooling, Lighting, Ventilation, Water Heating	
Industrial	mining (3) construction (1) forestry (1) manufacturing (35) 5 of which desegregated into 19 sub categories		Value Added, and tones and liters where possible
Transportation	Passenger Road (4): Motorcycles & Mopeds, Large Cars, Small Cars, Light-Duty Trucks Bus (3):Intercity, Urban Transit, School Rail Air Freight Truck (3): Less than 3.8t, 3.8t to 15t, Greater than 15t Rail Marine		Passenger-kilometers tonne-kilometers
Agriculture	n.a.		GDP

New Zealand

The Energy Efficiency and Conservation Act of 2000 mandates the Energy Efficiency and Conservation Authority (EECA) to monitor and review the state of energy efficiency in New Zealand. Moreover, in 2001, the National Energy Efficiency and Conservation Strategy (NEECS) of New Zealand set a national target of 20% improvement in energy efficiency by 2012. Lermit and Jolland (2001) published a report to assist the Energy Efficiency and Conservation Authority (EECA) responsible for monitoring progress against the NECCS 2001 targets. The report recommends to check progress through a national energy efficiency index, based on a set of bottom-up sectoral indicators. The indices track changes in energy efficiency and factor out other variables such as changes in activity levels or the mix of outputs from each sector. The factorization method recommended is the Logarithmic mean Divisia method II (LMDI II). The report also recommends developing indicators that measure the responsiveness to policy implement to improve energy efficiency.

Reaching the current New Zealand target of a 20% improvement in energy efficiency by 2012 would now require an annual improvement closer to 2.5% (EECA, 2006). The reports specified that measurement with the economy-wide energy efficiency target raised significant questions about the target's usefulness. An update of the energy strategy now specifies sectoral targets.
The latest energy efficiency progress report was published in Marsh 2009 and uses decomposition analysis to assess energy efficiency progress over the last 6 years. The factorization employed not only isolate the effect of structural, activity and energy intensity change like in other OECD, but it also look at the quality effect. The quality effect is defined as changes in total energy use due to fuel switch. For example switching from a high quality fuels (e.g. electricity) to a low quality fuel (e.g.

coal) would result in more energy being used overall to achieve the same outcome and this factor captures that (EECA, 2009).

Developing Countries Characteristics

As mentioned earlier, meaningful energy efficiency indicators are based on the capacity of identifying the factors that influence energy use and hence in understanding trends in energy use. The social-economic dynamics affecting energy use in developing countries are amplified by rapid change in living standards. The process of economic development involves a number of changes, including higher agricultural productivity, growth in the energy intensive industries, increasing demand for basic infrastructure such as roads, railways, buildings, power grids, etc, urbanization, and increase in mobility needs. Higher standard of living also leads to expansion in the ownership of appliances. All these changes have profound impacts on the amount and types of energy used. This section will describe some of the structural characteristics of a developing economy as well as some differences in socio-economic aspects with OECD countries.

Economy

The Informal sector

A distinguishing feature of developing economies is the importance of unregistered, untaxed or unregulated activities. The term 'informal sector' is used to denote small units working in the production of goods and services but whose activities are not recorded, protected or regulated by the public authorities. The informal sector is also sometimes referred as 'traditional', 'unorganized' or 'unregistered'. A wide range of activities from street vending, shoe-shining, food processing and other activities requiring little or no capital and skills to activities involving some amount of skill and capital such as tailoring, repair of electrical and electronic goods, and taxi drivers in the informal sector (Kolli, 2006). According to existing estimates, it is not unusual for the informal sector to account for over half of GDP and employment in low-income nations. The informal sector represents an important part of the economy in many countries, especially developing countries, and thus plays a major role in accounting for the activity.

The representation in term of energy efficiency indicators of these activities is challenging, as little data are collected concerning their activity and their energy consumption. Moreover, this sector includes very heterogeneous activities and is difficult to analyze without classifying them. Generally, a move toward a decrease of the informal activity in a subsector denotes a shift toward a more consolidation in the sector. It is difficult to make quick judgment about the consequences of organization to energy use: organization can mean a more efficient use of energy but also an increase of the automization of processes. Therefore, it is only at in analyzing subsector trends that one makes an argument for the consequence of organization on energy use.

Socio-demographic Aspects

Rural/Urban split

In developing countries, the distinction between urban and rural households is critical as the pattern of energy consumption differs significantly between urban and rural households. People living in urban areas are wealthier and have a higher standard of living than the rural population. Hence, urban households have a higher demand for energy services than rural households.

Migration of population from rural to urban areas constitutes a major structural factor in the change in energy consumption in developing countries.

Residential Floor Space

The construction aspect of household conditions how energy is consumed by the residential sector. In developed countries, the growth in per household floor space is one of the major drivers explaining increase in energy consumption (IEA, 2007c). As the average dwelling area rises in IEA countries, this puts upward pressure on per capita space heating. In warmer climates, however, floor space may be of less importance as a driving force of energy consumption. Space cooling can be explained by diffusion rate of equipment such as fan or room air conditioners which eliminates the need for data on floor space. However, it is important to consider household size as an important driver of energy use.

Biomass energy consumption

In developing countries, traditional fuels such as wood and charcoal are widely used for cooking, water heating, and in some case, space heating. With economic development, a move from low-quality fuels, such as traditional biomass, to more convenient and efficient fuels, such as kerosene, coal, oil, gas and electricity is often observed. This shift of fuel results in significant energy savings when looking at the overall final energy consumption. The main reason is that the transformation of biomass fuel wood, the form of biomass most often used, into useful energy is highly inefficient. Fuelwood requires about 10 times more energy to cook a meal than natural gas. Hence, fuel shifts in the residential sector can explain trends in total energy consumption. The development of energy efficiency indicators needs to reflect these trends.

The assessment of cooking and water heating in the residential sector can be based on a useful energy demand analysis[3] which helps to represent the energy needed by a household to cook and boil water independently of the type of fuel used. Final energy consumption is converted to useful energy demand by taking into account fuel efficiency.

B. The Challenge: Data Collection

The construction of energy efficiency indicators is a very data-intensive process. If we consider the energy efficiency indicator pyramid shown in Figure 1, a greater amount of data are needed as the analysis level becomes more disaggregated. Data available at a level of an energy balance are necessary to develop indicators at level 1 but generally not sufficient to develop indicators at more disaggregate levels. Collections of data based on surveys and energy modeling complement energy balance data and are used to get a more detailed picture of how energy is consumed in a country. Data necessary to construct energy efficiency indicators come from diverse sources. Many come from non-energy sources, that is to say statistics representing the economic activity and social aspects. This section identifies different schemes employed to collect data which can be helpful to developed energy efficiency indicators.

Activity Data

Measuring the underlying structure and magnitude of activities for which energy is used is an

[3] Useful energy is the energy available to the consumer after equipment conversion losses.

essential step in developing disaggregated energy indicators. Activity data can be collected through national accounting systems, censuses and surveys representative of the entire country. In some countries, a single agency is responsible for all national statistics, while in others the task is split among multiple agencies each of which collect official statistics related to their field. In these cases ministries may have their own statistics departments and can provide statistics on their field. Associations of industries also collect data on the industries represented in their association and can provide informative data.

Economic Activity

The most common variables to measure the activity that drives energy are the Gross Domestic Product (GDP), employments, commodities production and floor space.

National Accounts

Every country measures the size of its economy through national accounting. Generally, data on activity output is gathered from taxes received and questionnaires sent out to companies throughout the country. However, some enterprises are not registered in tax offices and are hence are not subject to the standard process. Hence, when using national accounts, attention should be given to the unregistered sector which often plays a major role in the country economic activity and certainly of the labor market, especially in developing countries.

The most common way of measuring the economic activity of a nation is the Gross Domestic Product (GDP). GDP is defined as the value of everything that is produced in an economy during a year. Total GDP can be broken down by sectors and subsectors and are more commonly refereed as sectors and subsectors value added.

To look at trends in GDP across years, GDP needs to be adjusted for inflation, so that changes in prices are eliminated and only change in production activity are accounted. GDP adjusted for inflation is called **real** GDP (as opposed to nominal, unadjusted GDP). The most common method of computing real GDP is the base year method. Real GDP is then reported in fix price for the base year chosen.

Moreover, two different methods exit to convert GDP in a common unit for country comparison. Either real GDP is converted using market exchange rate (MER) or using **purchasing power parity (PPP)**. The idea is that PPP conversion factors equalize the purchasing power of different currencies by eliminating the differences in price levels between countries. It is calculated based on the comparison of prices of a basket of goods and services between countries. PPP conversion factors are used to lessen the misleading effects of shifts in a national currency due to monetary policy and give a better estimate of the living standards.

Commodities Production

The production of commodities is the main driver of energy use in energy-intensive industries. Energy-intensive industries include industries that use large quantities of fuel and electricity to produce raw material (e.g., iron and steel, chemicals, petroleum refining, cement, aluminum, and pulp and paper). Data on production of commodities in physical terms are collected by means of questionnaires that also contain data in monetary terms. Problems pertaining national account also affect industrial commodity statistics. However, alternative sources of data are available. For example, national or international industries associations also gather comprehensive data on their members' output. These associations have sometimes even more detailed information. For example, the International Institute of Iron and Steel (IISI, 2007) collects detailed data concerning this industry, such as technology penetration and process output production.

Floor Space

Commercial and industrial floor space data are sometime collected through the taxation local office through properties taxes. However, since these data are often recorded at the local level gathering them for the whole country in a comparable and meaningful way can be a challenge.

Social Activity

Population

Population statistics are collected through censuses, sample surveys, and administrative records. The population and housing census is the primary source of information about the size of population, its geographical distribution and the social, demographic and economic characteristics of its people. Census data are based on a complete count of the whole population, and population and housing censuses have been carried out in almost every country of the world. However, they are expensive and time consuming. Therefore, population censuses are typically conducted in intervals of 5 to 10 years.

Along with the census, household sample surveys are a key source of statistics in many countries. They can provide a wealth of information on many aspects of household housing condition and consumer goods ownership. For example, the government of India conducts remarkable recurring household surveys on consumption of important commodities[4] which allows estimation of the diffusion of appliances as well as car and moped ownership by income class. These household surveys provide critical statistical information on the socio-demographic and cultural aspect of the population and housing situation, thus enabling thorough analysis of the living conditions. Household surveys often provide the average number of person per household in urban and rural areas which allows a calculation of the total number of households. Also, the number of square meters per household is frequently surveyed, which allows for an estimation of the total square meter of residential housing floor space.

Transport Activity

Passenger-kilometers and **tonne-kilometers** are good indicator of transport activity and are the main energy demand driving force. However, these indicators are not directly collected but results of bottom up computation. Passenger-kilometers and tonne-kilometers are calculated by multiplying the stock of vehicles organized by mode and types, the quantity of persons transported in the case of passenger travel and tonnes carried in the case of freight and kilometers traveled. This task requires an extensive data investigation, since load factors and efficiencies of cars and other forms of passenger transport are difficult to monitor.

Statistics on the **stock** of motor vehicles in circulation in a country can be collected through several organizations. Motor vehicles in use are generally registered by official licensing authorities. Details on the type of vehicles and fuel type are also gathered. Once these basic data are stored, further data during

[4] Report No. 461(55/1.0/4) "Consumption of Some Important Commodities in India 1999-2000" NSS 55th Round (July 1999 – June 2000) National Sample Survey Organisation. Ministry of Statistics & Programme Implementation. Government of India, July 2001

the rest of the vehicle's active life are generated when the vehicle is re-licensed, sold, or scrapped. However, it happens that the stock constituting the registered cars includes cars that have been retired from the circulation in the case where no systematic procedure allows retiring cars no longer in use. Hence, statistics need to be carefully analyzed to assess if retirements are also taking place and in a realistic manner. In the absence of an institutionalized car registration system, alternative data can be gathered from domestic sales of motor vehicles available from vehicle manufacturers and importers. The actual number of motor vehicles in use is calculated in the same statistic, by correcting the sales by type of vehicle with a retirement rate.[5] An alternate source consists of household's surveys that inquire household ownership of bicycles, motorcycles or cars. These data can be used to broadly estimate the level of private vehicle in circulation. However, little information is generally available on the types of car owned which is a serious limitation, as the rapid growth of larger vehicles and vehicles with air conditioning contributes to the overall evolution of transport energy consumption. Moreover, this type of survey does not provide information on vehicles used by businesses or government and requires finding other statistics to account for these vehicles. A combination vehicle sales data and surveys can provide a better estimate of motor vehicle stock.

Compiling and processing **traffic data**, such as the average kilometer traveled by motor vehicles in circulation as well as load factor constitute a challenging task. Traffic data are generally tracked for regional planning operation and maintenance of road, as well as for policy makers. The collection of these data is very important to identify the structural drivers of energy consumption. IEA countries have experienced a steady increase in car-kilometers per capita as personal consumption expenditure increase. This stems from the fact that people travel further and faster as they grow richer (IEA, 2007). Traffic data are estimated through two means: traffic counts and surveys. Traffic counts are the most basic type of data collected and involve counting vehicles passing a point for varying intervals of time either manually or automatically ways. Traffic counts are used to determine vehicle kilometers of travel. Vehicle occupancy or load factors, which refer to the number of persons in each vehicle, including the driver, are collected manually by field observers and statistical methods are used to provide average estimates. Surveys consist in gathering information through questionnaires either by phone or mail from the owner of the vehicles. For example, the Canadian Vehicle Survey (CVS) is a voluntary vehicle-based survey that provides annual estimates of road vehicle activity (vehicle kilometers and passenger-kilometers) of vehicles registered in Canada. The estimates are provided by type of vehicle and other variables, such as driver and vehicle characteristics, time of day and season. The survey consists in selecting a random sample of registered cars and in contacting the owner to fill out information about their transport habits. Data from the vehicle's odometer is collected at the beginning of the first day and last day of the survey as well as the quantity of fuel purchased over the time of the survey (CVS, 2007).

Community transport constitutes an important source of mobility in many countries, especially in developing countries. Often comprehensive information, including data on flows of passengers and goods, as well as on infrastructure, equipment, traffic, and mobility are monitored at a national level. Air and marine transport are challenging modes to consider as domestic and international traffic needs to be separated. The reason for that necessary split is that only domestic transport

[5] The active life of a car tends to be longer in developing countries than in developed countries.

competes with other modes inside a country. Hence, the structural modal changes needs to take into account change in domestic transportation.

Influence of Weather

Weather is a main driver of energy consumption. A cooler year in a warm climate region will reduce overall energy consumption, as the demand for space cooling will be reduced. However, this should not be considered as an energy efficiency improvement, but rather as a weather influence. Weather variation can be accounted by calculating cooling degree-days (CDD) and heating degree-days (HDD). HDDs and CDDs are measures of how cold/warm a location is over a period of time relative to a base temperature, most commonly specified as 18 °C (65 °F). Heating degree days are summations of negative differences between the mean daily temperature and the 18 °C base; while cooling degree days are summations of positive differences from the same base. Thus, a day with an average temperature of 10 °C will have 8 degree heating days, and a day with an average temperature of 29 °C will have 11 degree cooling days. For both heating and cooling degree days, the average temperature of a particular day is calculated by adding the daily high and low temperatures and dividing by two (Baumert and Selman, 2003). Heating and cooling degree days are used in energy analysis as an indicator of heating and cooling energy requirements or use.

Base temperatures are often set at 18 °C (65 °F) but can vary across countries. The base temperature is the outside temperature above which the building does not require heating or cooling. Inappropriate base temperature can lead to inaccuracy in estimating weather-dependent energy usage. Moreover, it is important to take into account the base temperature selected for each country when comparing indicators across countries.

Energy Balance

Overview

An energy balance is a key primary source of data to construct energy efficiency indicators for several reasons. First, because energy balances concentrate all flows of energy including the so called non-commercial sources into a table with a single common unit. It is a great tool to have a first understanding on what and how energy is consumed in a country. Generally, in order to construct an energy balance, outstanding issues concerning reconciliation of data from different sources must have been pursued and a good estimate of all energy consumed performed. The results of an energy balance over several years are a very useful input to the construction of energy efficiency indicators.

Source of Data

The main source of energy data pertaining to energy balances come from the energy supply industries (including importers). Historically, energy supply industries have often been regulated and state owned. This organization facilitated the collection of data since it was only necessary to investigate a single company in order to obtain information on produced and dispatched energy. However, market liberalization requires the establishment of a national data collection system that covers multiple enterprises. This collection of data is generally performed through questionnaires sent to the companies that produce and/or supply energy products.

Tracking data on energy products production is relatively simple compared to tracing consumption to end use sectors and subsectors. On the other hand, energy efficiency indicators are primarily based on looking at how energy is consumed in final sectors. Hence information on end use consumption is very important in developing energy efficiency indicators. The consumption of electricity and natural gas supplied through pipes are generally metered with measuring devices placed at the building/establishment site. In this case, gathering detailed information about consumption for industrial or commercial subsectors is relatively straightforward. Nonetheless, some countries have sectors for which electricity consumption is not metered. This is the case of the agriculture sector in India, where consumption in this sector used to be estimated as the difference between metered (non-agricultural) consumption and total electricity delivery, after estimating distribution loses. Metered consumption is generally a reliable source, but theft of electricity can occur, leading to misleading metered consumption. In this case, further analysis is necessary to better estimate the real consumption from each end user. Other factors are sometimes necessary to take into account from data provided by energy supplied statistics. For example, in China, energy used by employees for residential and transport purposes are accounted in the industry sector where their company belong. A re-allocation is then necessary.

Dispatch of coal and petroleum products to final consumers is more difficult to track. Sales to end consumer are not always broken down by type of end users. For example, when a LPG gas bottle is sold in a shop or from a truck in a village, there is no report on who bought it and for what purpose. This bottle can be used by a household to cook meals for a family or by an owner of a restaurant to cook meals for his customers. In some countries, energy data collected from energy suppliers are supplemented with data collected through questionnaires sent to final consumers, as will be explained in the next section.

Finally, non-commercial fuel consumption is the most challenging energy product to get a handle on, as no information from suppliers is available. Most of the time the production and distribution of biomass fuels do not pass through the monetized economy. Even if they do, they remain largely unrecorded. Unlike fossil fuels and electricity, there are no accounts of sales or bills from which data can be derived. Surveys or case studies have to be designed to represent the consumption of biomass. The integration of biomass into national energy planning is very important as it often represents a large share of the household's energy consumption and causes serious environmental problems[6].

Limits

Most of the information that is provided in energy balances comes from top down information, i.e. most of often energy providers. Only so much information concerning end users is known from suppliers, which limit considerably the scope of analysis concerning end use energy consumption. The prime interest in building energy efficiency indicators is to analyze the drivers of energy demand which are generally only visible in the end use sectors. The task of constructing an energy balance is a daunting one and necessary for the energy strategy planning of a country. The next step is to link this aggregate consumption with activity variables to show consumption patterns

[6] Indoor pollution and land degradation Smith et al., 2000

over time and the following step is to bring the level of analysis a step deeper to identify the drivers of energy demand.

Representative Sample Surveys

Representative sample surveys are a key component in constructing meaningful energy efficiency indicators. The statistics derived from energy supply information does not provide any detail on how the energy is consumed once it gets to the final consumers. Only surveys on the consumer side can help explain what the drivers of final energy consumption are. Consumption surveys typically gather information on the types of energy consumed by end users, along with the characteristics of those end users that can be associated with energy use. Surveys are based on a scientifically selected random sample from a population. Data for the population is obtained by extrapolating the sample size to the total population. Often census data are used as a reliable surrogate for extrapolating survey data to national statistics.

For example, the US Energy Information Administration (EIA) conducts 3 major consumption surveys: the Manufacturing Energy Consumption Survey (MECS), the Residential Energy Consumption Survey (RECS), and the Commercial Buildings Energy Consumption Survey (CBECS) (Table 6). MECS estimates energy use for 21 3-digit industry subsectors, and 48 industry groups (NAICS). The type of data collected includes number of employees, number of establishments, physical characteristics such as floorspace, equipment, etc; purchased fuel consumed including share of non fuel used for non-energy purposes; energy produced onsite, inputs of energy for heat and power cogeneration; and finally the survey also collects information on energy management activities. The RECS survey collects data on housing unit characteristics, appliances, household characteristics, types of fuels used, and other information that relates to energy use, such as the number of loads of laundry per month, the temperature setting for clothes washer, hours of lighting in use, etc. Finally, CBECS collects information on the stock of U.S. commercial buildings, their energy-related building characteristics, and their energy consumption and expenditures.

Table 5. US EIA Energy Consumption Surveys

Form #	Title	Respondents	Universe
EIA-846	MECS 2009	15,500	26,000
EIA-871	CBECS 2007	7,448	4.8 million
EIA-457	RECS 2005	9,430	97 million

The data collection of MECS consists in sending a mandatory questionnaire while the technique for RECS and CBECS is voluntary and also includes retrieving data from third parties. For example, RECS data are collected from three sources: in-person interviews with householders of sampled housing units, mailed questionnaires or telephone interviews with rental agents for sampled rental units, and mail questionnaires from energy suppliers who provide actual energy consumption and expenditure data for the sampled housing unit.

Statistics issued from these surveys are used by policy decision makers at the Federal, State, and local levels. The data provides critical data into EIA's National Energy Modeling System (NEMS) which is used as a guide in government planning for the future energy needs of the U.S.

These types of survey are conducted in many developed countries, generally through government statistics offices. However, in some cases these surveys are performed by private or semi-private companies. For example in France, CEREN—a semi-public institute conducts energy surveys at a very detailed level. In California, Pacific Gas and Electric Company, the largest utility company in the state, conducts surveys to determine reliable estimates of the end use characteristics related to electricity and gas consumption in PG&E's residential, commercial and industrial sectors.

Assembling all of this into a coherent picture is not easy. Energy consumption related to different end uses, e.g. space heating, lighting and services from household appliances are generally not directly measured through household surveys. Metering each end use for each households surveyed would be costly to achieve, and considerably difficult to put in practice. End use energy consumption are generally obtained by estimating how much of the total annual consumption for each energy source can be attributed to each of the end-use categories for each household, based on that collected through households surveys and by using a regression technique. Model of residential energy use will use physical building and appliance characteristics as well as socio-demographic factors to describe the energy consumption patterns and some of the energy services.

Sales and New Construction

Data collection on sales of new equipment that meets energy efficiency standards or label programs constitutes key input in evaluating energy efficiency programs. For example, quantitative studies evaluate the sales-weighted efficiency trends of appliances and compared these trends to the prevailing levels before implementation of government efficiency programs. This allows for evaluation of policy impacts. Yearly data on the sales volume and average retail prices of individual appliances needs to be collected. Some market research companies collate data on sales by label class. From these data, it is possible to make an evaluation of impacts of energy efficiency programs (CLASP, 2006). Test procedures (sometimes referred to as "test standards") are the foundation for energy-efficiency programs and provide a consistent definition of technical (equipment) efficiency.

Similarly, to measure the impact of building construction codes to changes in the average unit consumption of buildings, it is necessary to account for the number of new constructions compared to the existing building stock. High construction rates increase the penetration rate of more efficient building in the stock. It is also important to conduct surveys to estimate the level of compliance with building codes.

Expert Judgment

In some countries, methodical surveys that provide all the information necessary to estimate energy use at the most disaggregate level are not available, but some level of information is known. Energy experts who have a great deal of experience in the field of conducting energy analysis at the micro level can provide reasonable estimates that can be used as provisional sources of data. For example, in the case of transport, traffic counts or surveys that help estimating load factors and kilometers traveled by car are rarely available. However, it is possible to estimate these data by looking at values from other countries with similar profiles and possibly scale the data to reflect the level of traffic in the country studied. This leads to some uncertainties that can be estimated by giving a range of possible errors that bound the sensitivities. The use of expert judgments allows filling data gaps when no surveys are available. They often prove to be valid estimates. In any case, the method to proceed is to clearly describe each step of the estimations performed in a most transparent manner as possible.

Consolidation of activity as well as energy statistics at the national level is daunting task, even more so for large countries. However, the need to understand how energy is consumed and for what end use is essential to assess, measure and monitor energy efficiency improvements. Statistics are the backbone of strategic planning.

C. Application of Energy Efficiency Indicators

Energy intensity indicators are constructed to measure the energy and fuel impacts from changes in activity, structure and intensity. They help to better understand and assess how economic and technical driving factors, such as energy prices, gross domestic product (GDP) and new technologies, shape energy use and ultimately CO_2 and other emissions. They can be used (1) for historical trend analysis, (2) for benchmarking, (3) to design policy and monitor progress overtime, and (4) as input to economic and technological models. These applications are described briefly below.

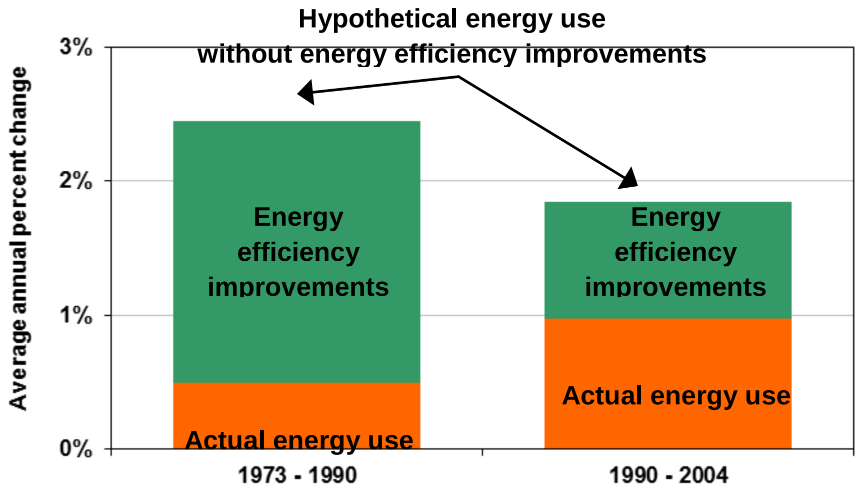
Decomposition Analysis

There are several factors that influence changes in energy consumption such as:

- *Change in level of activity*: a decrease in the level of material production can diminish the level of energy consumption,
- *Structural modification of the activity*: a change in the industrial production mix from energy intensive industries to light (or less-energy-intensive) industries can reduce energy consumption,
- *Fuel substitution*: a change from the use of energy to labor or other factor inputs can reduce energy consumption,
- *Energy intensity/efficiency*: improvement in energy efficiency will reduce energy consumption.

To separate the effect of various components over time, a factoral decomposition is necessary in which changes in sectoral energy use are analyzed in terms of sectoral / sub-sectoral activity, sectoral structure, and energy intensity of each sub-sector. The methodology combines data on energy use with data describing activities that drive energy demand to form selected energy indicators for the different sectors of the economy.

Figure 2. Impact of Energy Efficiency Improvements on Final Energy Use, IEA-11



Source: IEA, 2007

Figure 2 presents one of the key finding from a recent IEA publication (IEA, 2007). Using energy indicators, the publication analyzed the evolution of energy consumption in IEA countries for all sectors - manufacturing, residential, services, personal travel and freight transport.

The red area shows the average annual growth rate of energy consumption between 1973 to 1990 and from 1990 to 2004. During the period 1973 to 1990, energy consumption grew at an average annual growth rate of 0.4%, while it grew at an average rate of almost 1% between 1990 to 2004. The green area shows how much energy has been saved due to energy efficiency improvements. This aggregate result is based on a bottom up approach that estimates energy efficiency savings for each sector described in section B.4.1. The aggregate result allows policy makers to quickly see the relative impact that energy efficiency has had on energy consumption. One major conclusion is that, since 1990, the overall rate of energy efficiency improvement in IEA countries has been less than 1% per year. This is much lower than in previous decades and is not enough to stem the growth of CO_2 emissions. Had the earlier rate of efficiency improvement been sustained, there would have been almost no increase in energy consumption in the IEA. The good news is that the hypothetical demand for energy without efficiency improvements is lower after 1990 than preceding periods.

Benchmarking

Energy intensity indicators allow comparison of energy performance with international practice to evaluate level of performance and to identify industry best practice values. They are useful indicators for energy management because they can be used to develop relative measures of energy performance, track change over time, and identify best energy management practices. An assessment of the potential for energy savings can then be carried out.

Figure 3 shows international comparison of process used in steel production for 7 countries. It points out the importance of considering the type of process used in a country when making comparisons. For example, looking only at energy use per unit of steel produced leads to the conclusion that Venezuela and Indonesia are the most efficient compared to India and China. However, Indonesia and Venezuela only produced secondary steel based on scrap material, while India and China mostly produce primary steel. Producing primary steel is a much more energy intensive process than producing it from recycled steel. Countries like China and India produce large quantity of steel every year and do not have access to large quantity of scrap, which is highly dependent on foreign ship breaking.

Figure 3. 1995 Cross Country Comparison

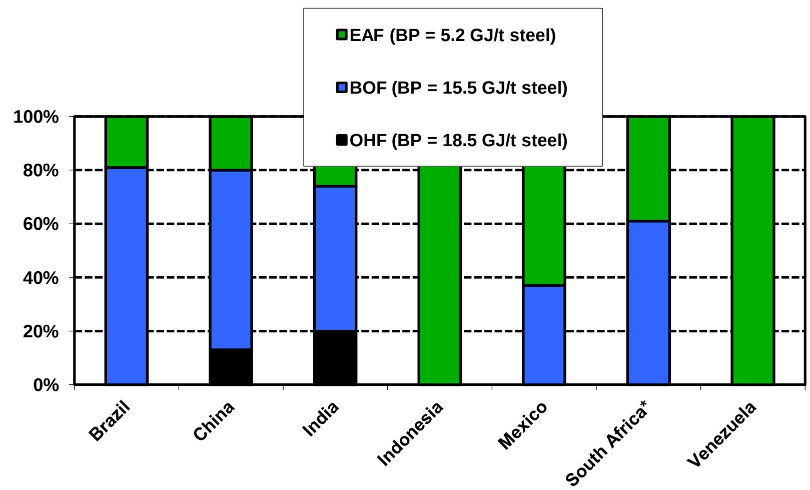
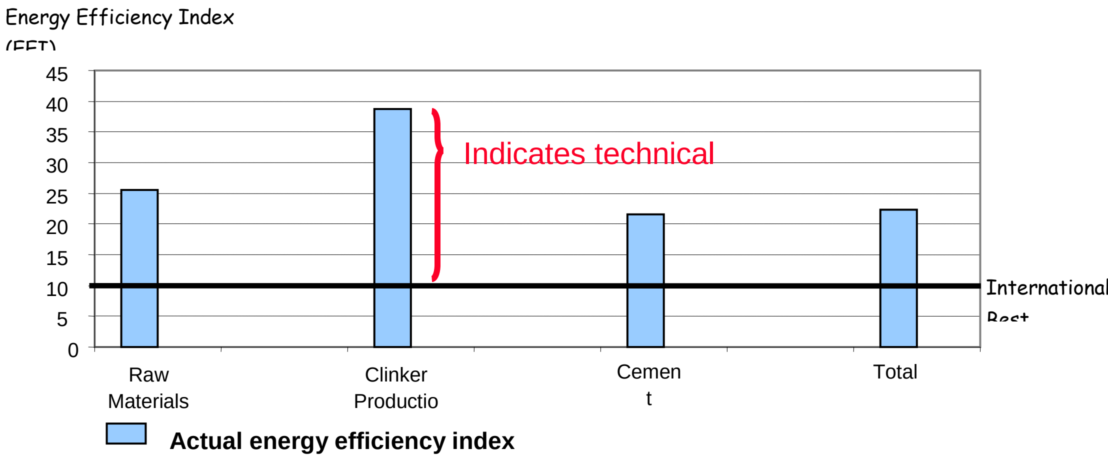


Figure 4 shows how energy efficiency can be used to conduct benchmarking at the plant level. Benchmarking consists in calculating physical energy intensity at the process level and comparing it with international best practices. On this graph, best practices have been set to 100 for each process and a hypothetical plant is compared to that index. The energy use exceeding the index represent potential energy savings that can be achieve using international best practices.

Figure 4. Plant Benchmarking



Policy design and progress monitoring

Development of EEI is a great tool that allows a country, region or city to construct an energy strategy plan in a very transparent manner. It gives the possibility to compare alternative policies and to monitor progress over time. The separation of aforementioned influences on energy use is critical for policy analysis, since most energy-related policies target energy intensities and efficiencies by promoting new technologies. Energy intensity indicators can be used to better inform decision makers. In-depth indicators provide “state-of-the-art” data and analysis of energy use, efficiency improvements and policy pointers. They help identify best practices and indicate potential for efficiency improvements and appropriate policy approaches to realize that potential. Tracking changes in indicators allows decision makers to monitor the progress of their projects and policies.

Figure 5. Refrigerators Unit Energy Consumption (UEC)

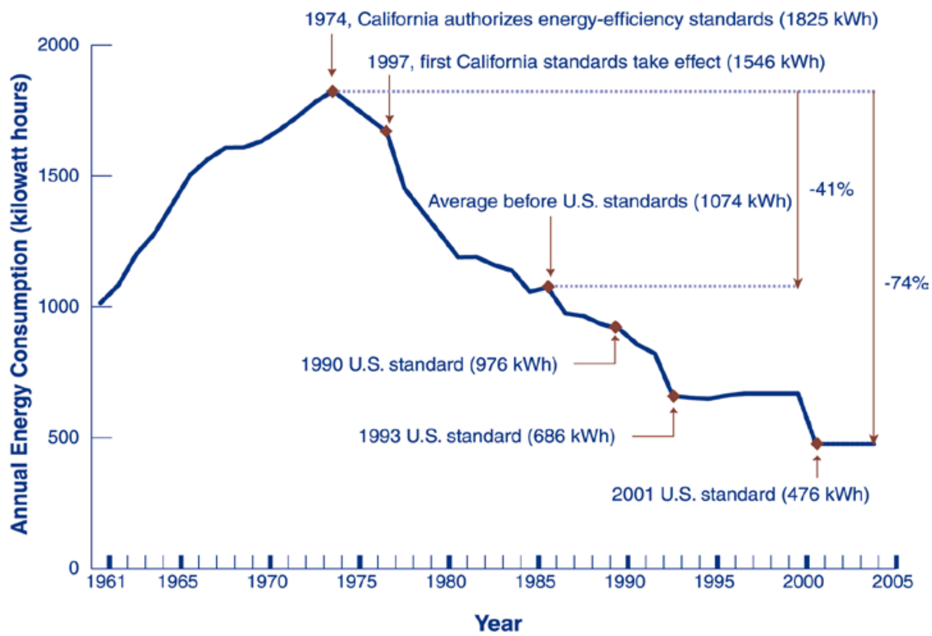


Figure 5 shows a very well-known graph in the energy efficiency community in the US. It shows how unit of energy consumption of refrigerators has been reduced over time thanks largely to implementation of minimum efficiency standards and labeling programs. Over the last 30 year, UEC has been reduced by 73%.

Figure 6. Avoided Electricity Consumption – Mexican Minimum Efficiency Standards

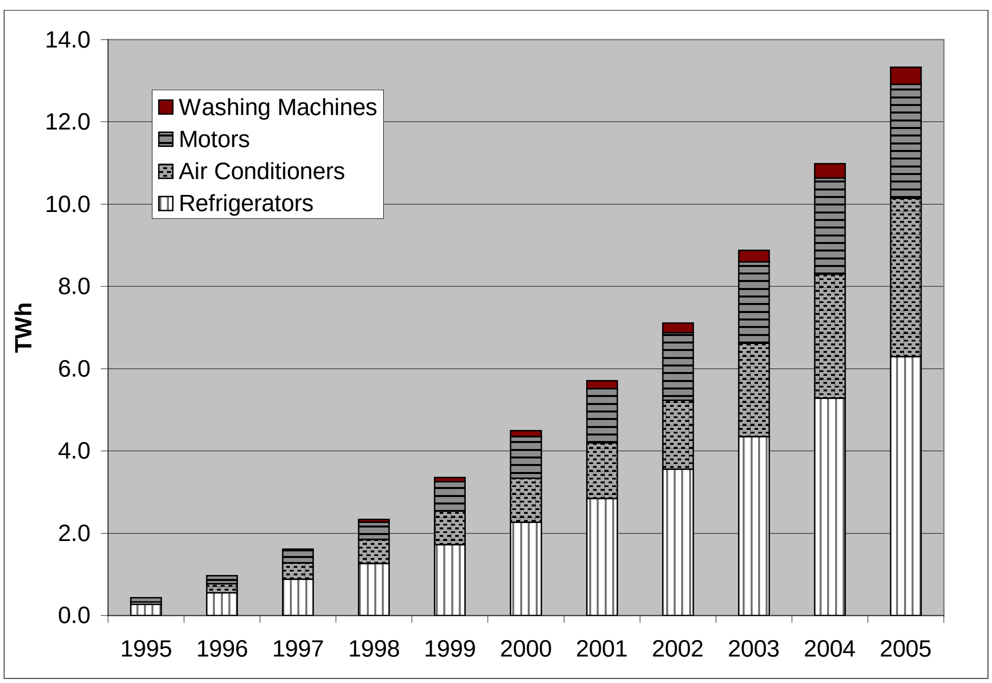
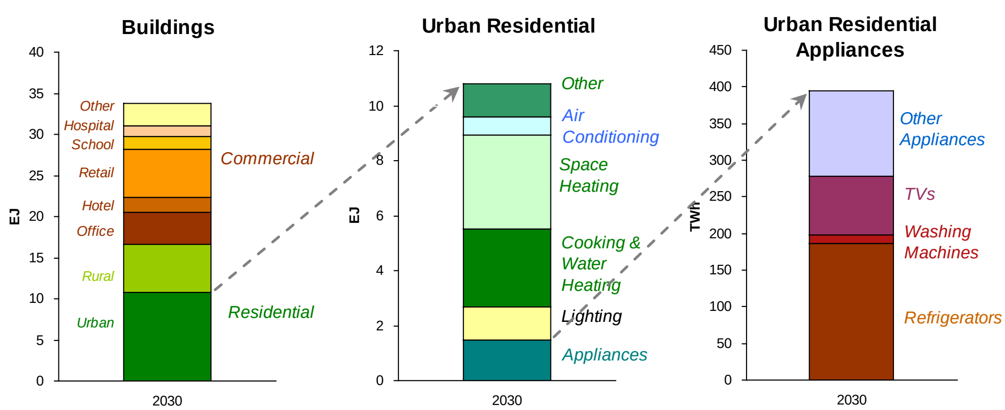


Figure 6 shows how energy efficiency indicators can be used to track policy impacts over time. In 1995, Mexico has implemented minimum efficiency performance standards (MEPS) for 3 major appliances and motors. This has results in considerable electricity savings that energy efficiency indicators have allowed analysts to estimate.

End Use Modeling

End-use sector-level information regarding adoption of particular technologies and policies provide key inputs in bottom-up scenario modeling. A bottom-up approach helps ground policy choices to the efficiency and saturation levels of specific technologies.

Figure 7. Modeling End Use Analysis



Energy efficiency indicators are a valuable input to scenarios forecasting exercises. In 2000, the IPCC published a set of energy scenarios based on top down models. Little information was available on the type of assumptions describing energy efficiency. Only total energy per GDP was available for use in that study. The detail concerning results in energy consumption was also very limited; only total energy use for the transport, industry, and total building being available.

LBNL conducted an analysis to disaggregate the top down results of the IPCC scenarios for China for the buildings sector to more meaningful results by using a bottom up approach. The buildings sector was split into building types. Figure 7 shows an example of urban residential buildings. Energy consumption was then separated into end uses, and within the end uses, by equipment types. Figure 7 includes the example of urban household refrigerators. The analysis then further decomposes the energy consumption by efficiency class. This type of analysis allowed an assessment of the implied technology trends in a top-down forecast. One of the main findings is that the top down scenario under-estimates electricity consumption relative to the bottom-up scenario, or implies an efficiency improvement of over 2% annually (Price et al, 2006).

II. Energy Efficiency Indicators by Sector and by Level

Energy efficiency indicators combine data on energy use with data describing activities that drive the demand for energy services into explanatory indicators that can be used by analysts and policymakers to better understand energy efficiency trends. An essential step in the development of energy efficiency indicators is to determine the underlying structure and level of activities for which energy is used. However, a comprehensive data set representing the whole economy is not always available, and obtaining such data over a period of time long enough to allow trend analysis is often a challenge. Hence, this section describes energy efficiency indicators through different levels of analysis that can be undertaken depending on data availability.

Table 7 provides a hierarchy of energy efficiency indicators and associated data sources, limitations, and applications. The most aggregate indicators are the Level 1 macro-level indicators and the most disaggregated indicators are the Level 3 indicators based on a breakout of major end uses. The more disaggregated level requires detailed data and more complex analysis but also provides for more powerful analysis of trends for planning and policy making. Level 3 often requires that surveys are conducted to estimate technology penetration and its unit energy consumption (see A.II.3).

Table 6. Hierarchy of Energy Efficiency Indicators

Level	***Description***	***Energy Data Source***	***Possible Assessment***	***Application***
0	Macro-level	Energy balance	Limited analysis possible	All countries
1	Minimal detail	Energy balance	Analysis of the sectoral contributions to energy use and Separation of structural effect for industry	Countries w/ limited sectoral data
2	Moderate detail	Energy balance	Some separation of structural effect	Countries w/ sectoral data
3	Breakout of major end uses	Energy survey/ End use modeling	Complete separation of major structural effects	Countries w/ surveys and end use modeling

It may not be possible to construct energy efficiency indicators for all levels for all years. However, it is recommended that energy efficiency indicators be developed at the most detailed level possible depending upon the data availability. The detailed indicators can then be compared with indicators at a more macro level. It may be necessary to develop indicators at different levels for different sectors. Furthermore, in the case where data are difficult to gather, priority should focus on gathering data for two years separated in time, and not necessarily filling out data for every year.

The following sections describe the different indicators that can be constructed for each sector. The sections also provide information on the purpose and target of the indicator, advantages and limitations of the indicator, if the indicator can be used for cross-country comparisons, and the data needed to construct the indicator.

Information on socioeconomic and energy data needs be collected for sectors including:

- residential,
- commercial,
- industry,
- transportation, and
- agriculture

The energy transformation sector, which records the energy spent upstream to produce cleaner and more convenient fuel, also needs to be covered. However, the types of indicators that can be developed are somewhat distinct and represent the energy lost in the transformation process.

The next sections describe the treatment of various sectors at different levels of analysis. While the equations themselves are conceptually simple and represent only a moderate level of detail, supplying and organizing the information needed to run these equations for even a few countries requires considerable effort.

D. Whole Economy Indicators

Analysis of the energy efficiency performance of an economy at the aggregate level is very complex because structural effects shaping the way energy is consumed also need to be taken into account. Ratios of energy consumption to gross domestic product (GDP) have been widely used internationally to measure the energy efficiency performance of national economies. However, it is now recognized this ratio is a weak indicator for measuring the technical efficiency of a nation's energy usage.

Indicator 1. Whole Economy Energy Intensity

	Ordinary	Alternative 1	Disaggregated Level
Indicator	TPES/GDP	TPES/GDP PPP	Index or Indices
Definition	GDP Primary Energy intensity: E/GDP	GDP Primary Energy intensity: E/GDP PPP	Sum of Bottom up Analyses
Units	MJ/currency (local or international)	MJ/currency (international) expressed in PPP	%

<u>Target</u>: The ratio of total primary energy use per unit of GDP measures the overall energy consumption to produce a unit of GDP. Some countries have used this indicator to construct a target to reduce the energy intensity of their economy.

<u>Limitations:</u> There are significant limitations to using this indicator for target setting as factors other than energy efficiency, such as changes in structure or weather patterns influence this measure.

Alternative 1: In cross countries comparison, the use of purchasing power parity (PPP) represents a better conversion factor of value of output in a common unit. However, the use of PPP does not solve the problem that GDP is a measure of output too heterogeneous to be compared between countries.

Disaggregated Level: Experiences in several OECD countries have shown that it is possible to develop an alternative indicator or indices of energy efficiency better suited to monitoring progress in energy efficiency improvements. The need to construct an energy efficiency indicator at the level of the whole economy is often desirable so that policymakers can quickly grasp information and understand trends. The development of an Energy Efficiency Index instead of the use of the E/GDP indicator is an alternative approach that reflects disaggregated end use energy efficiency improvement at the level of the economy. Such an index is based on development of detailed indicators from each sector, which is described in the next sections of this report.

E. Transformation of Energy

The transformation of primary energy to secondary energy requires considerable amount of energy (see section A.I.3.4). Final energy consumption represents the direct amount of energy consumed by end user while primary energy consumption includes final consumption plus losses incurred in converting energy resources into secondary energy.

Energy efficiency indicators expressed in primary term are more adequate for comparing overall energy requirements, since they account for both the final consumption of energy and the self-consumption and losses of the energy transformation system.

Indicator 2. Primary Energy factors

	Aggregate Level	**Disaggregated Level**
Indicator	Primary Energy Supply/Final Energy Consumption	Primary Energy supply to electricity Production/Electricity delivered
Definition	Efficiency of production of secondary energy	Efficiency of production of electricity
Units	Factor (E/E)	Factor (E/E)

Target: Primary Energy factors reflect the inverse efficiency of energy conversion occurring in the economy. They are most often calculated for electricity and heat and are derived as the ratio of fuel inputs at power plants to electricity or heat delivered. They are used to observe trend in the efficiency of energy conversion.

Advantages: They are relatively simple to construct and are good indicators of energy efficiency conversion. At the sectoral level, primary energy associated with secondary energy consumption can then be calculated by multiplying the amount of secondary energy consumed in the end-use sectors by these primary factors.

This factor can be calculated for each type of secondary product: electricity, petroleum products, coal products, charcoal, etc.

Limitations: Attention needs to be given to the different accounting rules adopted for primary electricity (hydro, geothermal) as they can false the interpretation of overall efficiency, (see Appendix 1 for a review of different account methodology).

Cross-Country Comparison: This is a relatively simple indicator to construct and can provide a good basis for cross-country comparison of the efficiency of power plants, refineries, pipeline and grid losses, etc.

Disaggregated Level: It is possible to calculate this indicator at a more disaggregate level where only one secondary energy type is considered, such as electricity in this case. They are relatively simple to construct and are good indicators of energy efficiency conversion for a particular type of secondary energy produced.

In general, it is good practice to provide results in terms of both final and primary energy consumption at the end use sectors and to clearly indicate the accounting methods chosen to calculate primary energy for electricity produced from non-fossil fuel.

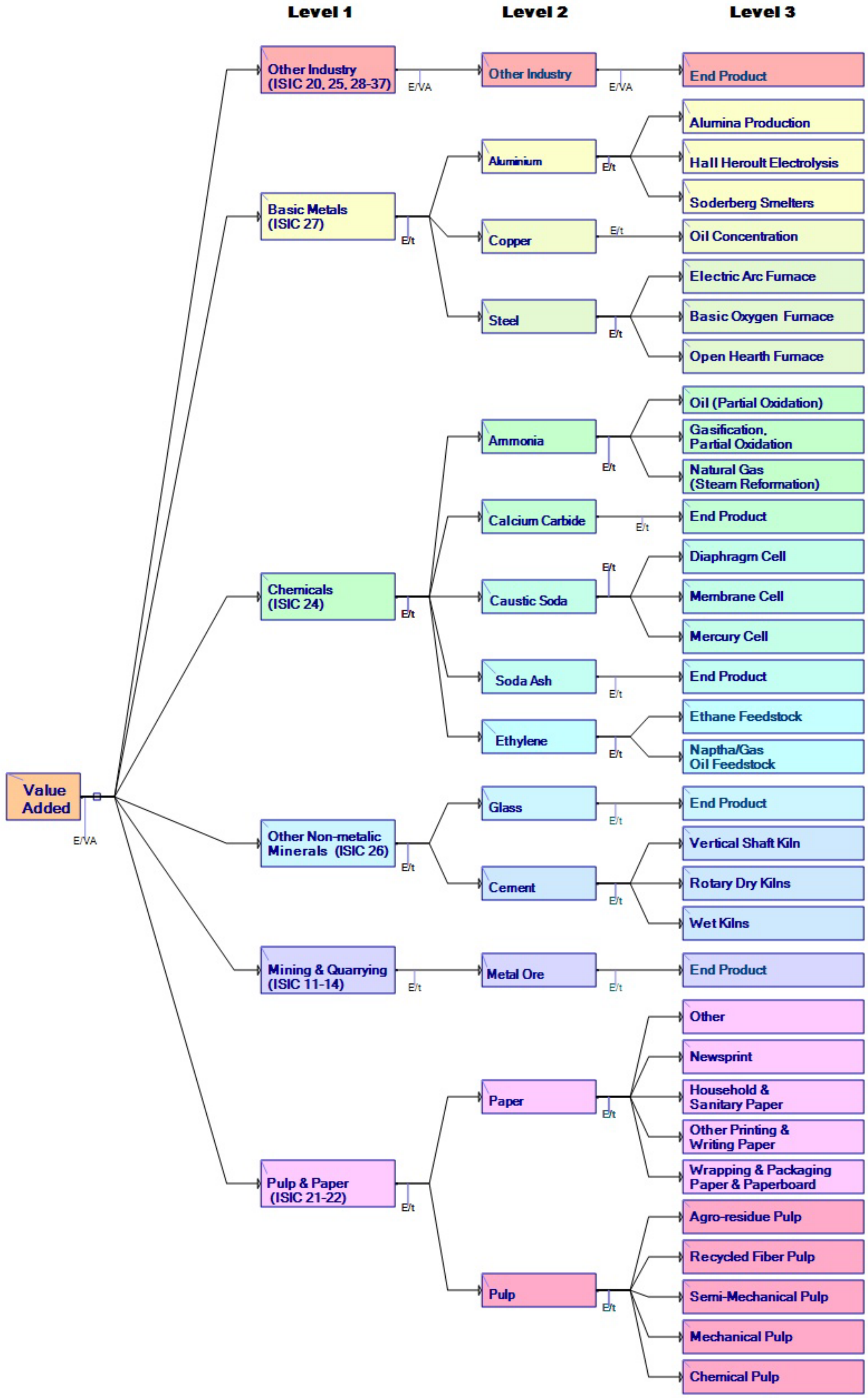
F. Industry

The industrial sector is extremely diverse and includes a wide range of activities. This sector is particularly energy intensive, as it requires energy to extract natural resources, convert them into raw materials, and manufacture finished products. The industrial sector can be broadly defined as consisting of energy-intensive industries (e.g., iron and steel, chemicals, petroleum refining, cement, aluminium, and pulp and paper) and light industries (e.g., food processing, textiles, wood products, printing and publishing, metal processing). Energy intensive industry represents a large share of energy use in developing countries. For example in China, it represents more than half the energy use in industry sector.

The aggregate energy use depends on technology and resource availability, but also on the structure of the industrial sector. The share of energy-intensive industry in the total output is a key determinant of the level of energy use.

Figure 8 illustrates how it is possible to disaggregate energy consumption in the industrial sector into three levels of increasing detail. The first level simply provides energy use per unit of value added for specific industrial sectors, using the International Standard Industrial Classification (ISIC) system. The second level provides more detail, giving energy use per physical unit of production for most industries. The third level accounts for sector-specific technologies and processes that can explain variations in energy intensity. This breakdown allows identification of the largest drivers of energy consumption as well as a better understanding of flows of energy use in the industrial sector. A more detailed understanding of industrial sector energy consumption drivers can assist in developing energy efficiency policies that target the areas of highest energy efficiency potential. Furthermore, energy efficiency performance can then be more easily monitored.

Figure 8. Industry Energy Efficiency Indicators Broken Down by Level



Note: ISIC Rev.3.1, http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=17

Macro – Sector Intensity

At this level, energy use in industry can be analyzed simply by looking at total industry energy use per unit of industrial value added (**economic energy intensity**). If information on energy use is broken out by energy type, then this treatment should be included. Otherwise, a single energy intensity aggregating all energy types can be used. Moreover, value added needs to be expressed in real terms to exclude the effect of inflation variations.

Indicator 3. Industry Energy Intensity

		Alternative
Indicator	E_{indus}/VA^*_{Indus}	Index or Indices
Definition	Industry energy intensity: E/VA	Sum of bottom-up analysis
Units	MJ/currency (local or international)	%

Application: It is a very easy indicator to construct and can be used to observe trends in aggregate industrial energy use per unit of industrial output measured in monetary value.

Limitations: However, this indicator does not identify the sub-sectors which are contributing the most in reducing its value versus the sub-sectors which are driving its increase. Industry value added fluctuates over time for reasons other than the quantity of output produced. More detail is needed to better understand the factors influencing this indicator.

Cross-Country Comparison: E_{indus}/VA_{indus} is a very limited indicator for cross-country comparison due to its aggregate nature and the difficulties comparing economic units between differing economies. PPP can also be used for such comparisons and often then very different results are obtained. However, in both cases, total industry value added comprises too many heterogeneous outputs to allow for meaningful use of the indicator without looking at deeper levels for further explanation.

Alternative: It is possible to construct an index based on bottom up detail by subsectors, such as the one constructed for OECD countries and shown in Section B.I.4. This represents a better alternative to estimate trends in energy efficiency at a sectoral level.

Level 1 – Economic Intensity

Level 1 indicators are calculated for each sub-sector in terms of energy per value added. Such **economic energy intensities** are constructed for the energy intensive sub-sectors and any other industrial subsectors is treated as a remainder.

Indicator 4. Subsector Economic Intensity

Indicator	E/VA* for each energy intensive sub-sector ▪ Mining and quarrying (ISIC 11-14) ▪ Pulp and paper (ISIC 21-22) ▪ Chemicals (ISIC 24) ▪ Non-metallic minerals (ISIC 26) ▪ Basic Metals (ISIC 27) ▪ Other manufacturing – all remaining manufacturing sub-sectors, excluding oil refining. *VA needs to be expressed in real currency level, if possible by using a deflator for a sector or a branch to a base year.
Definition	Subsector Economic Energy Efficiency Indicators
Units	MJ/currency (local or international)

Applications: At this level, it is possible to explain what have been the impacts of energy intensive industries over the total energy use in the industrial sector. This level allows for factoring out the structural effect on energy consumption. The introduction of sub-sectors energy intensity allows for calculation of what the change in the representation of each sector in total energy consumption has for effect on increasing or decreasing the total energy consumption. This indicator can be used to evaluate and monitoring progress of each subsectors.

Advantages: The use of a common monetary measure for all sub-sectoral activity facilitates the decomposition analysis.

Limitations: However, sub-sectors at this level are still aggregates of heterogeneous industries having different energy intensity. For example, the non-metallic sub-sector includes very different sub-industries such as glass, ceramics and cement industries. Moreover, the representation of industrial activity in terms of value added can be misleading due to influence of commodities' price variation.

Cross-Country Comparison: E/VA is a very limited indicator for cross-country comparisons due to its aggregate nature and the difficulties in comparing monetary units between differing economies.

Level 2 – Physical Intensity

A more detailed disaggregation of industry is possible by introducing **physical energy intensities** in terms of energy use per tonne (or other unit) of industrial product produced for a portion of the industrial sector.

Indicator 5. Subsector Physical Intensity

Indicator	E/tonne for each sub-sector ▪ crude steel ▪ paper ▪ cement ▪ ammonia ▪ aluminium ▪ Etc…
Definition	Physical energy intensity: energy per physical unit of output generally measured in tonne
Units	MJ/tonne

Applications: At this level, it is possible to explain what the main drivers of energy use are. The indicators can be used to set specific energy consumption targets, to evaluate trends and monitor progress over time. Also, comparisons with best practice allows for estimating potential energy savings.

Advantages: Change over time represents a more reliable estimate of energy efficiency than economic indicators. Moreover, it is relatively easy to understand the relationship between the amounts of energy needed to produce one physical unit of a product.

Limitations:

1- The representation of output in several different units does not permit an easy aggregation, which constrains the possibility of estimating the structural effect (Farla et al., 1997).

1- For some sectors, the weight of output does not reflect the driver of energy consumption as output is heterogeneous and quality is an important energy driver. This is the case of the petroleum refining industry, where energy use depends on the crude processed, complexity of refinery, as well as the sulfur content of the final products.

Cross Country Comparison: Physical energy indicators allow cross-country comparisons. However, different parameters need to be taken into account to allow better comparisons:

- First, attention must be given to only compare industries with similar outputs. (ref Section B.III.2). Some countries may produce a different grade of the same product, requiring a different level of energy. Also, industries that have a high rate of recycling material have lower energy intensity, as secondary production of materials is less energy-intensive. This is true for the steel, aluminium, and paper industries. Hence attention must be given to identify industries with high rates of recycling when comparing to others.
- Factors such as energy resource endowment can explain observed differences between countries. For example, in China, ammonia energy intensity is relatively high because a large share of its production uses coal as a raw material which requires much more energy than other hydrocarbon feedstocks.
- Moreover, comparisons also need to be done on a primary energy basis; i.e., final energy should be translated into primary energy equivalents by accounting for

losses in power and steam generation. This allows for a better comparison, as energy use in self generation (captive power) is often accounted at the source.

Level 3 – Process Intensity

Disaggregation to account for **structural differences in production and differences in products** is the third level of detail. The introduction of technology penetration allows for better understanding of how energy is used and what are the opportunities to reduce it. For example in the pulp and paper industry, the production of pulp requires significant quantities of energy to break apart wood fibers. Pulping can be performed using chemical, mechanical, or combined chemical-mechanical techniques which require different levels of energy. Utilization of agro-residue and recycle fibers also has different energy requirements. Hence, gathering information at this level of detail allows for a deeper understanding of the mechanisms at play in the overall energy consumption and the potential for energy efficiency.

Figure 8 shows the sub-sectoral break down where information on outputs and energy is needed. Further levels of disaggregation could divide industrial sub-sectors by scale or by phase of production (e.g., raw and finish grinding and pyroprocessing in cement production). For countries or regions where data are available, cross-cutting end uses, such as motor, steam, and compressed air systems could be explicitly represented.

Indicator 6. Process Energy Intensity and/or Technology Penetration

	Process Energy Intensity (PEI)	**Technology Penetration**
Indicator	E/t by process	% share of technology
Definition	Physical energy intensity: Energy per physical unit (PU) of output	Penetration rate of different technology used for each energy-intensive process
Units	MJ/tonne	%

Application: Monitoring and evaluating at this level can prove to be very efficient in setting achievable targets.

Advantages: Analyze at micro level provides very reliable estimate of energy efficiency. Process Energy Intensity (PEI) also represents interesting information for each plant composing a subsector. Technology penetration rate can provide very insightful information to understand energy use.

Limitations: data are very difficult to gather at this level for a whole country.

Cross-Country Comparison: This level of detail allows conducting very meaningful country comparison. It is possible to compare across countries and also with best practices, and estimate energy savings potential.

Data Needed: Data needed needs to be collected through surveys. Propriety data can sometimes be an issue but less so since some countries have been implementing energy efficiency policies requiring monitoring and displaying progress. Moreover, some companies are interested in comparing their performance with current and best practice and so increasingly willing to share their own data.

Technology Penetration Indicator

Technology penetration indicators measure the penetration of energy efficient technologies and practices in a sub-sector. They are good indicators of energy efficiency progress and give valuable information toward assessing the energy efficient performance of a sub-sector. Data on the penetration of different technology in use are usually easier to obtain than the energy use.

Performance toward best Practice Indicator

When process energy intensities are not available, it is then possible to assess the energy efficiency performance of a subsector by comparing its energy use with what would be its energy use if best practices technologies were used at all process level. The IEA (2007a) recently used this methodology and calculated for some subsectors and some countries their performance gap with best practices.

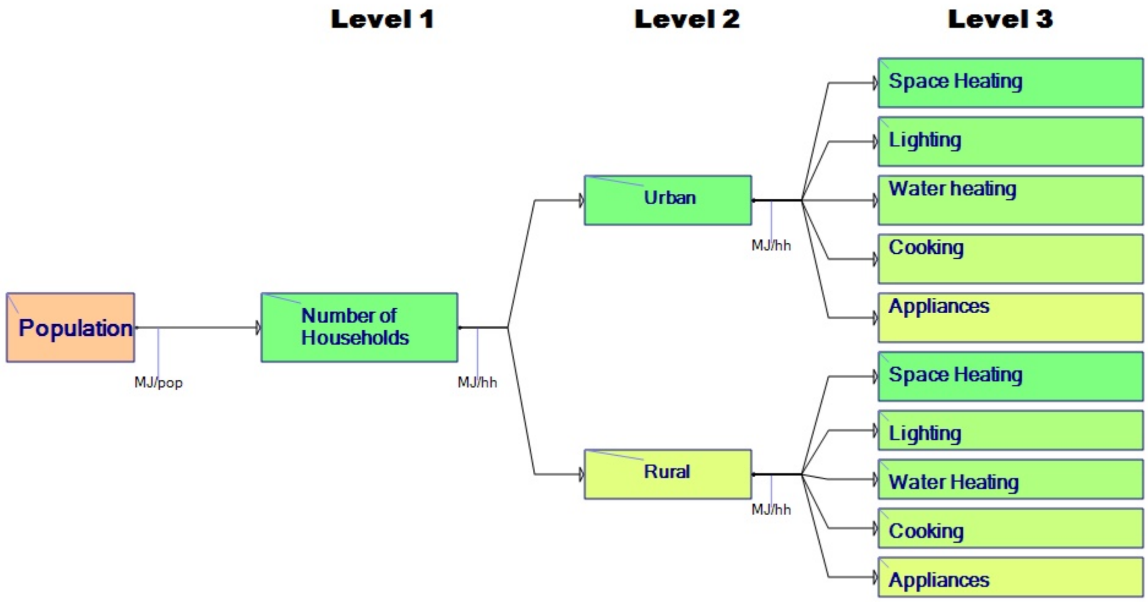
G. Residential

Energy use in the residential sector represents more than one third of global primary energy use (Price et al., 2006). The residential sector is characterized by a striking contrast in fuel use between developed and developing countries. More than half the world's population lives in rural areas, of which more than 90% are in developing countries. The vast majority of this population is dependent upon traditional wood fuel to serve the basic need of cooking and water heating. Hence the share of biomass in the global residential final consumption represents more than 40% in 2006. In developed countries, natural gas and electricity are the most used fuel in residential buildings.

How energy is used?

Energy is used in the residential sector to serve the energy needs of five main end uses. The predominant energy requirements serve the needs of cooking and water heating. Space heating is often an allied services but geographical coverage makes it a much less needed service in developing countries than in most industrialized countries. Lighting and appliances such as TVs, fans and refrigerators constitute fast growing energy use with increasing income. Energy consumption in the residential sector is closely linked to the urbanization rate. Urban households tend to have higher levels of energy needs and hence the migration of rural population towards urban centers increases the level of energy use. In addition, other factors, such as the diminution in household size and increase in housing floorspace represent major drivers of energy demand. For example, a shift toward smaller household size increases the total number of households and hence the number of appliances sold and total energy consumed. Other drivers also influence the level or the type of energy consumed. Electrification level and access to cleaner fuels have a direct impact on rural energy consumption. Evidently, economic development is also an important factor that influences the quantity of services demanded. Figure 9 shows the breakdown of energy consumption in the residential sector by level.

Figure 9. Residential Energy Efficiency Indicators Broken Down by Level



What kind of data is needed?

In the residential sector, activity includes population and households. In countries where urbanization is still an important factor of development which drives the energy use, it is important to split between urban and rural households. The population and housing census is the primary source of information about the size of population, its geographical distribution and the social, demographic and economic characteristics of its people. Along with the census, household sample surveys are a key source of statistics in many countries. They can provide a wealth of information on many aspects of household housing condition and consumer goods ownership. For example, the government of India conducts remarkable recurring household surveys on consumption of important commodities[7] which includes diffusion of appliances by income class.

In terms of energy consumption, data at level 1 and 2 are generally available in energy balances. However, in some countries energy used by employees of some large industrial state companies is sometimes included in the industrial sector. This is the case of China for example. Level 3 requires considerably more detail data that is generally obtained by national energy consumption surveys. Energy consumption surveys typically gather information on the types of energy consumed by end users, along with the characteristics of those end users that can be associated with energy use. Surveys are based on a scientifically selected random sample from a population. Data for the population is obtained by extrapolating the sample size to the total population. Often census data are used as a reliable surrogate for extrapolating survey data to national statistics (see Section B.II for more information).

Macro - Population Intensity

[7] Report No. 461(55/1.0/4) "Consumption of Some Important Commodities in India 1999-2000" NSS 55th Round (July 1999 – June 2000) National Sample Survey Organisation. Ministry of Statistics & Programme Implementation. Government of India, July 2001

At this level, the indicator of energy use is simply the ratio of residential energy consumption divided by population. If information on energy use is broken out by fuel (or energy type), then this treatment can include summing over fuels. Otherwise, a single energy intensity that aggregates all types of energy use may be used.

Indicator 7. Residential Energy Use per Capita

		Alternative 2
Indicator	$E_{residential}$/Population	Index or Indices
Definition	Residential energy use per capita	Sum of bottom-up analysis
Units	MJ/pop	%

Applications: This indicator can be used to observe how residential energy use on a per capita basis is evolving.

Limitation: However, little can be said on the drivers of the trends that can be observed. This indicator does not distinguish the different effects that influence energy consumption and is a poor indicator of energy efficiency, even more so in developing countries where rapid saturation of equipment is driving energy consumption.

Cross Country Comparison: comparison of residential energy per capita between countries reveals the different levels of energy use across countries. However, fuels are not equal due to difference in fuel efficiency. Hence several factors need to be taking into account:

- First, the use of biomass is misleading as its transformation into useful energy is very inefficient. Hence large quantity of biomass energy is required to serve basic energy services, while other fuel type will require much less quantity to serve the same energy services. Therefore, residential commercialized energy per capita, i.e. without including biomass use, is a more meaningful indicator, because it is likely to be more uniform across countries.
- To the contrary electricity is a very efficient energy carrier at the end use level. However, it requires considerable quantity of primary energy to be produced, depending on the primary energy used. Hence, a comparison in primary energy terms allows a better comparison.
- Finally, energy use also depends on climate and variation of climate among countries. These variation across countries need to be taking into account when comparing between countries.

Level 1 – Households Intensity

This level is very similar to the previous one, the macro level. However one adjustment is made to better reflect how energy consumed in the residential sector. Residential energy use is divided by the number of households.

Household size affects consumption associated with energy services such as cooking, heating, cooling, which are shared among household members. For example, in industrialized countries, decreasing household size is one of the main factors that cause an increase in per capita and aggregate energy use in residential sector. The number of households can be obtained by dividing total population with the average number of persons per household.

Indicator 8. Residential Energy Use per Household

Indicator	$E_{residential}$ /household
Definition	Residential energy use per household
Units	MJ/hh

Applications: This indicator allows trend analysis of household energy consumption. It is slightly more meaningful than Indicator 7 as energy use is generally used at the level of household. It is a relatively simple indicator that is easy to understand, and allows estimating the household size effect on energy consumption.

Limitations: This indicator does not separate the different end-uses that affect energy consumption.

Cross Country Comparison: The same limitations applied as for Indicator 7, biomass energy use, primary energy and variation of climate among countries need to be taking into account.

Level 2- Locale Intensity

Urbanization rate is a key driver in residential energy demand in some developing countries. People living in urban areas are wealthier and have a higher standard of living than the rural population and have much better access to modern energy sources. Hence, urban households have a higher demand for energy services and a different end-use profile than rural households. Hence, the second level introduces the rural/urban area split. If data are available broken out by fuel/energy type, then the treatment can sum over fuel types.

Indicator 9. Residential Energy Use per Households

Indicator	E/hh in rural and urban areas ▪ Rural ▪ Urban
Definition	Primary residential energy use per capita
Units	MJ/hh

Applications: Trend analysis, monitoring the rate of penetration of commercialized fuel for rural households. The split between urban and rural areas allows better analysis of how energy is used in a country.

Limitations: At this level, estimation of energy efficiency still remains vague as no detail on equipment penetration is taken into account in this indicator, which could explain rise in energy consumption.

Cross Country Comparison: It is possible to conduct meaningful cross countries comparison at this level. For example, energy consumption in urban households in developing countries can be compared with household energy consumption in developed countries. However, care should be taken over biomass energy, electricity use and climate variations.

Note: the split between urban and rural in countries may not be necessary in the case where the country has a high level of urbanization and energy use in rural and urban households are similar.

Level 3 - End Uses Intensity

Energy use in the residential sector can be further disaggregated. Five major end uses account for most of the energy demand by households: cooking, space heating, space cooling, water heating, lighting and appliance use. Cooking and water heating energy end uses are driven by number of households, while lighting, space heating and cooling energy use are analyzed per square meter of floor space. Appliance energy consumption is observed by the diffusion rate of appliance per households.

Water heating is sometimes considered in a single category with cooking in developing countries due to difficulties in separating them. Space heating use is limited in most developing countries; however some region may need to be studied separately in the case where space heating is an important energy driver. Lighting and services from major appliances such as TV, fans and refrigerators constitute the fastest growing demand when income increases. Space cooling can be represented by treating room air conditioners as appliances, i.e., in terms of diffusion rate and unit energy consumption (UEC). However, in some cases, space conditioning may represent both room and central air conditioners, and the latter should be considered as a separate end use. Table 7 shows detail on a break down by technology.

Table 7. Residential End Use Technology Characteristics

			Diffusion	Capacity	Usage
Appliances	Television		unit/ hh	kW/appliance	hours/day
	Refrigerator		unit/ hh	kW/appliance	hours/day
	Freezer		unit/ hh	kW/appliance	hours/day
	Washing Machine		unit/ hh	kW/appliance	hours/day
	Air-Conditioner		unit/ hh	kW/appliance	hours/day
	Fan		unit/ hh	kW/appliance	hours/day
Lighting	Tubular fluorescent		Bulb/hh	kW/bulb	hours/day
	Compact fluorescent		Bulb/hh	kW/bulb	hours/day
	Halogen		Bulb/hh	kW/bulb	hours/day
	Kerosene lamp		unit/hh	MJ/hh yr	
Cooking/ Water Heating	Wood Stove		unit/ hh	MJ/hh yr	
	Biogas Stove		unit/ hh	MJ/hh yr	
	Charcoal Stove		unit/ hh	MJ/hh yr	
	Coal Stove		unit/ hh	MJ/hh yr	
	Kerosene Stove		unit/ hh	MJ/hh yr	
	LPG Stove		unit/ hh	MJ/hh yr	
	Natural Gas Stove		unit/ hh	MJ/hh yr	
	LPG Water Heater		unit/ hh	MJ/hh yr	
	Natural Gas Water Heater		unit/ hh	MJ/hh yr	
	Electric Water Heater		unit/ hh	MJ/hh yr	
Space Heating	Furnace (forced Air)	Electric	unit/ hh	MJ/hh yr	
		natural gas	unit/ hh	MJ/hh yr	
		kerosene	unit/ hh	MJ/hh yr	
		LPG	unit/ hh	MJ/hh yr	
		other oil	unit/ hh	MJ/hh yr	
	Boiler	Natural gas	unit/ hh	MJ/hh yr	
		Oil	unit/ hh	MJ/hh yr	
		Gas	unit/ hh	MJ/hh yr	
	Electric resistance heating		unit/ hh	MJ/hh yr	
	Heat pump (air source)	Electric	unit/ hh	MJ/hh yr	
		natural gas	unit/ hh	MJ/hh yr	
	Heat pump (ground source)		unit/ hh	MJ/hh yr	
	District heating		unit/ hh	MJ/hh yr	
	Stove/ Room Heater	Wood	unit/ hh	MJ/hh yr	
		Biogas	unit/ hh	MJ/hh yr	
		Charcoal	unit/ hh	MJ/hh yr	
		Coal	unit/ hh	MJ/hh yr	
		Kerosene	unit/ hh	MJ/hh yr	
		LPG	unit/ hh	MJ/hh yr	
		Natural Gas	unit/ hh	MJ/hh yr	
		Electric	unit/ hh	MJ/hh yr	

Indicator 10. Residential Energy Use per Households

Indicator	E/hh by end use in rural and urban areas ▪ Cooking ▪ Water Heating ▪ Space heating ▪ Space Cooling ▪ Lighting ▪ Appliance
Definition	Energy use per household living in urban or rural area for each end use
Units	MJ/hh

Application: At this level, it is possible to use the indicators developed to monitor progress in energy efficiency policy. The partition of energy use by end use allows having a better understanding of the driver of the energy use in the residential sector. It allows setting policy targets and helping construct efficiency programs for appliances and code for buildings in the residential sector.

This indicator dissociates structural changes between the different end uses. Decomposition analysis can attribute changes in total residential energy use to a combination of:

- growth or decline in activity (number of households and/or total floor area);
- changes in structure (the types of energy used for various end-uses, such as appliance or lighting);
- changes in weather (e.g., warmer or colder summer or winter relative to the base year); and
- changes in energy efficiency for each end-use (e.g., the use of more efficient appliances or heating equipment).

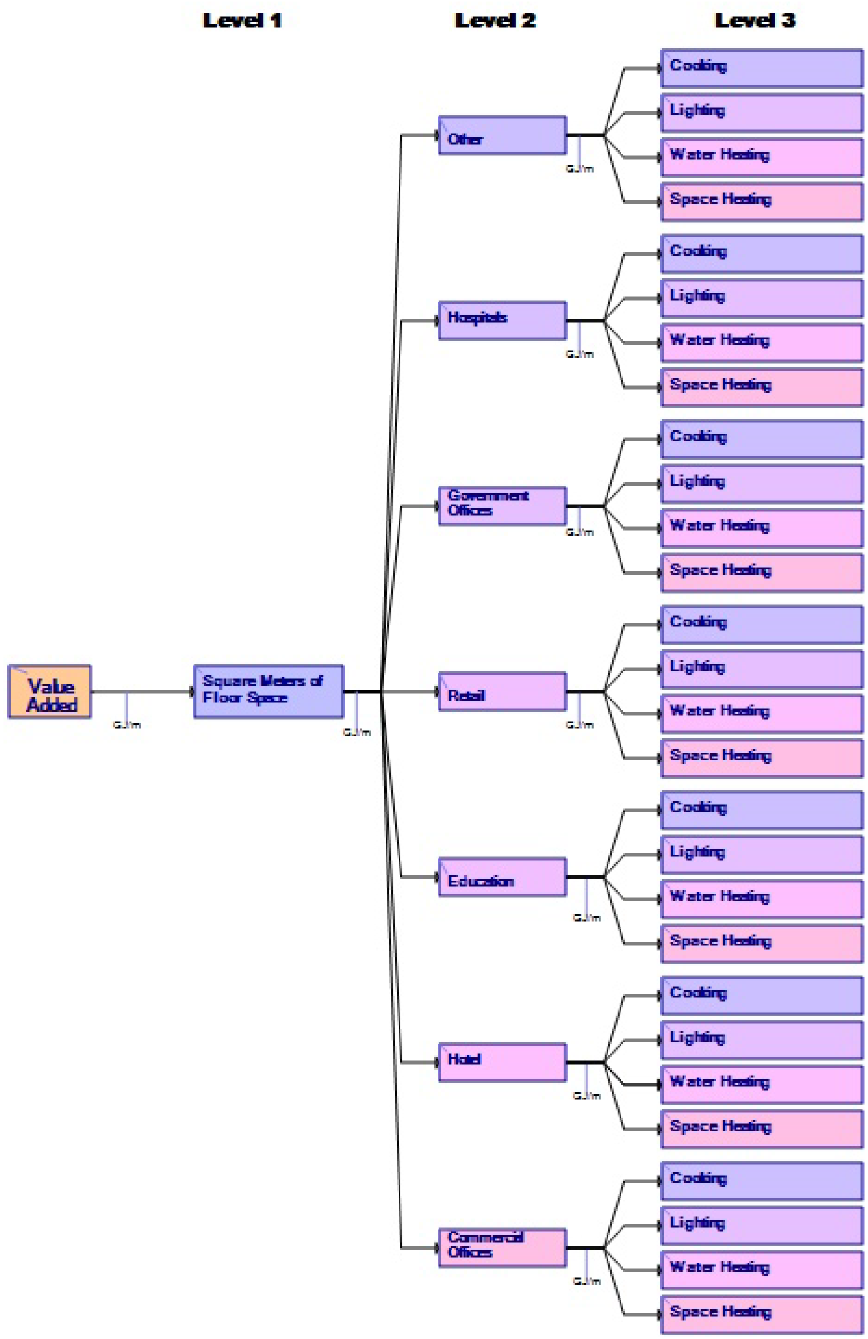
Limitations: End use energy consumption is not directly measurable, and even more so at the national level. Hence, end use energy consumption is always obtained through estimations based on modeling approaches that include detailed data on the way energy is used per households. Data are collected through comprehensive energy surveys that can be costly. Annex 1 shows the type of detailed data needed. Hence, even if level 3 represents the ultimate goal for understanding trends in residential energy use, it requires significant efforts.

Cross Country Comparison: Cross country comparison at this level can reveal interesting facts in cultural differences between countries, energy efficiency practices and the relationship between economic development and energy consumption.

Technology Penetration Indicator: It is not always possible to conduct a complete analysis of the residential sector as described herein. However, it is possible to develop analysis only for one end use or to develop activity indicators that provide insightful information. For example, penetration rate of appliances are very interesting activity indicators of energy demand.

H. Services[8]

Figure 10. Service Sector Energy Efficiency Indicators Broken Down by Level



---

8 ISIC 50 - 99: 50 – 52 G: Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods; 55 H: Hotels and restaurants; 60 – 64 I: Transport, storage and communications; 65 – 67 J: Financial intermediation; 70 – 74 K: Real estate, renting and business activities; 75 L: Public administration and defense; compulsory social security; 80 M: Education; 85 N: Health and social work; 90 – 93 O: Other community, social and personal service activities; 95 P: Private households with employed persons; 99 Q: Extra-territorial organizations and bodies

In developing countries, the services sector constitutes a growing part of the economy both in terms of employment and its contribution to national income. The Sector covers a wide range of activities from the most sophisticated in the field of information and communication technology to simple services such as repair shops or restaurants. This sector also tends to include a large share of the informal sector (see section A.I.5.1.1).

The service sector is less energy intensive than manufacturing in term of value added, and the faster growth of this sector relative to manufacturing can contribute to the long-term reduction in the ratio of total energy consumption to GDP. The service sector is generally characterized by a high level of electricity consumption, globally electricity represents almost half of the total energy use of that sector (47%) in 2005 (IEA, 2007). A significant proportion of energy use in commercial buildings is in space heating and cooling. In countries or regions where the climate significantly influences energy use, energy consumption needs to be adjusted to take account of degree days. The major drivers of energy demand in this sector are building floor area, economic development, and diffusion level of energy using equipment. The most frequently used measure is energy use per value added or square meters.

Macro - Service Sector Intensity

This level refers only to energy use in the service sector per unit of value added. For some regions, it may be possible to break out economic energy intensities by energy type, e.g., by electricity and by a sum of other fuels.

Indicator 11. Whole Service Energy Intensity

		Alternative
Indicator	$E_{service}$/VA	Index or Indices
Definition	Service energy intensity: E/VA	Sum of bottom-up analysis
Units	MJ/currency (local or international)	%

Applications: This indicator can be used to observe how service energy use on a per value of output produced, measured in local or international currency and in real terms, is evolving.

Limitation: However, little can be said on the drivers of the trends that can be observed. This indicator does not distinguish the different effects that influence energy consumption and is a poor indicator of energy efficiency.

Cross-Country Comparison: Cross-country comparison is limited by the fact that value of goods varies across countries.

Alternative: Index indicator based on bottom up detail by building type and/or subsectors.

Level 1 - Floor Space Intensity

Two basic approaches are possible for representation of aggregated physical energy intensities. One is to put intensities in terms of energy use per unit of service floor space, and another is to put them in terms of energy use per employee in the sector.

Indicator 12. Service Floor Area Energy Intensity

		Alternative
Indicator	E/m^2	E/employee
Definition	Energy use per square meter	Energy use per employee
Units	MJ/m^2	MJ/employee

Applications: Both indicators allow trend analysis of energy consumption in the service sector. Energy use per square meter is slightly more meaningful as energy use is generally used at the level of floor space.

Limitations: This indicator does not separate the different end-uses that affect energy consumption. However, data on floor space are difficult to obtain.

Cross-Country Comparison: Climate variation needs to be taken into account. This is possible by normalization of energy consumption by cooling or heating degree-days.

Data Needed: Data on floor space for the commercial sector are not easy to collect. Plus, the separation between industry and service activity, and residential and commercial energy does not always follow international standards.

Level 2 - Building Type Intensity

The service sector includes a wide range of different activities, from subsectors that require a great deal of electricity per unit of square meter (retail trade), those that use large quantities of fuel for water heating and cooking (restaurant, hotel), and those that by their nature consume little energy (warehousing, parking). Hence, if data are available broken out by subsector, then a more detailed treatment is possible by analyzing energy use per subsector or building type within the service sector, such as retail, office, hotel, education, health care, and other.

Indicator 13. Service Building Type Floor Area Energy Intensity

		Alternative
Indicator	E/m^2 per building type	E/employee per subsector activity
Definition	Energy per square meter for each building type	Energy per employee per subsector activity
Units	MJ/m^2	MJ/m^2

Applications: Trend analysis, monitoring energy use per building type allows better analysis of how energy is used in the service sector. A factorization method can estimate the structural effect of the variation in building types on total energy consumption. This indicator allows setting target and helping construct Building Code. It is also useful to monitor and evaluate codes implemented

Limitations: Energy efficiency in the service sector that is directly related to the efficiency of energy services such as lighting and space conditioning for example are not represented at this level.

Cross-Country Comparison: Country comparisons can be undertaken however, climate differences need to be taken into account. This is possible by normalization of consumption by cooling or heating degree day.

Alternative: Electricity per building type can provide a meaningful indicator, specifically in region of the world where space heating is not an important end use.

Level 3 - End Use Intensity

Energy efficiency in the service sector is directly related to the efficiency of energy services than to the efficiency of the particular sectoral activities. A treatment at this level introduces end uses, either for the service sector as a whole, or by the subsectors listed above. Key end uses would include:

- space heating,
- space conditioning,
- cooking and water heating,
- lighting, and
- other uses.

Indicator 14. Service End Use Floor Area Energy Intensity

Indicator	E/m^2 per building type per end use
Definition	energy per square meter for each building type and for each end use
Units	MJ/m^2

Application: Similarly as for Indicator 2, this indicator can help developing building code, but in a more helpful manner.

Advantages: - This level allows a close assessment of energy efficiency.
- Structural effect of variation in shares of end use on energy consumption can be factored out.
- Potential energy savings can be estimated for a greater management of energy reduction.
- Evaluation of equipment efficiency programs can be conducted.

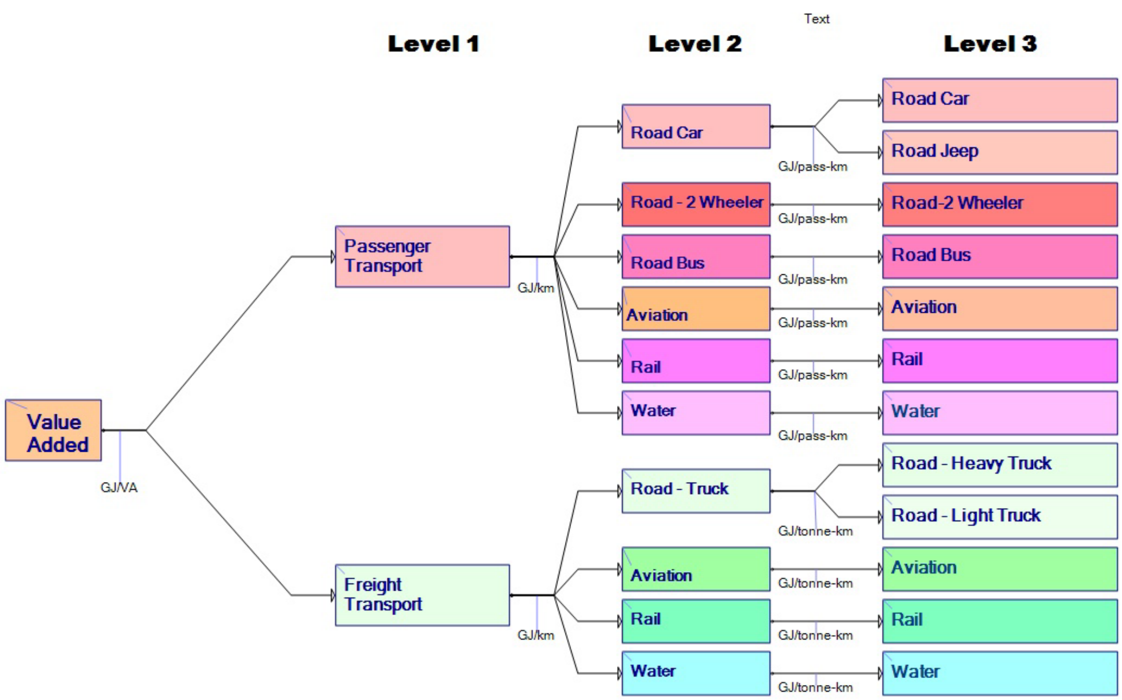
Limitations: Requires conducting survey on energy consumption.

Cross-Country Comparison: very good, specifically for the end uses not influenced by climate.

I. Transport

The transport sector is very different from the other sectors for several reasons. First, the use of petroleum products represents the bulk of the sector's energy use. Globally petroleum products account for 94% of the energy use in this sector, while natural gas represents 3%, and electricity and biofuels represent 1% each (IEA, 2007). Secondly, energy use in this sector is driven by the mobility of two completely distinct services: the transport of passengers and the transport of goods. Finally, in a fashion peculiar to the transport sector, final energy is employed in a large variety of modes and technologies. It is thus necessary to introduce a breakdown by *type* of transport (passenger and freight) as well as by *mode* of transport (i.e., road, rail, air, water, and pipeline).

Figure 11. Transport Sector Energy Efficiency Indicators Broken Down by Level



Macro - None

The fact that two completely different energy services (passenger and freight) are the main drivers of this sector make it extremely difficult to build an indicator of energy intensity use at the macro level. Both population and transport value added represent major drivers. However, data on transport energy consumption are not easily available for each of these drivers. Fuel energy use in this sector is reported as a total and statistics that distinct quantities that are sold to cars or to truck are generally not available. Hence, at the macro level, no simple indicator can be built.

Indicator 15. Index of Transport Energy Use

	Alternative

Indicator	Index or Indices
Definition	Sum of bottom-up analysis
Units	%

Alternative: Meaningful energy efficiency indicator at the level of the entire sector can only be based on an index indicator using bottom up detail by energy services (passenger and freight), mode and vehicle type.

Level 1- Motor Gasoline and Other Fuel Energy Use Intensity

At this level, only a broad indicator of transport energy use can be constructed. In order to assess trends of passenger road transport versus freight road transport, one can assume that most motor gasoline is used for passenger transport while other fuels are used for freight transportation. Hence, motor gasoline is divided by population and to some extent represents gasoline car use, while other fuels used in the transport sector are divided by transport value added and represent energy use for freight.

Indicator 16. Transport Energy Use Indicator

Indicator	Motor Gasoline per capita and Other fuel per value added
Definition	-
Units	MJ/ca and MJ/currency (local or international)

Application: Trend analysis. Motor gasoline per capita measures the quantity of this fuel use per inhabitant and other fuel per value added give an estimate of the fuel use in transport economic activity.

Limitations: In some countries, diesel cars for passenger transportation are more widely used making this indicator useless. Moreover, electricity is often used in rail passenger transport.

Cross-Country Comparison: Can show different patterns in personal motor use across different countries.

Level 2- None

The logical next steps would be to analyze transport energy use by modes. However, this level is also faced to the conflict of energy driving forces, passenger and freight which cannot be distinguished in total energy use. Hence, it is necessary to go directly to level 3 as no meaningful energy use indicator can be constructed at this level.

Level 3- Passenger-km and Freight tonne-km Intensity

The physical energy intensities used at this level are in terms of energy use per passenger-km, or per tonne-km, per mode and per vehicle type. If data are available broken out by fuel, then the treatment can sum over fuel types. It is particularly important to break out by *mode* of transport. This can be written as:

Equation 1. $$E_{TR,i} = \sum_{k}^{OPTION} \sum_{t}^{OPTION} \sum_{r}^{OPTION} \sum_{j}^{OPTION} Q_{t,r,m} \times s_{t,r,j} \times f_{k,t,r,j} \times EI_{TR,k,t,r,j}$$

Where:

$E_{TR,i}$	=	energy demand in the transport sector,
r	=	mode type (road, rail, water, air, pipeline)
t	=	transport type (passenger, freight)
j	=	transport technology class (e.g., vehicle classes),
$Q_{t,r}$	=	quantity of transport service of type *t* in mode *r* in passenger-km and tonne-km, and
$s_{t,i}$	=	share of transport services *t*, delivered through the mode *m* employing the transport end-use technology *j*, and
$f_{k,t,i}$	=	share of fuel *k* used for technology *j* in providing transport services of type *t*.
$EI_{TR,k,t,}$	=	average energy intensity of energy type *k* for transport service of type *t* in mode *r* in MJ/(passenger-km-year) and MJ/(tonne-km-year)

Disaggregation into end-uses technology classes correspond to a level 3 as it requires detailed data and some of which from surveys. With road transportation, for instance, data on fleet shares and average fuel consumption are needed for vehicle classes (e.g., motorcycles, cars, buses, and light and heavy trucks).

For the other transport subsectors the class breakdowns could be:

- water (internal waterways vessels, sea transport vessels, international transport vessels)
- air (national and international air transport),
- rail (intracity and intercity mass transit)

Passenger-kilometers and tonne-kilometers are calculated by multiplying the stock of vehicles organized by mode and types, the quantity of tonnes carried in the case of freight and persons transported in the case of passenger travel, and kilometers traveled. This task requires an extensive data investigation, since load factors and efficiencies of cars and other forms of passenger transport are difficult to monitor at the level of the whole economy.

Indicator 17. Passenger and Freight fuel Intensity Indicator

Indicator	E/passenger km and E/ tonne-km by mode and vehicle type
Definition	Energy per passenger-km and per tonne-km by mode and vehicle type measure the energy necessary for different modes and vehicle type to move one person in the case of passengers and one tonne in the case of freight over one kilometer.
Units	GJ/pass-km and GJ/tonne-km

Application: At this level, indicators on energy per passenger-km and per tonne-km by mode and vehicle type, as well as share of the different modes and vehicle type used, are very valuable for policy makers that wish to implement policies directed at reducing energy consumption and enhancing sustainable development in the transport sector.

This level allows for a close assessment of energy efficiency. Indicators can help with monitoring and evaluating fuel standards. The structural effect of variation in shares of mode and vehicle types on energy consumption can be factored out for each energy services, i.e. passenger and freight mobility.

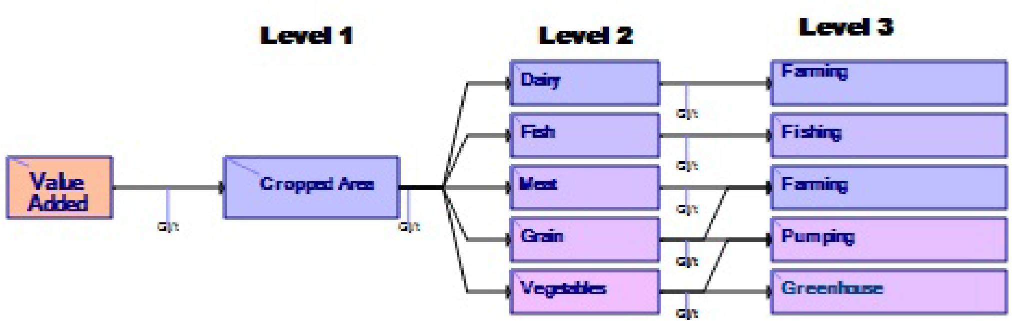
Limitations: Often this detail of analysis requires some level of estimation. For example passenger vehicle occupancy is not always surveyed and expert judgments can be used to fill the gap.

Cross-Country Comparison: Indicators at this level are very valuable in term of cross-country comparisons. However, care needs to be taken so that socio-economic, geographic and other importance differences between countries are taken into account when conducting the analysis. For example, population density and urbanization affect transport activity and related energy use.

J. Agriculture

The agriculture sector generally employs a large share of the active population in developing countries. Despite the relative importance of this sector to employment and economic activity, agricultural energy use tends to be small compared to that of industry or transport. Energy is mainly used for ground water pumping and farm machinery such as threshers and tractors. Petroleum fuels and electricity are generally the main energy products in use.

Figure 12. Agriculture Sector Energy Efficiency Indicators Broken Down by Level



Macro - Sector Intensity

At this level, energy use in the agriculture sector can be analyzed simply by looking at total agriculture energy use per unit of agriculture value added (**economic energy intensity**). If information on energy use is broken out by energy type, then this treatment should be included. Otherwise, a single energy intensity aggregating all energy types can be used. Moreover, value added needs to be expressed in real terms to exclude the effect of inflation variations.

Indicator 18. Agriculture Economic Energy intensity

		Alternative
Indicator	E/VA	Index or Indices
Definition	Energy consumption in the agriculture sector divided by transport value added	Sum of bottom-up analysis
Units	MJ/currency (local or international)	%

Application: It is a very easy indicator to construct and can be used to observe trends in aggregate agriculture energy use per unit of industrial output measured in monetary value.

Limitations: However, this indicator does not identify the sub-sectors which are contributing the most in reducing its value versus the sub-sectors which are driving its increase. Agriculture value added fluctuates over time for reasons other than the quantity of output produced. More detail is needed to better understand the factors influencing this indicator.

Cross-Country Comparison: E/VA is a very limited indicator for cross-country comparison due to its aggregate nature and the difficulties comparing economic units between differing economies.

Alternative: Index indicator based on bottom up detail by subsectors.

Level 1- Cultivated Area Intensity

At this level, agriculture value added is simply replaced by the quantity of land cultivated. This allows eliminating the monetary variations of agriculture production which are often subject to wide variations.

Indicator 19. Agriculture Area Energy intensity

Indicator	E/ha
Definition	ratio of energy use per unit of agriculture cultivated
Units	MJ/ha

Application: This indicator can be used to observe how agriculture energy use on a per hectare basis is evolving.

Limitations: However, energy consumed depends not only on the overall amount of hectares of land cultivated but also on the penetration of farming equipment, irrigation pumps, and the use of greenhouses. Moreover, the agriculture sector includes diverse subsectors that are not dependent on area cultivated such as fishing, dairy production, etc.

Cross-Country Comparison: E/ha is a very limited indicator for cross-country comparison due to its aggregate nature and the difficulties comparing countries with very different agriculture practices

Level 2: Physical Intensity

At this level, the agriculture sector is broken down into main subsectors production: grain, vegetables, meat, dairy, and fishing.

Indicator 20. Agriculture Physical Energy intensity

Indicator	E/t
Definition	Energy consumption in the main agriculture subsector divided by tonne of output
Units	MJ/tonne

Application: This level provides a better understanding on the factors influencing trends in the agriculture energy use. It is possible then to dissociate structural changes between the different sub-sectors.

Limitations: However, this level does include the equipment penetration and so limit the analysis of energy efficiency performance.

Cross Country Comparison: Countries have very different practices, some have a much more intensive grain production than others and depending on the climate, some countries are heavily dependent on irrigation schemes which require significant amounts of energy. These characteristics need to be taken into account when comparing energy use across countries.

Level 3- End Use Intensity

Energy use in the agriculture sector can be further disaggregated. Five major end uses account for most of the energy demand: farming, water pumping, greenhouse heating and fishing. This level takes into account the penetration of equipment, their capacity and hours of use that are necessary to estimate energy requirements by end use. Table 7 gives details on the type data that needs to be collected at this level.

Table 8. Agriculture End Use Technology

End Use	Equipment		Diffusion	Capacity	Usage
Farming	Tractors	Diesel	million	HP	hours/yr
		other	million	HP	hours/yr
Greenhouse Heating	heating system	Coal	10^6 m2	MJ/m2	
		Natural Gas	10^6 m2	MJ/m2	
		Electricity	10^6 m2	MJ/m2	
		Oil	10^6 m2	MJ/m2	
		Biomass	10^6 m2	MJ/m2	
Irrigation	Pumps	Diesel	10^6	kW	hours/yr
		Electricity	10^6	kW	hours/yr
Fishing	Fishing Boats	Gasoline	10^6	MJ/km	km
		Diesel	10^6	MJ/km	km

Indicator 21. Agriculture End Use Energy intensity

Indicator	E/t, E/m² and E/km
Definition	Energy consumption is estimated by main end use needs: farming, pumping, greenhouse heating, and fishing
Units	MJ/tonne

Application: Analysis at this level provides very reliable estimate of energy efficiency. Policy target setting, evaluation and monitoring, and benchmarking

Limitation: data collection at this level is very challenging and requires timely investigation, often based on energy use survey.

Cross-Country Comparison: This level of detail allows conducting very meaningful comparisons and benchmarking. It is possible to compare across countries and with best practices available, and estimate energy savings potential.

Conclusions

Improving our understanding of where and how energy is used is a necessary condition for more sustainable development. It helps identify opportunities to improve energy efficiency and to use cleaner technologies and it sheds light on behavioral changes that shape energy consumption patterns. Non-OECD countries represent more than 80% of the world population, and yet consume only half of the energy supplied in the world. There is little doubt that energy used in non-OECD countries will grow; it is already growing rapidly in China and India. Policies aimed at increasing energy efficiency performance are increasingly seen as a possibility to contain this surge in energy use. Many developing countries have implemented standard and labeling programs, efficiency awareness programs and energy efficiency targets at different levels. Tools such as efficiency indicators are necessary to track the potential of these programs and to measure their progress over time.

Constructing energy efficiency indicators in developing countries is a challenging task, notably in very populous and large countries with different climatic zones and cultural practices. Nevertheless, many countries have national statistical offices that survey various aspects of socio-economic activity taking place in the entire country or specific regions. They provide valuable input to the production of energy efficiency indicators. On the other hand, official statistics often fail to provide detailed data on energy. Little information exists on the energy used per unit of activity at a detailed level, and often energy surveys are required to provide that detail. Indeed, energy balances are often the extent of the energy data available in most countries and detailed energy consumption surveys for different aspects of the economy are lacking.

The inadequacy of available data and the urgent need for measuring energy use performance have underlined the necessity to elaborate different levels of analyses corresponding to different levels of data availability. Indicators of energy use can be organized in descending order where level 1 indicators display an aggregate result based on energy balances and where level 3 shows greater disaggregation, based on energy consumption surveys. Each detailed indicator requires more data, but it also provides a more accurate and better fitting estimate of energy efficiency savings. Moreover, the construction of alternative indicators, based on the penetration of energy efficiency technologies, provides interesting insight on energy efficiency performances that are often more easy to produce. This document presents background information for a developing country desiring to construct energy efficiency indicators. For each sector, ways to estimate different levels of energy efficiency indicators are provided with their potential application and limitations.

The increasing need for constructing meaningful energy efficiency indicators pressures the necessity for collecting new data on energy consumption at a detailed level. Currently, regular periodic energy consumption surveys in developing countries are rare, but it is critical that more resources be allocated to the design and implementation of energy consumption surveys in developing countries. Energy efficiency indicators provide the tool to learn from the past, which will allow a better understanding of the future.

References

Ang B.W. and S.Y. Lee, "*Decomposition of industrial energy consumption: some methodological and application issues*", Energy Economics 16 (1994), pp. 83–92.

Ang, B.W. and K.H. Choi. 1997. "*Decomposition of aggregate energy and gas emission intensities for industry: a refined Divisia index method*". The Energy Journal 1997; 18(3):59-73.

Ang, B.W., 2004. "*Decomposition analysis for policymaking in energy: which is the preferred method?*", Energy Policy 32 (2004), pp. 1131–1139.

Ang, 2006. "*Monitoring changes in economy-wide energy efficiency: From energy–GDP ratio to composite efficiency index*", Energy Policy (2006), Volume: 34, Issue: 5, Pages: 574-582

Ang, B.W. and N. Liu, 2007. "*Energy Decomposition Analysis: IEA model versus other methods*", Energy Policy, Volume 35, Issue 3, March 2007, Pages 1426-1432

Asia Pacific Energy Research Centre (APERC), 2001."*Energy Efficiency Indicators: a Study of Energy Efficiency Indicators in APEC Economies*", March 2001.

Baumert K. and Selman M., "*Data Note: Heating and Cooling Degree Days*", World Resources Institute, 2003.

Bosseboeuf D., B. Chateau and B. Lapillonne, 1997. "*Cross-country comparison on energy efficiency indicators: the on-going European effort towards a common Methodology*", Energy Policy, Vol. 25, Nos. 7-9, pp. 673-682, 1997.

de la Rue du Can S. and L. Price, 2008 "Sectoral Trends in Global Energy Use and Greenhouse Gas Emissions", Energy Policy 36 (2008) 1386–1403.

Energy Efficiency and Conservation Authority (EECA), 2006. *"Situation Assessment Report on the National Energy Efficiency and Conservation Strategy"*, New Zealand, March 2006.

Energy Efficiency and Conservation Authority (EECA), 2009. "*Energy Efficiency and Renewable Energy in New Zealand Year Six Report: March 2001 to 2007"*, New Zealand, March 2009.

Energy Information Administration (EIA), 1995. "*Measuring energy efficiency in the United States' economy: a beginning"*. DOE/EIA-0555(95)/2, Washington, DC, USA, October 1995.

Energy Information Administration (EIA), 1996. "*Economy Energy-Efficiency Workshop EIA Session Summary*", Washington, DC, USA, March 21, 1996. http://www.eia.doe.gov/emeu/efficiency/economy_ws.htm

Energy Efficiency and Renewable Energy (EREE), 2003. "*Energy Indicators System: Index*

Construction Methodology", Office of Energy Efficiency and Renewable Energy, Washington D.C. http://www1.eere.energy.gov/ba/pba/intensityindicators/

Farla, J.C.M., Blok, K., 2000. "*The use of physical indicators for the monitoring of energy intensity developments in the Netherlands*", 1980–1995. Energy 25, 609–638.

Hass, 1997. "*Energy efficiency indicators in the residential sector: What do we know and what has to be ensured?*", Energy Polity, Vol. 25, Nos. 7-9, pp. 789-802, 1997

International Energy Agency (IEA):

1997a. Indicators of Energy Use and Energy Efficiency. Understanding the Link Between Energy And Human Activity. Author: Schipper L., aris: OECD

1997b. The Link Between Energy and Human Activity, Authors: Schipper L, Des Rosiers J-P, Justus D, Cornell R, Sullivan S. Paris: OECD

1998. Energy Use in Canada in An International Perspective: Comparison of Trends Through The Early 1990s, Authors: Schipper L, Unander F, Marie C, Ting M, Khrushch M, Krackeler T., Paris: Int. Energy Agency

1999. Energy Use in the Netherlands in an International Perspective: Comparison of Trends Through The Mid-1990s, Authors: Schipper L, Unander F, Marie C, Ting M, Khrushch M, Krackeler T., Paris: Int. Energy Agency

2000a. Energy Use in New Zealand in an International Perspective: Comparison of Trends Through the Mid 1990s, Authors: Schipper L, Unander F, Marie-Lilliu C, Walker I, Murtishaw S. Paris: Int. Energy Agency/Wellington, NZ: Energy Effic. Conserv. Authority

2000b. Energy Use In Australia In An International Perspective: Comparison of Trends Through The Mid 1990s, , Authors: Schipper L, Unander F, Marie-Lilliu C, Walker I, Gorham R., Paris: Int. Energy Agency/Canberra, Aust.: Dep. Ind., Sci. Resourc.

2004 IEA, Oil Crisis & Climate Challenges—30 years of Energy Use in IEA Countries" Authors: Unander F., Ting M., Fulton L., Justus D., and Karbuz S., Paris: IEA.

2007a. Tracking Industrial Eneergy Efficiency and Co2 Emissions". Authors: Gielen D., Bennacoeur K., Kerr T., Tam C., Tnaka K., Taylor M., and Taylor P. Paris: IEA

2007b. Energy Balances of Non-OECD Countries: 2004-2005,Paris: IEA.

2007c "Energy Use in the New Millenium: Trends in IEA Countries", Authors: Taylor P., Cazzola P., Francoeur M., Lavagne d'Ortigue, Sturc M., Tam C. and Taylor M.,Paris: IEA.

Intergovernmental Panel on Climate Change (IPCC), 2001. Climate Change 2001: Synthesis Report. Cambridge, UK and New York, NY: Cambridge University Press. Glossary: http://www.ipcc.ch/pub/syrgloss.pdf

International Iron and Steel Institute, IISI, 2007. Steel Statistical Yearbook, 2006. IISI: Brussels, Belgium.

Jollands, N. J. Lermit, and Patterson M. 2004, Aggregate eco-efficiency indices for New Zealand—a principal components analysis. Journal of Environmental Management 73 (2004) 293–305

Kolli Ramesh, 2006. "Delhi Group on Informal Sector and System of National Accounts", Delhi Group on Informal Sector and System of National Accounts, 2006, http://www.unescap.org/stat/isie/National-Accounts-GDP-Estimation/Delhi-Group-Informal-Sector-SNA.pdf

Lermit and Jollands, 2001 J. Lermit and N. Jollands, Monitoring Energy Efficiency Performance in New Zealand: A Conceptual and Methodological Framework, National Energy Efficiency and Conservation Authority, Wellington (2001).

Martin, N, Worrell, E, Schipper, L J and Blok, K (1994) 'International comparisons of energy efficiency' summary report of a workshop at LBNL, 6-9 March, Berkeley

Nanduri, M., Nyboer, J., Jaccard, M., 2002. Aggregating physical intensity indicators: results of applying the composite indicator approach to the Canadian industrial sector. Energy Policy 30, 151–163.

NRCAN, 1996. Energy Efficiency Trends in Canada. Natural Resources Canada's Office of Energy Efficiency, Ottawa.

NRCAN, 2000. Energy Efficiency Trends in Canada 1990 to 1998: A Review of Secondary Energy Use, Energy Efficiency and Greenhouse Gas Emissions October 2000

NRCAN, 2006. Energy Efficiency Trends in Canada 1990 to 2004, August 2006. Natural Resources Canada's Office of Energy Efficiency, Ottawa.

NRCAN, 2009. Energy Efficiency Trends in Canada 1990 to 2005, August 2009. Natural Resources Canada's Office of Energy Efficiency, Ottawa.

ODYSSEE, 2005 ODYSSEE (2005). http://www.odyssee-indicators.org.

Patterson M. G., 1993. An accounting framework for decomposing the energy-to-GDP ratio into its structural components of change, Energy, Volume 18, Issue 7, July 1993, Pages 741-761

Patterson, M.G., 1996. What is energy efficiency? Concepts, issues and methodological issues. Energy Policy 24, 377–390.

Phylipsen, G. J. M., K. Blok and E. Worrell. 1998. Handbook on International Comparisons of Energy Efficiency in the Manufacturing Industry. Utrecht: Department of Science, Technology and Society, Utrecht University.

Price, L., S. de la Rue du Can, J. Sinton,, and E. Worrell., 2006. Sectoral Trends in Global Energy Use and Greenhouse Gas Emissions. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-56144). http://ies.lbl.gov/iespubs/56144.pdf

Price, L., Worrell, E., Martin, N., Farla, J., Schaeffer, R., 1997. "Energy Efficiency in the United States Iron and Steel Industry," Proceedings of the 1997 American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Industry, Washington, DC: ACEEE

Schipper, L J, Bartlett, S, Hawk, D, & Vine, E (1989). Linking lifestyles and energy use: a matter of time?. Annual Review of Energy, 14, 273-320.

Schipper, L., Meyers, S. et al. (1992) Energy Efficiency and Human Activities: Past Trends, Future Prospects. Cambridge University Press, Cambridge, UK.

Schipper L., Unander F., Murtishaw S. , and M. Ting, 2001. Indicators of Energy Use and Carbon Emissions: Explaining the Energy Economy Link.

Sinton JE et al. An assessment of programs to promote improved household stoves in China. Energy for Sustainable Development, 2004, Vol 8 No 3. http://ieiglobal.org/vol8_issue3.html

Smith K.R., R. Uma, V.V.N. Kishore, K. Lata, V. Joshi, Junfeng Zhang, R.A. Rasmussen and M.A.K. Khalil. 2000. Greenhouse gases from small-scale combustion devices in developing countries: Phase IIA. Household Stoves in India. EPA 2000. http://ehs.sph.berkeley.edu/krsmith/publications/00_smith_3.pdf)

SNA, 19931993 System of National Accounts. United Nations http://unstats.un.org/unsd/sna1993/toctop.asp

Unander F, Schipper L. 2000. Trends in Norwegian Stationary Energy Use: An International Perspective. NVE-Rep. 2000/2. Oslo: OECD/Int. Energy Agency & Nor. Water Resourc. Energy Direct.

F. Unander, Energy indicators and sustainable development, IEA Publication for COP7, Marrakesh (2001).

UNDESA "Incorporating housing statistics in the Demographic Yearbook data collection", Social and Housing Statistics Section, Demographic and Social Statistics Branch, UNITED NATIONS

SECRETARIAT ESA/STAT/AC.91/7, Department of Economic and Social Affairs, Statistics Division, Expert Group Meeting to
Review the United Nations Demographic Yearbook System , 31 October 2003

Worrell, Ernst, Lynn Price, Nathan Martin, Jacco Farla and Roberto Schaeffer. 1997. Energy intensity in the iron and steel industry: a comparison of physical and economic indicators. Energy Policy, 25(7-9): 727-744.

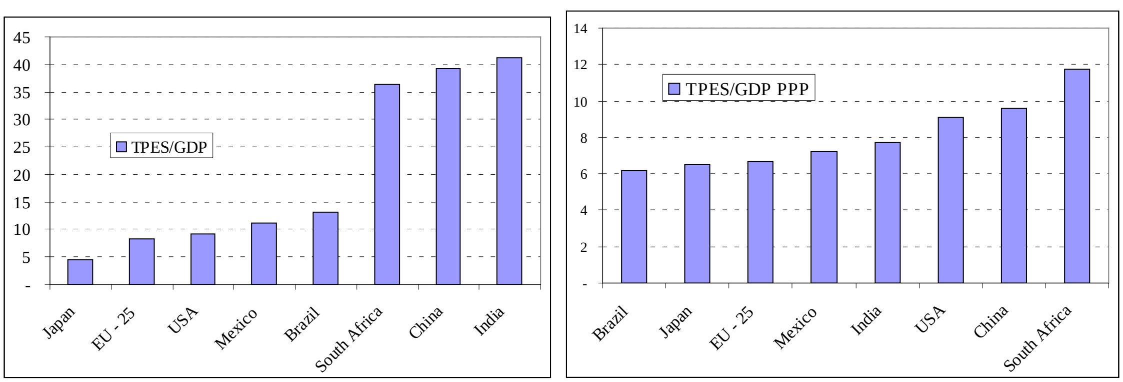
Appendixes

Annex 1. Purchasing Power Parity

Internationally, Energy Intensity of GDP or subsector activities are sometimes used for cross countries comparison. The units used to measure output need to be the same (e.g. in US dollars). Two main approaches are used to convert local currency to a common unit: market exchange rates (MERs) and purchasing power parity (PPP). PPP conversion allows national accounts aggregates in national currencies to be compared on the basis of their purchasing powers of the currencies in their respective domestic markets free from differences in price levels across countries, much the same way as constant price estimates do in a time series comparison of real values free from differences in prices over time.

Different results are obtained depending on the approach used, affecting how countries compare with one another. Figure 8 shows GDP primary energy intensity measured according to MERs and to PPP. In the first case, Japan appears as the least energy intensive economy as opposed to India which appears to be the most energy intensive economy, requiring about 10 times more energy to produce the same value of output. However, when using PPP, not only the rank is very different but also energy intensity magnitude between countries differs. In the case where PPP are used, Brazil appears as the least energy intensive economy, and the US and China appears to have similar energy intensity. The magnitude of difference is only double, contrary to when using MER where difference is in the order of 10 times.

Figure 8. Measuring Energy Intensity: The Impact of Measuring GDP at Market Exchange Rates or Purchasing Power Parities



Source: IEA, 2007

The main difference between these two indicators are due to differences in how value of output is measured. This also reflects the limitation of using energy to GDP ratios as indicators of energy efficiency trends. GDP encompass too many heterogeneous products to reflect a meaningful indicator.

Annex 2. Primary Energy Accounting Methodologies

Direct equivalent method (SRES method): the primary energy of the non fossil fuel energy is accounted for at the level of secondary energy, that is, the first usable energy form or "currency" available to the energy. For instance, the primary energy equivalence of electricity generated from solar photo-voltaic or nuclear power plants is set equal to their respective gross electricity output, not to the heat equivalent of radiation energy from fissile reaction, the solar radiance that falls onto a photo-voltaic panel, or the heat that would have been necessary by burning fossil fuels to produce the same amount of electricity as generated in a photo-voltaic cell or a nuclear reactor (as used in the so-called "substitution" accounting method) (Nakicenovic et al., 2000).

Physical energy content method (IEA method): this method uses the physical energy content of the primary energy source as its primary energy equivalent. In the case of nuclear and geothermal electricity, heat is the primary energy form considered and the conventional efficiencies are 33% and 10% respectively. In the case of other non fossil fuel energy (hydro, solar, wave/tide), the primary form of energy considered is the electricity produced and hence efficiency of 100% applies, similar to the previous method.

Substitution energy method: this method attributes 33% efficiency for all non fossil fuel i.e. as if this energy had been generated by a fossil fuel power plant.