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Energy Efficiency Indicators and Impact Metrics

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ENERGY EFFICIENCY INDICATORS AND IMPACT METRICS

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INTRODUCTION

Energy efficiency refers to using less energy to produce the same service or useful output (Patterson, 1996). An engineer may define energy efficiency narrowly, for example with a focus on equipment output such as considering a car energy-efficient if it requires less energy to drive the exact same distance at exactly the same speed as another car. By contrast, an environmentalist or a politician may define an energy-efficient car more broadly including societal impacts, for example having 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. In its updated strategic plan for increasing philanthropy's impact on the climate challenge, ClimateWorks Foundation (CWF) worked with Lawrence Berkeley National Laboratory (LBNL) to define a set of comprehensive indicators to track changes in energy efficiency progress, measure progress, and assess strategic opportunities.

As a first step, a round table was organized in November 2014 with international and regional experts on energy efficiency to discuss the main challenges in developing metrics for energy efficiency. Some of the insights from that event included:

Data Availability – Data availability is a concern in every sector and region and is highly variable. While data from programs in the U.S. allow for the construction of many different metrics and evaluations of energy savings, there are still some remaining gaps. At the other end of the spectrum, data constraints are severe in India where even basic energy balance data are missing. At the same time, data may be more available in India at the disaggregated, or program, level. Data lag time is an issue even in Organization for Economic Co-operation and Development (OECD) countries. The International Energy Agency (IEA) has dedicated considerable effort to improving the data capacity of developing countries, but more is needed to collect and increase the quality of data in many of the developing countries.

Value and Awareness of Measurements – Even for the most well established programs, such as minimum energy performance standards (MEPS) for appliances, awareness of program impacts is poor. Developing countries in particular are looking for the means to conduct program impact assessments. Metrics and measurements are not only a means of tracking progress, but a key communications and messaging component critical for building political support for policies and programs.

Multiple Benefits / Non-Traditional Metrics Definitions – There are different ways to tell the energy efficiency story depending on the audience; that is, different metrics can be used to show the different aspects of benefits from actions. For example, energy efficiency metrics can be tied to broader political goals, including economic growth, jobs, energy security, energy access, and health and well-being. In addition to measuring different parameters, metrics can be modified or extended to include energy demand outcomes and percentage improvement rather than just energy savings.

Energy Efficiency is one of the six philanthropic investment portfolios[1] developed by ClimateWorks Foundation (CWF) to take action on climate change. The Energy Efficiency portfolio aims to address emissions from the building and industry sectors by improving the energy use efficiency of these sectors. Direct greenhouse gas (GHG) emissions from the industry and building sectors account for 21% and 6.4% of all GHG emissions, respectively, and 23% and 18.4% of indirect emissions from the production of electricity and heat used in these sectors, resulting in a total of 41.4% of global GHG emissions (IPCC, 2013). Contributing to improving the energy efficiency of these sectors is essential to mitigate global energy-related GHG emissions.

CWF has developed a comprehensive portfolio of investment opportunities to address the potential for energy efficiency in these two sectors with the goals of accelerating the adoption of energy-efficiency policies and targets, improving their implementation, integrating renewable energy, increasing investment in energy efficiency, and increasing data access.

This report provides insights gained from the initial process of identifying meaningful metrics for tracking progress toward energy efficiency for CWF. The authors considered a wide range of indicators drawing upon literature, their own experience, and consultation with experts and practitioners. From these, we undertook the difficult task of choosing only a handful of indicators to form campaign decisions based on identified data sources. While we made this choice in order to end up with a manageable and communicable set of guidelines for the CWF stakeholder community, we recognize that valuable information was omitted as part of the process.

Having completed this initial report, a second phase is under way to identify necessary steps toward 'operationalizing' some of the metrics identified in this process. This phase will elaborate practical plans for defining indicators of success, accessing data, applying sound methodologies based on feedback from grantees, and will seek to optimize resources applied to data collection and analysis.

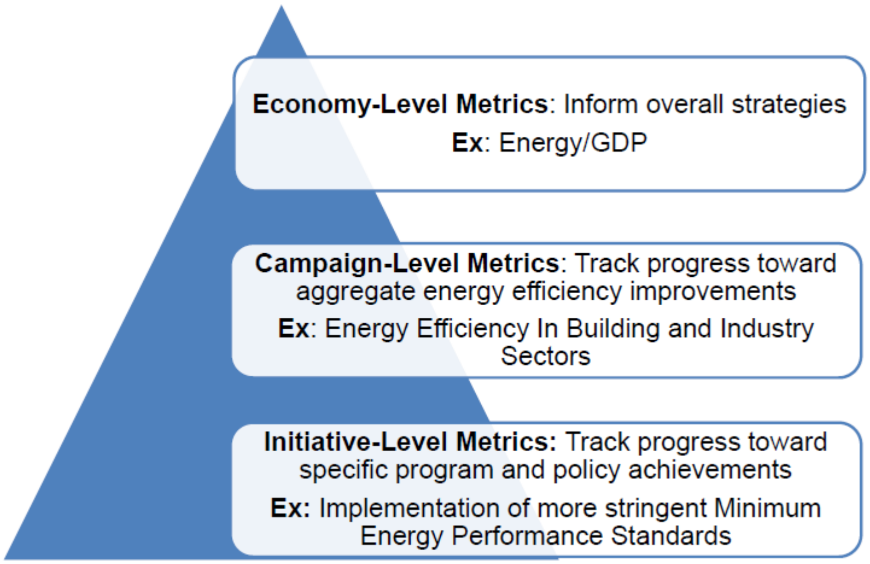
Metrics Hierarchy

The introduction of the concept of *level of analysis* helps to identify the precision of the energy efficiency assessment. Analysis at a macro level provides a broad assessment of trends in energy consumption at an economy level and allows for strategic decision-making. Analysis at more disaggregate levels (e.g., sectors and regions) allows for deeper understanding of the progress and challenges of improving energy efficiency. Finally, at the most micro level, it is possible to develop metrics to measure progress of actions taken on specific initiatives.

This report is divided into metrics that compose a hierarchy with three levels, as shown in Figure 1. Hierarchy levels represent levels of disaggregation and vary by data availability, source, and purpose.

[1] The six philanthropic investment portfolios are Clean Power, Oil, Energy Efficiency, Forests and Land Use, Non-CO_2 Mitigation, and Cross-Cutting Strategies.

FIGURE 1. HIERARCHY OF METRICS



Economy-Wide Metrics: Economy-wide metrics are highly aggregated and are typically made available by national governments and/or international organizations. In some countries, however, even these are not easily accessed. Economy-wide metrics provide the most direct connection between the energy-economy system and the physical climate system where energy efficiency has its ultimate effects. However, the aggregate nature of these metrics means that they include many other effects besides end-use energy efficiency, such as development-driven increases in energy services provided, the fuel mix used to provide electricity, the efficiency of the power sector, etc. For this reason, economy-level metrics can inform high-level campaign strategy but are not short-term indicators of progress.

Campaign-Level Metrics: Campaign-level metrics zoom in on the energy efficiency of the end-use sectors (appliances, buildings, and industry) and attempt to "take the pulse" of energy efficiency in key regions. Over the course of several years, they will allow for tracking aggregate energy efficiency improvements. Although these metrics promise to provide a concise indicator of status and progress in energy efficiency, they are affected by the challenges of data availability and interpretation.

Initiative-Level Metrics: Initiative-level metrics are "bottom-up" type measurements and provide the most concrete, if not comprehensive, picture of energy efficiency. These metrics are constructed using highly specific data sets, some of which may be provided by implementing grantees. Initiative-level metrics include measurement of energy savings potential (*ex-ante* or *ex-post*) and therefore play an important role in evaluating initiative impacts.

ECONOMY-WIDE METRICS

Economy-wide metrics are valuable for setting strategy at the highest level. For example, total GHG emissions of an economy are the most obvious input toward determining geographic priorities. In addition, trends in these metrics may play a role by providing insight into tomorrow's biggest emitters. Energy productivity is a useful metric because it uses economic growth as a primary driver of emissions and is a further step closer to characterizing efficiency *per se*. Energy savings from efficiency can be viewed either retrospectively or prospectively, providing a picture of the results of efficiency programs by region and indicating currently available opportunities. Likewise, investments in energy efficiency quantify where strong efforts have been made and where there are gaps. Finally, energy subsidy is a "leading indicator" for efficiency because it informs on the level of market-driven efficiency improvement.

Metric	Geography	Purpose	Source	Frequency	Time Lag	Cost / Availability
CO_2 EMISSIONS FROM FUEL COMBUSTION	Global, Regional, Country	Strategic / Prioritization	IEA, 2014a CW, CTI	Annual	2.8 years (2013 data released in October 2015)	Track every year because of low cost and good availability
ENERGY PRODUCTIVITY	Global, Country	Strategic / Prioritization	IEA, 2014a	Annual	2.5 years (2013 data released in June 2015)	Track every year because of low cost and good availability
ENERGY SAVINGS	US, EU, IEA-11	Strategic / Prioritization	IEA, 2014a / Kalavase, 2012 Regional Climate Foundations	Annual	3 years (2011 data released in 2014)	Track every 4-5 years because of high cost and low availability Need more research for additional countries
ENERGY-EFFICIENCY INVESTMENT	Global, US, EU	Strategic / Prioritization	IEA, 2014a	Annual	2.5 years (2013 data released in June 2015)	Track every year because of low cost and good availability Need more research for additional countries
ENERGY SUBSIDIES	Regional, Country	Strategic / Prioritization	IEA, 2014d	Annual	1 year	Track every year because of low cost and good availability

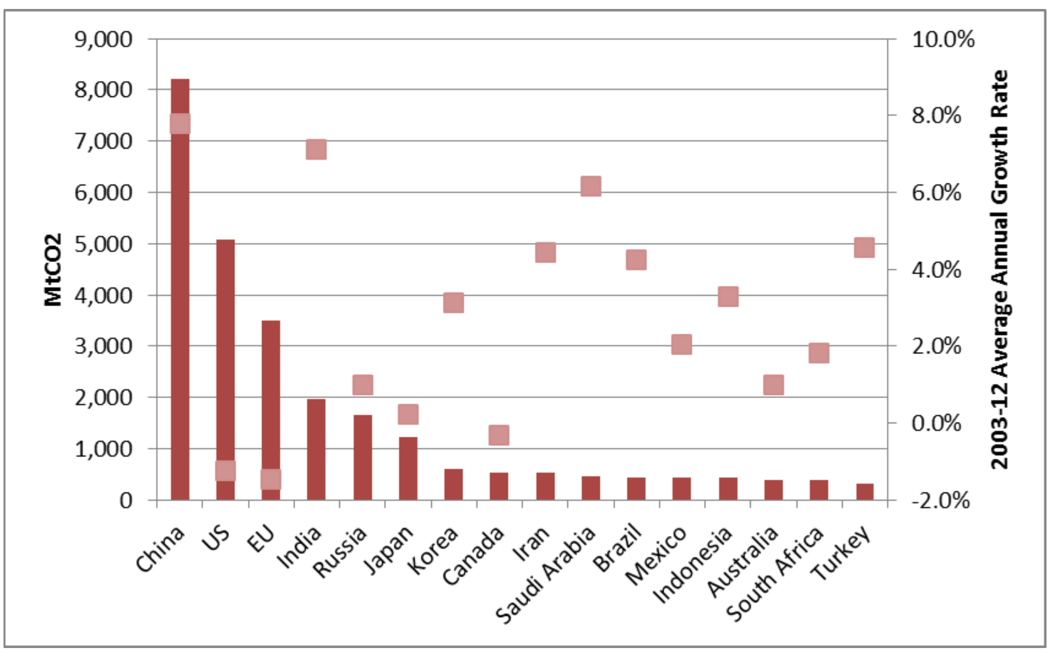
CO_2 Emissions From Fuel Combustion

Brief Description	Economy-wide carbon dioxide emitted from fuel combustion shows the amount of GHG emissions related to the use of energy in an economy. It is the direct connection between energy use and GHG emissions.
Purpose	This indicator is strategic and can be used to: • Prioritize country support and identify the largest emitters in the world • Identify new opportunities: countries with significant GHG emissions and fast growth may represent opportunities for CWF • Top line index most directly related to climate change.
Units	Million metric tons of carbon dioxide ($MtCO_2$)
Challenges / Barriers	• Data readily available • Emissions do not correlate directly to efficiency but are driven by fuel mix and economic activity.

Source of Data	• IEA online database with 138 countries (IEA, 2014a)
	    o Updated every year in July/August
	    o 2.5-year lag
	• UNFCCC online database (UNFCC, 2016)
	• Emission database for atmospheric research (JRC, 2016)

Figure 2 shows 2012 energy-related emissions of the largest emitters in the world and their average annual growth over the period 2003-2012.

FIGURE 2. ENERGY-RELATED CO2 EMISSIONS: 2012 LARGEST EMITTERS AND TRENDS 2003 TO 2012

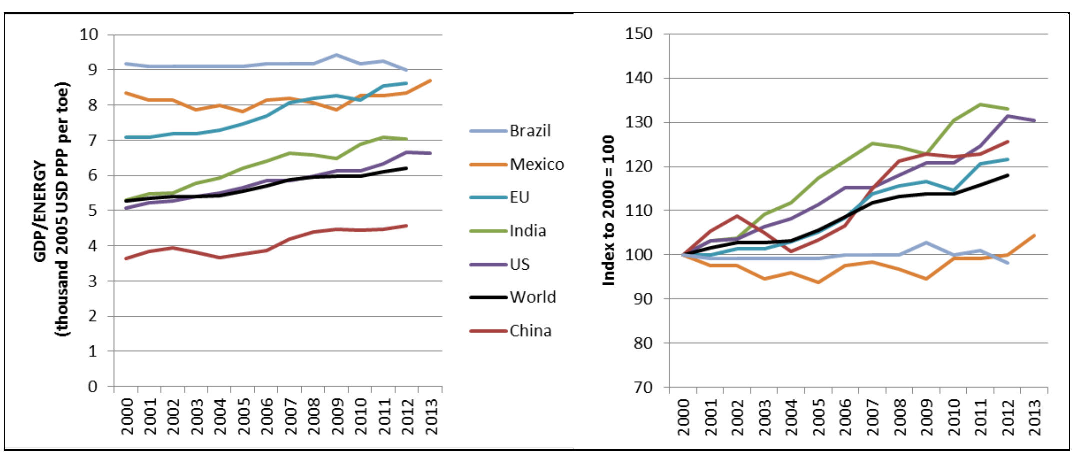


Source: IEA, 2014a.

ENERGY PRODUCTIVITY

Brief Description	Energy productivity measures the level of economic value produced per unit of energy consumed in an economy. Growth in energy productivity reflects that more economic value is produced for a constant quantity of energy consumed.
Purpose	This is the broadest metric of energy efficiency objectives for many countries and programs. Although increase in energy productivity arises from factors other than efficiency improvement, initiative and campaign-level impacts *may* be judged by their contribution to increases in overall energy productivity.
Units	Unit used by the IEA: Thousands of US dollars per ton of oil equivalent (k USD/toe) **GDP:** Gross domestic product, expressed in terms of purchasing power parity (PPP) to facilitate cross-country comparison. **ENERGY**: Energy consumption is expressed in terms of total primary energy supply (TPES). Different conventions exist to estimate the primary energy content of non-fossil-fuel electricity such as nuclear, hydro, wind, solar photovoltaic (PV), and geothermal (see Appendix 1).
Challenges / Barriers	The main challenge of this indicator is that it is not a direct measure of energy efficiency and can be misleading. Not all the energy supplied in an economy is used to produce economic output; some energy is consumed by the non-productive economic sectors such as the residential sector. Moreover, some economic sectors are much more energy intensive than others. Therefore, the energy productivity of an economy increases when an economy moves from industrialized to a more service-based productive structure. In this case, the increase in energy productivity does not derive from energy efficiency but reflects structural change of economic development.
Source of Data	• IEA online database with 138 countries (IEA, 2014a) • Updated every year in July/August • 2.5-year lag (e.g., 2013 data became available in October 2015)

FIGURE 3. ENERGY PRODUCTIVITY SINCE 2000



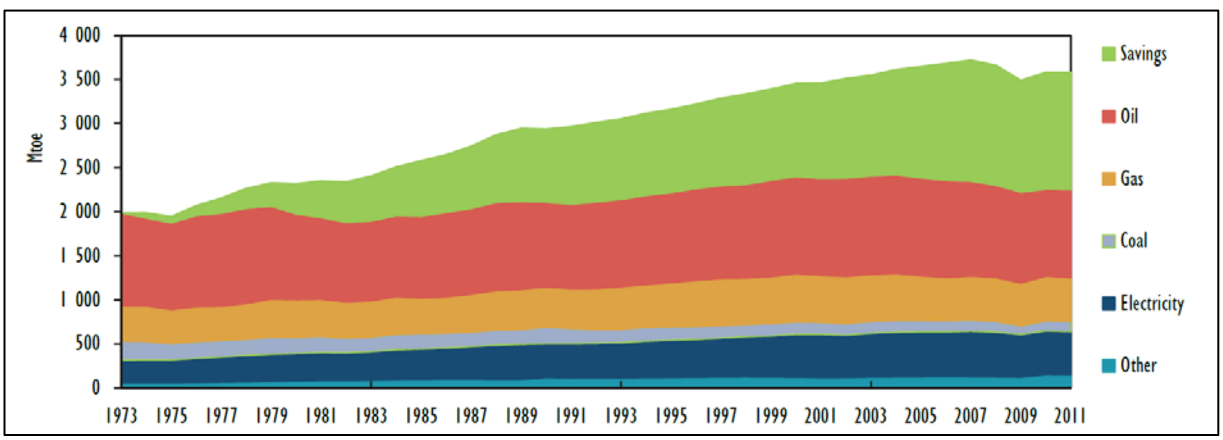
Source: IEA, 2014a. Note: the IEA uses the physical energy content conversion method (see Appendix 2).

Energy Savings

Brief Description	Energy savings from energy efficiency improvements can be measured by changes in the structure-adjusted intensities for each end-use sector. Energy savings are calculated based on a bottom-up methodology using detailed sub-sector energy efficiency indicators (see Appendix 2 for more details).
Purpose	Aggregate energy savings show the contribution of energy efficiency on the same scale as other energy sources and therefore are a measure of accomplishments.
Units	Terawatt-hours (TWh), petajoules (PJ) per annum, or cumulative over a specific time period.
Challenges / Barriers	Energy savings measure energy-efficiency progress at an economy level. However, the biggest challenge is the data requirement, which is based on detailed end-use energy-efficiency indicators as shown in Appendix 2. Data required to calculate these indicators generally come from national surveys that are not systematically conducted across countries.
Source of Data	No single source provides energy savings estimates for all countries across all sectors. However, data for some countries are available at: • **IEA**: data for 11 IEA countries (Australia, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Sweden, United Kingdom, and United States) (IEA, 2014b) • **Odyssee Database**: data for most European Union countries • **LBNL**: data for China (Zhou, McNeil, and Levine, 2013) • **CWF Foundation Regional Climate Foundations**: bottom-up estimates can be aggregated Additional work would be needed to calculate annual energy savings for all countries covered by CWF and make sure that savings estimates follow the same methodology.

IEA-11 savings from energy efficiency in 2011 were 56 exajoules (EJ), representing more avoided energy than the amount of final consumption met by any other single energy supply source (Figure 4).

FIGURE 4. ENERGY SAVINGS RELATIVE TO OTHER FUEL AND ELECTRICITY CONSUMPTION IN 11 IEA MEMBER COUNTRIES, 2011



Source: IEA, 2014b.

INVESTMENT IN ENERGY EFFICIENCY

Brief Description	The amount of public and private investment in energy efficiency allows assessment of the significance and growth of global annual investment in energy efficiency.
Purpose	This indicator can help assess the level of government spending and private financing that support energy efficiency in a country.
Units	Millions of USD or Euros
Challenges / Barriers	The IEA energy-efficiency annual report provides valuable information and analysis on global investment in energy efficiency, but more research is needed to develop standards and sources of data for meaningful metrics at the country level.
Source of Data	• Private investment: The *IEA Market Energy Efficiency* report (IEA, 2014b), published annually, estimates the size of investment in the efficiency market using bottom-up and top-down approaches. It estimates energy-efficiency investment at between USD 316 billion and USD 350 billion in 2012, with the resulting energy savings generated over succeeding years. No additional breakdown per country was available for this estimation. • Public investment o Data for some countries for some programs are available in the IEA energy efficiency annual report o Data for the US rate-funded programs are available in the annual publication of the Consortium for Energy Efficiency (CEE, 2014) o Bloomberg New Energy Finance and the Carbon Policy Initiative also provide estimates

TABLE 1. PUBLIC INVESTMENT IN ENERGY EFFICIENCY 2010-2013

Country/region	Program/Bank	2010	2011	2012	2013	Data Source
Units		Million Euros	Million Euros	Million Euros	Million Euros	
US	Utility programs			5,140		CEE annual industry report
Germany	kfW	10,315	9,701	13,697	16,000	IEA EE Market Report
UK	United Kingdom Green Investment Bank			181		IEA EE Market Report
France	France's CDC (Caisse des Dépôts et Consignations)	233	380	453		IEA EE Market Report
Europe	European Investment Bank	2,200	1,300	1,100	2,100	IEA EE Market Report
International Agencies				22,000		IEA EE Market Report

Source: IEA, 2014b; CEE, 2014.

Energy Subsidies

Brief Description	Energy subsidies distort resource allocation by encouraging excessive energy consumption and reducing incentives for investment in energy efficiency. The removal of fossil-fuel subsidies will reduce GHGs by 6% to 13% by 2050 according to a recent review study (Merrill et al., 2014). Per IEA (2013), the phase-out of subsidies is one of the major policy measures needed to keep temperature rise below 2 °C.
Purpose	CWF should track global progress toward achieving cost-reflective tariffs that encourage "market-driven" uptake of energy-efficiency measures by making these measures more cost effective. Cost-reflective tariffs can also boost efficiency policies and regulations toward higher stringency. Moreover, the transition to cost-reflective tariffs can offer opportunities for reinvesting government financial savings from subsidy reform to support low-carbon options.
Units	Billion USD
Challenges / Barriers	Estimates vary among sources depending on the form of subsidy. Here are the main approaches: • Consumer subsidies: IEA and IMF follow a similar methodology consisting of comparing average end-user prices with the full cost of supply. It represents the amount by which an end-use price falls short of the full cost of supply. • Producer subsidies: ODI uses a top-down approach and sums up investment by state-owned enterprises, national subsidies delivered through direct spending and tax breaks, and public finance from domestic or international banks and financial institutions. Additionally, the IMF also calculates **post-tax subsidies** that factor in the negative environmental and health externalities from energy consumption.
Source of Data	• IEA on-line database (IEA, 2014d). • IMF (2013) • Overseas Development Institute (ODI) (Bast et al., 2014)

FIGURE 5. GLOBAL ENERGY SUBSIDY ESTIMATES FROM DIFFERENT SOURCES

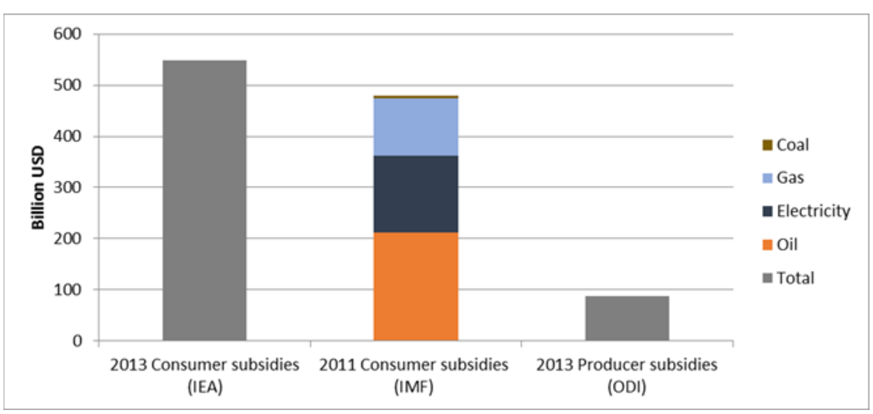


Figure 5 shows global energy subsidy estimates from different sources for 2011 (IMF estimates) and 2013 (IEA and ODI estimates). Estimates vary across source according to methodologies and definition.

CAMPAIGN-LEVEL INDICATORS

Campaign-level indicators are generally sector-level variables. Unfortunately, no single, simple indicator exists for energy efficiency in the appliance, buildings, and industrial sectors. Total sector energy consumption and energy per unit of floor area or household are, at best, approximate indicators of efficiency because the nature and amount of energy services are changing (generally increasing) together with efficiency improvements. Nevertheless, it is possible to identify some engineering-based and energy-economic indicators that give concrete insights into efficiency trends. For appliances, this can mean tracking the average efficiency of specific appliances according to accepted test procedures, a parameter carefully defined by most appliance-efficiency programs. In the building area, data can be collected on the thermal conductivity of the building envelope. In the industrial sector, energy intensity can be measured either in physical terms, such as the amount of energy used to produce a ton of cement or steel, or in terms of energy produced per unit value added. Finally, with sufficient data and analysis, it is possible to evaluate energy savings in specific sectors over time. Together, these elements create a fairly complete picture of where progress has been made as well as where future campaign opportunities lie.

Metric	**Sector**	**Purpose**	**Source**	**Frequency**	**Time lag**	**Cost/availability**
ENERGY-SAVINGS IMPACTS	All	Tracking EE progress	LBNL Modeling	Annual	Variable	Modeling
MARKET AVERAGE EFFICIENCY OF APPLIANCES	Appliances	Tracking EE progress	Market Research / Internet Survey	Annual or sub-annual	Less than 1 year	LBNL developing low-cost data platform for appliance data
BUILDING PERFORMANCE PARAMETERS (U-Value)	Residential and Commercial Buildings	Tracking EE progress	Multiple-Country based	Occasional	Not defined	Need compilation from multiple sources and some surveys (e.g., in India)
INDUSTRY ENERGY PRODUCTIVITY	Industry	Tracking EE progress	Multiple-Country based	Annual	3-4 years	Need compilation from multiple sources

ENERGY-SAVINGS IMPACTS

Brief Description	Future savings from proposed or recently implemented programs and policies.
Purpose	Assessment of progress to date in existing programs and identification and prioritization of areas of opportunity.
Units	TWh, PJ, and/or $MtCO_2$
Challenges / Barriers	Requires effort (analysis) to calculate energy savings. Some data (e.g., usage) may be scarce but can be estimated using data from other regions, etc. Methodology used should be transparent, and assumptions used should be described.
Source of Data	Implementers (grantees), government, industry, and other sources.

Estimating energy savings from policy implementation is necessary to assess impact, better advise program design, and prioritize investment. Impact is calculated based on modeling tools, generally using a bottom-up approach that models energy performance of the equipment, building or industrial technology production process with or without the policy being evaluated. The next section provides examples of savings estimates for minimum energy performance standards (MEPS) implementation. Similar impact analyses exist for other policies and programs in different countries. However, no global and transparent bottom-up model with detailed end-use technologies representation exists to provide a complete accounting of the impact of all programs and policy types.

Examples for Appliances, Lighting, and Equipment

In addition to a listing of regulations and areas of activity, tracking energy savings impact provides a quantitative link between these activities and the magnitude of energy savings; savings are driven by the size of the market affected and the stringency, or "depth" of the targets. A quantitative analysis of impact is not trivial, but methodologies are well established and some resources exist.

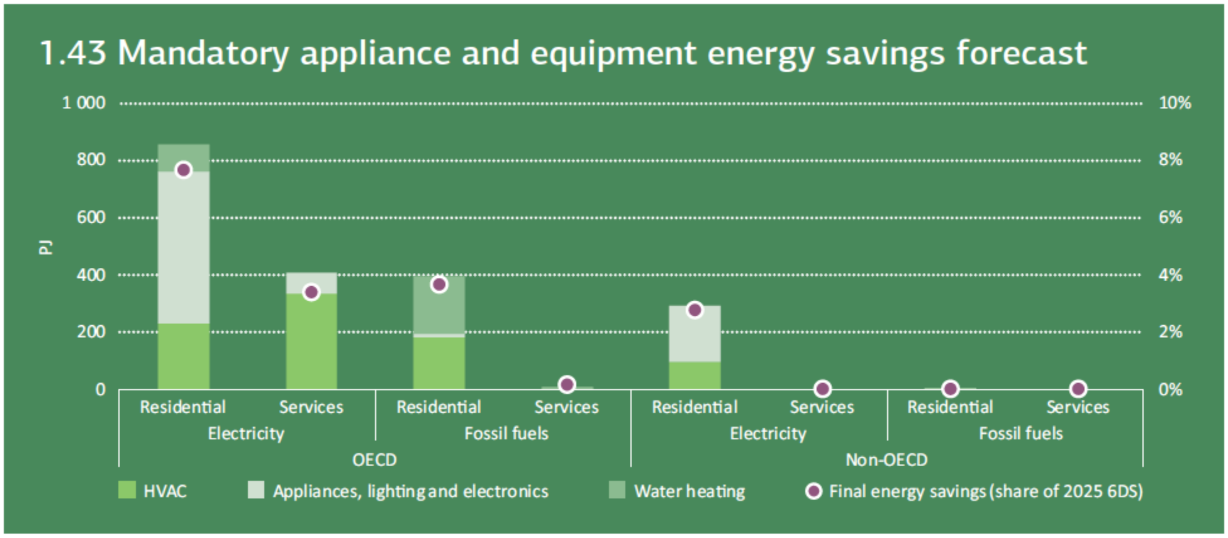
U.S. National Impacts Analysis – The U.S. standards program publishes an *ex-ante* analysis of impacts of each rulemaking as part of the regulatory process. In addition, LBNL has published *ex-post* reports summarizing the impact of the program as it relates to the residential and commercial buildings sector (USDOE, 2015; Meyers, 2011).

Ecodesign Preparatory Studies – Similar to the U.S., the European Commission makes available a Preparatory Study for each new MEPS. In addition, the EC recently commissioned a study evaluating the impacts of all program standards. Details of Ecodesign regulations are available through the website of the European Council for an Energy Efficient Economy (ECEEE, 2015).

Super-efficient Equipment and Appliance Deployment (SEAD) Recent Achievements Scenario – The SEAD Initiative analyzes all MEPS issued by its member countries since 2010 if sufficient data are available.

These analyses are implemented within LBNL's BUENAS model and therefore use a common methodology (Kalavase, 2012).

FIGURE 6. 2025 FINAL ENERGY IMPACTS OF MEPS PROMULGATED BY SEAD MEMBER ECONOMIES



Source: SEAD Recent Achievements Analysis Featured in IEA *Tracking Clean Energy Progress 2015* report, available at http://www.iea.org/etp/tracking2015/.

Australia Analysis - The Australian government commissioned a report, completed in 2010, that tracked the efficiency of appliances over the length of Australia's standards and labeling program (1993-2009) (EES, 2010).

IEA Tracking Clean Energy Progress (TCEP) – The IEA publishes an annual report on the status of efficiency worldwide, sector-by-sector. This year's TCEP report for appliances will feature highlights of the number of efficiency measures by region as well as a summary of savings from recent MEPS in SEAD member countries.

LBNL China Efficiency Program Assessments – LBNL's China Energy Group has performed several studies on the energy savings impact of programs in individual countries (e.g., Zhou, McNeil, and Levine, 2012 on China). These studies have found, for example, that the projected 2020 cumulative electricity savings from energy efficiency standards and labeling programs issued by 2014 represents more than three times the amount of electricity produced annually by the Three Gorges Dam.

Market-Average Efficiency per Appliance Type

Any appliance-efficiency program is designed to save energy by lowering the average energy consumption of appliances in use. Most often, efficiency programs such as standards and labeling programs target the efficiency of appliances for sale.[2] For this reason, tracking of units sold or models offered for sale is critical.

Brief Description	Sales-weighted or model-level average efficiency of appliances for sale in a specific product class.
Purpose	Tracking progress of appliance initiatives.
Units	Engineering-defined units (energy-efficiency ratio, kilowatt-hours/liter, kWh/cycle, lumens/watt, etc.).
Challenges / Barriers	Current data sources are slow to update or expensive to purchase. Internet retail data hold promise for reducing some of these barriers.
Source of Data	Government certification databases, market research reports, or internet retail data.

Tracking the energy efficiency of appliances sold on the market is a common metric for all appliance initiatives and has been the subject of much recent research. We describe the various collection methods below.

<u>Government certification databases</u> – When available, government certification databases may provide a good estimate of market transformation. For example, when a MEPS is passed, manufacturers should phase out sales of failing products, and this phase-out should be represented in changes in the certification database from one year to the next. Likewise, under a labeling program, manufacturers are incentivized to eliminate products with a low rating and introduce new products with high ratings.

> *Cost* – Although these data sets are often non-existent (e.g., in the European Union) or not publicly available (e.g., in China), when they are available, they are typically offered free of charge although there may be some cost associated with downloading and processing the available data.
>
> *Challenges/barriers* – Data may be kept confidential by governments. Data sets may be updated only annually. Certification database differs from sales. Poor compliance rates may adversely affect the accuracy of data.

<u>Market Research Reports</u> – These are data sets of varying detail generally used by appliance industries in developing business strategy. Historically, these have not focused on efficiency but include a wider range of features and provide information about manufacturers and retailers. These reports, however, provide data, by model, concerning energy efficiency weighted by sales, as estimated through interviews with retailers or “cash register” data.

[2] A few program types, such as early replacement incentives, target already installed products.

Cost – Roughly $10,000 to $30,000 per product year per market, depending on level of aggregation

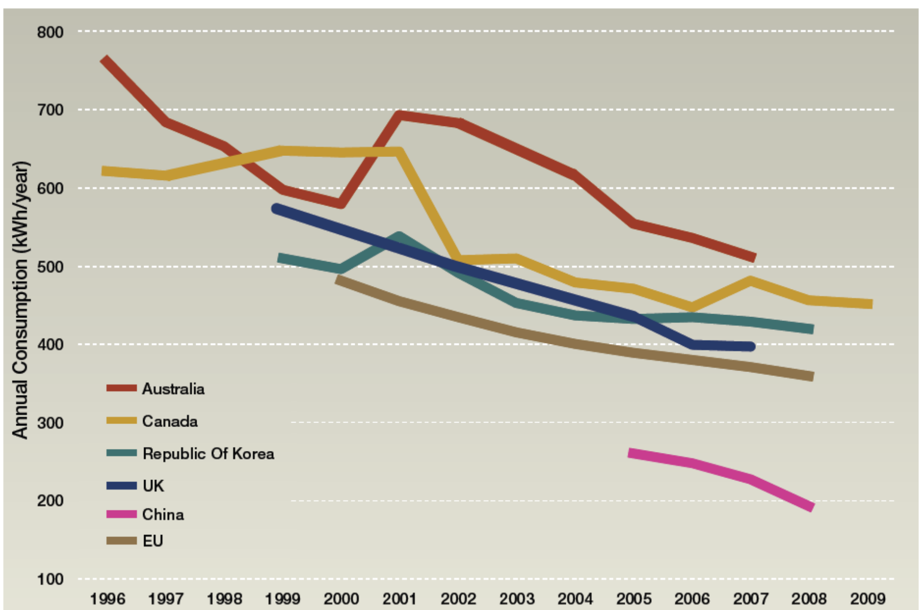
Challenges/barriers – Can be quite expensive; data may not be available for smaller markets.

Internet Retail Data – These data are collected from internet retail sites via connection to an Application Programming Interface or by "scraping" data directly from within the web browser. Once the database and algorithm are set up, these data are inexpensive to collect and can be refreshed often. Data on websites include brand, configuration, and price. Energy- efficiency information is not always available, and is highly economy specific. Sales information is generally not available but may be estimated from sales rank. Internet data can be cross-referenced against government certification data, which greatly enhances the value of both data sets.

Cost – The initial cost of software development is high, but expansion to additional economies and appliance types as well as data refresh is much lower cost.

Challenges/barriers – Research is currently proposed/under way to establish comparability with sales-weighted data and improve correlation to certification databases, including those from exporting economies.

FIGURE 7. AVERAGE ENERGY CONSUMPTION OF REFRIGERATORS IN MAJOR ECONOMIES



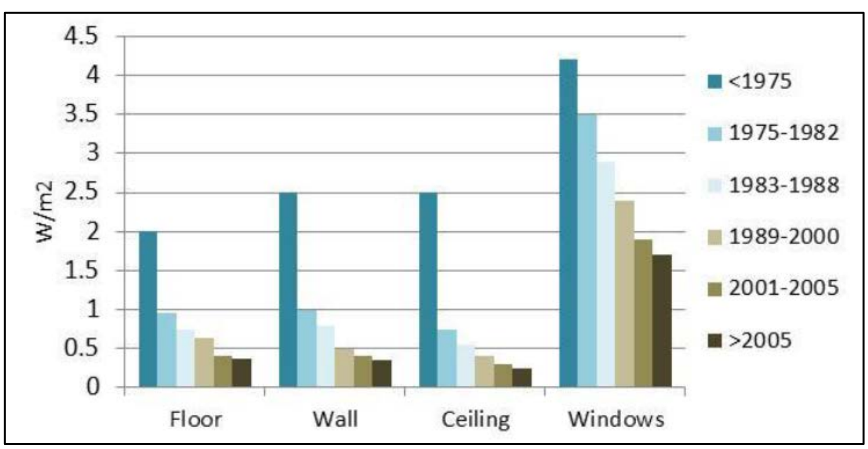
Source: IEA, 2012.

BUILDING PERFORMANCE

Brief Description	U-value (thermal conductivity) and R-value (thermal insulation) are the main heat loss parameters describing thermal properties of walls, floors, roofs, and windows. A low U-value indicates higher levels of insulation. R-value is the inverse of U-value and is the unit used in the US.
Purpose	This indicator gives information about building insulation practices in a country. It can be used to measure progress in thermal energy performance of buildings.
Units	U- Value: watts per meter squared kelvin (W/m^2K), R-value: British thermal unit inch per hour per square foot per degree Fahrenheit ($ft^2 \cdot °F \cdot hr/Btu$)
Challenges / Barriers	In countries where building codes have been in place for a long period, the U-value of building stock can be derived from the evolution of building code requirements. In other countries, surveys may be necessary to assess the building stock and new construction U-value practices. Building retrofits can also be measured in terms of U-value improvements by estimating the thickness of insulation of refurbishment compared to baseline.
Source of Data	Average U-values of existing construction must be determined for the different vintages of baseline building models. For new construction, the prevailing building code serves as a reference. An alternative approach based on infrared thermography can also be considered to provide measurements. Regional sources include: • **EU:** TABULA and EPISCOPE project funded by EU Energy Intelligence Program • **US:** National Renewable Energy Laboratory (Deru et al., 2011)

Figure 8 shows the evolution of U-values of building construction in France over 30 years. Insulation has improved by 60%, with the biggest improvements in ceiling and wall insulation.

FIGURE 8. U-VALUES BY CONSTRUCTION PERIOD (MULTIFAMILY AND SINGLE FAMILY, 2008)



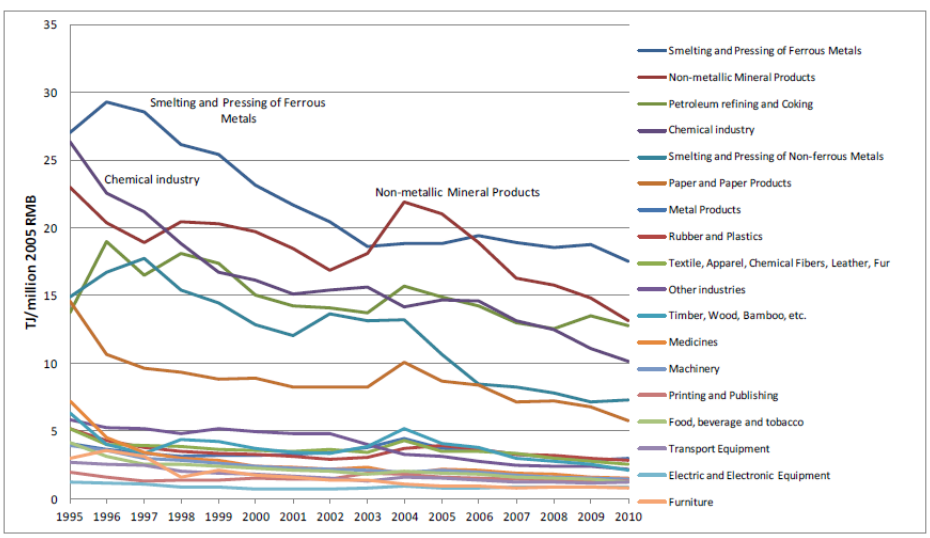
Source: EU ENTRANZE, 2014.

INDUSTRY ENERGY PRODUCTIVITY

Brief Description	This indicator represents the energy consumption per unit of added value produced for each subsector. The subsectors' share of total value added can be used as a structural indicator, with decomposition analysis showing the effects of structural changes versus changes in energy intensity in the total industry sector.
Purpose	This indicator should be used to track progress in industrial energy efficiency.
Units	TJ/ manufactured value added (MVA) expressed in USD
Challenges / Barriers	The disadvantage of this metric is that it measures economic energy intensity, not physical energy intensity, which introduces uncertainty related to cross-country economic comparisons because of currency conversion and comparability issues. The advantage of this metric is that changes in economic energy intensity that are used as a proxy for energy efficiency can be aggregated at the industrial-sector level to show the overall effect of efficiency improvements on energy consumption.
Source of Data	The IEA publishes data on energy consumption per industry subsectors in an energy balance database that includes most of the countries in the world, and the World Bank publishes some level of detail on MVA per subsector. However, more detail and a more complete data set can be obtained from national statistics offices such as the National Bureau of Statistics in China, Ministry of Statistics and Programme Implementation in India, and the Energy Information Administration in the US.

Figure 9 gives an example of trends in economic energy intensity (the inverse of productivity) for each industrial subsector in China.

FIGURE 9. CHINA INDUSTRY SECTOR ENERGY INTENSITY



Source: Hasanbeigi et al., 2013.

Initiative-Level Metrics

Initiative-level metrics provide a means to track progress in specific areas and are closely related to estimating the impact of initiative/campaign investments. A variety of parameters give an indication of the intensity of activity driven by a specific initiative and the effectiveness of each activity. Much of this can be boiled down, however, to two “bottom-line” indicators:

- Energy saved (projected through 2030) from initiatives, by sector and region
- Additional public and private energy-efficiency financing (projected through 2030) as a result of initiatives by sector and region

Primary among these is energy saved/GHG emissions mitigated. However, important indicators also include the number of efficiency policies enacted, their scope of coverage, and the tracking of the specific markets that the initiatives are designed to transform. Initiative-level metrics are “bottom-up” type measurements and provide the most concrete, if not comprehensive, picture of energy efficiency. These metrics are constructed using highly specific data sets, some of which may be provided by implementing grantees. Initiative-level metrics include measurements of energy-savings potential (*ex-ante or ex-post*), and therefore play an important role in the evaluation of initiative impacts.

In any effort to evaluate the impact of an efficiency program, and particularly those involving policy actions, there are questions of causality and attribution. The first of these concerns the difficulty in establishing the direct causal nature of ‘soft’ actions, such as information networks, advocacy, etc. The second refers to the amount of credit that can be taken by any one actor in a complex network of stakeholders and facilitators. We acknowledge that these factors introduce uncertainty in evaluating results. In order to address them, we adopt a strategy of measuring relevant quantitative impact as accurately as possible, and necessarily leaving some assessment to a quasi-quantitative or narrative description.

Metric	Sector	Purpose	Source	Frequency	Cost/availability
ENERGY SAVED	All	Measuring Impacts	Varied / Grantees	Annual	Modeling
ENERGY EFFICIENCY FINANCING	All	Tracking progress	Survey / Grantees	Annual	Surveys study report

Initiative Energy Savings

Well-established methods exist for evaluating the energy savings of specific initiatives. Energy-savings evaluations can be performed either before implementation (*ex-ante*) in order quantify the opportunity presented by the initiative, or after implementation (*ex-post*) to measure the actual results. Because efficiency policies affect equipment, infrastructure, and industrial practice over a period of decades, a necessary aspect of energy-savings evaluations is to project energy consumption and incremental improvements into the future.

Evaluation of energy efficiency initiatives rely on assessing the following:

1. Type of regulation/policies implemented
2. Coverage (equipment/building/sector affected)
3. Baseline - base case unit, annual energy consumption, and projected business as usual trends (kWh, kW/m^2, PJ/tonne)
4. Energy efficiency case - unit of annual energy consumption of energy efficient technology or practice (kWh, kW/m2, PJ/tonne)
5. Rate of change - rate of diffusion of technology or practice compared to non-impacted technology or practice, expected market growth and rate of retirement of inefficient technology/practice.

Once these elements are known, energy savings can be calculated for each year following initiative implementation. Often the initiative influences policies and programs, leading to a delay of implementation for several years, thus results may not be seen for a number of years but they may be predicted with reasonable accuracy. Once the initiative is implemented, actual efficiency levels may be tracked and compared to projected ones. Critical data elements needed to perform such an analysis include regulatory/program technical specifications, baseline assessments, historical product sales and product lifetimes, and macroeconomic projections of population, GDP, urbanization, etc. These elements may come from sources such as government agencies, statistics bureaus, and industry groups. It is likely, however, that some data are best provided by those closest to the initiatives, i.e., the initiative implementers (grantees).

Finally, it should be noted that evaluation based on the above parameters may be sufficient for initiative evaluation, but it will not be complete. Issues such as compliance, "free ridership,"[3] and rebound and attribution effects can be significant and should be considered to the degree feasible.

Appliances and Equipment

Product energy-efficiency standards and labeling (S&L) programs are the most widely implemented energy efficiency program in the world. About 60 countries have implemented S&L and a large potential remains to revise and expand their scope to reduce greatly the energy consumption of specific appliances, equipment, lighting, and other devices. Other policies such as incentive programs and energy efficient procurement are complementary to S&L and amplify market transformation toward more efficient equipment. These programs contribute to expand the availability of top efficiency appliances and motivate sellers or purchasers to invest in energy efficiency.

Appliance efficiency programs target specific equipment types, and efficiency metrics are part of the program definition. Impact on energy consumption can therefore be estimated based on a bottom-up model that accounts for a gradual stock turnover. The scope of impact of these programs is best known

[3] In the energy efficiency literature, a "free rider" is one who takes advantage of a financial incentive, etc., but who would have implemented the efficiency measure without the incentive.

for S&L programs, but can also be estimated for other programs given data or assumptions of the share of the market impacted.

BUILDINGS

Building efficiency program energy-savings assessments are similar to those for appliances and equipment programs in that they rely on clear technical descriptions of the regulations/programs, and reliable estimates of baselines and projections of stock evolution, in this case through new construction, demolitions, and retrofits. A key program for buildings is building energy codes implemented by governments, often at the state or municipality level. In addition to this, major programs include certification (labeling) schemes and, increasingly, incentives or funding to construct a significant number of very-high-performance buildings (often called "near-zero" or "net-zero" energy buildings). In addition to these policies, which generally impact new construction only, policies can be designed to encourage or require energy-efficiency retrofits of existing buildings.[4]

As is the case for appliance and equipment programs, energy-savings estimates for building programs require a projection of increases and turnover in stock, however with generally much longer lifetimes because in some countries buildings are designed to last for more than 100 years. Because of improvements in general construction practices, lifetimes may be getting longer. Additionally, forecasts of construction depend on projection of demographic trends, particularly population, household size, urbanization, and the increase in the importance of the service sector in the economy.

Finally, building efficiency is governed by technical parameters generally defined by programs and regulations. Conversion of these into energy saved per building is generally more complex than in the appliance and equipment cases for the following reasons:

- <u>Occupant behavior</u> –Uncertainties regarding behavior of building occupants limit the ability of energy models to predict accurately actual building performance.
- <u>Compliance rate</u> – An important factor in achieving the potential energy savings from building code regulations is to assess the compliance rate of the building code implementation and the rigor of the certification process.
- <u>Need for simulation</u> – Even in the case where technical parameters are clear, the wide variety of building configurations, orientations, and climates necessitate that energy savings be determined through computer simulations of building load and performance. This type of simulation is well established with many professionals skilled in its use.

INDUSTRY

The industrial sector can be broadly defined as consisting of energy-intensive industries (e.g., iron and steel, chemicals, cement, aluminum, and pulp and paper) and light industries (e.g., food processing, textiles, wood products, printing and publishing, and metal processing). Energy-intensive industries emit the largest share of the industrial-sector GHG emissions and are often the focus of specific energy efficiency programs implemented by governments. For example, target-setting agreements, also known

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[4] Particularly important, for example, in Europe, which has a relatively old building stock.

as voluntary or negotiated agreements, have been used by a number of governments as a mechanism for promoting energy efficiency within the industrial sector. These targets can be expressed as a percentage reduction over a baseline or in terms of specific energy consumption (SEC). The target SEC can then be used to estimate the energy-savings impact.

The adoption of energy management systems (EMS) in industries has been increasingly encouraged by governments as a means to integrate energy efficiency into management practices. Energy-savings results associated with EMS can be diverse and difficult to estimate. However, some countries have adopted complementary programs to track the progress of energy efficiency improvement of industries that achieve specific targets. This is the case of the Superior Energy Performance program in the US, for example (Therkelsen, 2013). These targets can then be used to estimate future potential savings.

Another effective policy in the industry sector has been the implementation of equipment energy efficiency standards, such as for motors and motor systems, including pumps, fans, and air compressors. These standards can also result in a great amount of energy savings and are useful for reaching the less-energy-intensive industries. Energy savings from these programs can be estimated by following the same methodology as described for appliances.

Estimating the energy savings in the industry sector depends on the type of policy implemented, which can vary significantly from country to country. Therefore, methods for estimating energy savings should be developed based on the specific program characteristics.

Multiple Benefits Strategy: Telling the story

The previous sections focus on indicators and metrics to evaluate the status of energy efficiency at the macro level and within campaign target sectors and geographic areas, and to quantify progress toward improving efficiency. It is increasingly apparent, however, that the benefits of energy efficiency go well beyond reducing GHG emissions or energy costs. As summarized by a recent IEA report entitled *Capturing the Multiple Benefits of Energy Efficiency* (IEA, 2014c), non-energy benefits include macroeconomic benefits, influence on public budgets, health and well-being, industrial benefits, and effects on energy-delivery.

Although some of these metrics may not be the core objective of energy-efficiency initiatives, it is crucial to track and quantify them because they may be a priority for decision makers. This is particularly true in developing countries where health and effects on energy infrastructure and security may be more pressing than global environmental benefits. Some specific metrics that can be quantified include:

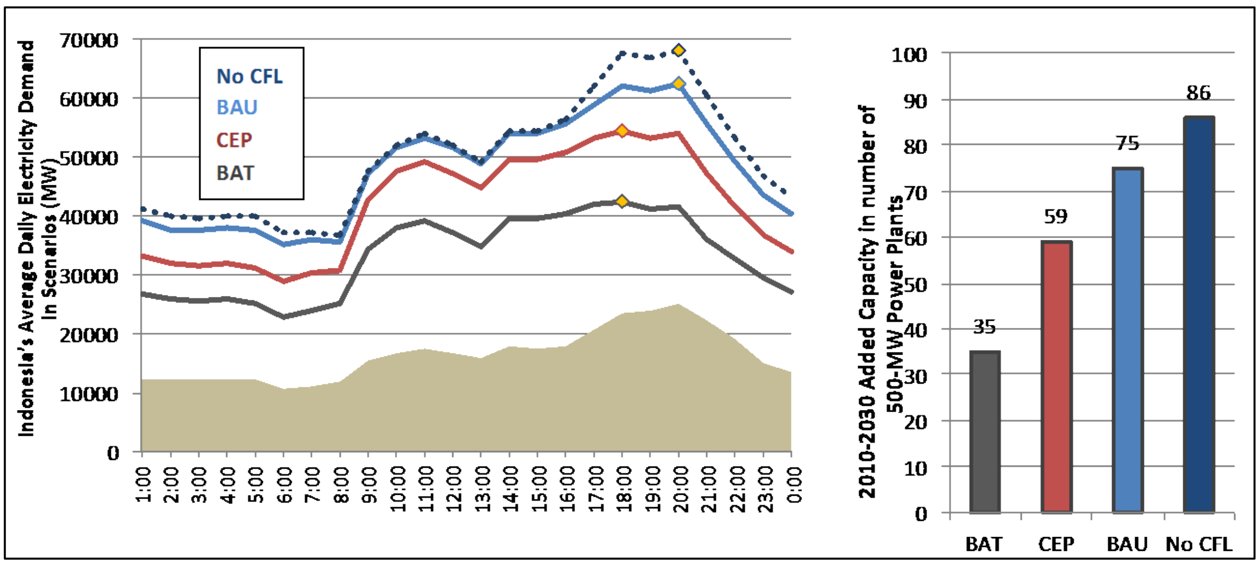
- Economic growth achieved because of energy efficiency
- Jobs created
- Peak load reduced
- Emissions of energy-related pollutants reduced
- Water use reduced
- Need for additional energy supply reduced
- Energy security enhanced

- Energy access increased
- Public health improved
- Peak carbon emissions year shifted
- Mortality and morbidity reduced because of improved air quality
- Productivity increased

Some of these metrics flow directly from energy savings, while others are less direct. In many cases, there is emerging literature devoted to methodologies to quantify these results, given a specific amount of energy savings.

An important example of multiple benefits from energy efficiency is the reduction of additional power generation capacity needed to meet demand in developing countries. This metric is derived from energy-savings potential using known load profiles of lighting, major appliances, and other equipment. Because this variable relates directly to required capital investments, it is likely to be of great interest to government actors (such as finance ministries) responsible for planning for power plant investments.

FIGURE 10. REDUCTION IN 2030 PEAK DEMAND IN INDONESIA FROM APPLIANCE AND EQUIPMENT EFFICIENCY



Source: Karali et al., 2015.

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APPENDICES

APPENDIX 1. PRIMARY ENERGY CALCULATION METHODS

Different methodological conventions exist to account for the primary energy associated with electricity production from non-fossil-fuel energy such as renewable and nuclear energy.

	Hydro, Wind, Solar PV	Geothermal	Nuclear
Direct equivalent method	100%	100%	100%
Physical energy content method	100%	10%	33%
Substitution energy method	30-40%	30-40%	30-40%
Power plant coal consumption method	30-40%	30-40%	30-40%

Direct equivalent method (IPCC method): The primary energy of 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 photovoltaic or nuclear power plants is set equal to their respective gross electricity output. This is not to the heat equivalent of radiation energy from fissile reaction, the solar radiance that falls onto a photovoltaic panel, or the heat that would have been necessary by burning fossil fuels to produce the same amount of electricity as generated in a photovoltaic cell or a nuclear reactor (as used in the so-called ‘‘substitution’’ accounting method).

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, and wave/tide), the primary form of energy considered is the electricity produced, so an efficiency of 100% applies, similar to the previous method.

Substitution energy method: The substitution method calculates efficiency for all electricity production as if it had been generated by a fossil-fuel power plant with an average electricity conversion factor (typically between 30% and 40%). The U.S. Energy Information Administration (EIA) and the World Energy Council use this method.

Power Plant Coal Consumption Method: The power plant coal consumption method is a fourth, distinct method used in China and is rarely discussed in the literature. In this method, conversion to standard units is based on the average heat rate of coal-fired plants in a given year.

APPENDIX 2. VARIABLES AND METRICS USED FOR SECTORAL INDICATORS IN THE DECOMPOSITION ANALYSIS

Sector	Service/sub-sector	Activity	Structure	Intensity (efficiency effect)
Residential	Space heating	Population	Floor area/ population	Space heating energy*/ floor area
	Water heating	Population	Occupied dwellings/ population	Water heating energy**/occupied dwellings
	Cooking	Population	Occupied dwellings/ population	Cooking energy**/occupied dwellings
	Lighting	Population	Floor area/ population	Lighting energy/ floor area
	Appliances	Population	Appliances ownership/ population	Appliances energy/ appliance stocks
Passenger transport	Car; bus; rail; domestic air	Passenger-kilometre	Share of passenger-kilometres	Energy/passenger-kilometre
Freight transport	Truck; rail; domestic shipping	Tonne-kilometre	Share of tonne-kilometres	Energy/tonne-kilometre
Manufacturing	Food, beverages and tobacco; paper, pulp and printing; chemicals; non-metallic minerals; primary metals; metal products and equipment; other manufacturing	Value-added	Share of value-added	Energy/ value-added
Services	Service	Value-added	Share of value-added	Energy/value-added
Other industries***	Agriculture and fishing; construction	Value-added	Share of value-added	Energy/value-added

* Adjusted for climate variations using heating degree days.

** Adjusted for household occupancy.

*** The following ISIC groups are not included in the analysis: 10-14 Mining and quarrying; 23 Fuel processing; and 40-41 Electricity, gas and water supply. Industries in category "Other industries" are analysed only to a very limited extent in this study.

Source: IEA (2014b), *Energy Efficiency Indicators: Fundamentals on Statistics*, OECD/IEA, Paris.